PHASE TO PHASE

Users manual Vision 9.6.0

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Contents

1	General	11
1.1	Information	11
1.2	Vision Updates	12
1.3	Vision: introduction	36
1.4	Vision: structure	37
1.5	Menu and mouse control	38
1.6	Shortcut keys	39
2	Getting started	41
2.1	Creating a new empty workspace	41
2.2	Adding new nodes	42
2.3	Adding new connections	46
2.4	Adding an external grid and loads	52
2.5	Computing a load flow	55
2.6	Computing the short circuit current	59
3	User interface	63
3.1	Network	63
3.1.1	Network presentation	63
3.1.2	Sheet	65
3.1.3	Multiple object presentation	67
3.1.4	View	69
3.1.5	Views	72
3.1.6	Group	73
3.1.7	Direction	73
3.1.8	Area	74
3.2	Object types	75
3.2.1	Type	76
3.2.2	Alias	78
3.3	Application menu	78
3.3.1	File handling	78
3.3.2	Sending	79
3.3.3	Prepare	80
3.4	Finding and selecting components	81
3.4.1	Select and search	82
3.4.2	Memory selection	85
3.5	Adding components	85
3.5.1	Insert	85
3.5.2	Place	87
3.5.3	Copy and paste	88

3.5.4 Represent 89
3.5.5 Library 90
3.6 Edit components 91
3.6.1 Edit individual 91
3.6.2 Edit collective 91
3.6.3 Update types 92
3.6.4 Special, Simultaneity 92
3.6.5 Special, Subnet border 93
3.6.6 Special, Profile situation 93
3.6.7 Special, Change voltage 94
3.6.8 Transfer 94
3.6.9 Split 94
3.6.10 Shift 96
3.6.11 Take out 96
3.6.12 Join 96
3.6.13 Undo 96
3.6.14 Redo 96
3.7 Moving components 96
3.7.1 Move 96
3.7.2 Bend 97
3.7.3 Align 97
3.7.4 Replace 97
3.7.5 Scale 97
3.8 Deleting objects 98
3.9 Printing and reporting 98
3.10 Tools 99
3.10.1 Compare networks 100
3.10.2 Take over from network 100
3.10.3 Add a network 100
3.10.4 Protections 101
3.10.5 Import 103
3.10.6 Export 113
3.10.7 Maps 113
3.10.8 Geographical export 115
3.10.9 Type viewer 115
3.10.10 Define views 115
3.10.11 Reports 116
3.10.12 Options file 116
3.10.13 Options 117
3.10.14 Transformer phase tool 117
3.10.15 Cable rating tool 118
3.10.16 Arc Flash 119
3.10.17 Overhead lines 122
3.10.18 Solar panel 125
3.10.19 Macro 125

4 Options 127

4.1 Options Editor 127
4.1.1 Options Editor General 127
4.1.2 Options Editor Drawing 128
4.1.3 Options Editor Presentation defaults 128
4.1.4 Options Editor Position defaults 129
4.1.5 Options Editor Appearance 129
4.1.6 Options Editor Variables 130
4.2 Options File locations 130
4.3 Options Network 131
4.4 Options Calculations 131
4.5 Options Print 134
4.6 Options Geography 135
4.7 Options Key 136

5 Components and parameters 137

5.1 Nodes 138
5.1.1 Node 138
5.1.2 Busbar system 143
5.2 Branches 144
5.2.1 Line 145
5.2.2 Mutual coupling 147
5.2.3 Link 149
5.2.4 Cable 150
5.2.5 Reactance coil 154
5.2.6 Transformer 155
5.2.7 Special transformer 161
5.2.8 Three winding transformer 166
5.3 Elements 171
5.3.1 Source 172
5.3.2 Synchronous generator 174
5.3.3 Synchronous motor 178
5.3.4 Asynchronous generator 180
5.3.5 Asynchronous motor 182
5.3.6 Asynchronous motor group 186
5.3.7 Load 188
5.3.8 Transformer load 190
5.3.9 Shunt capacitor 192
5.3.10 Shunt reactor 194
5.3.11 Zigzag transformer 195
5.3.12 Wind turbine 196
5.3.13 Battery 198
5.3.14 PV 199
5.4 Switches and protections 201
5.4.1 Load switch 201
5.4.2 Fuse 202
5.4.3 Circuit breaker 203
5.4.4 Current protection 205

5.4.5 Earth fault protection 211
5.4.6 Voltage protection 212
5.4.7 Differential protection 213
5.4.8 Distance protection 214
5.4.9 Unbalance protection 219
5.4.10 Thermal protection 219
5.4.11 Earth fault differential 221
5.4.12 Short circuit indicator 221
5.4.13 Measure field 222
5.5 Other 223
5.5.1 Text 224
5.5.2 Frame 225
5.5.3 Legend 226
5.5.4 Load behaviour 227
5.5.5 Load growth 229
5.5.6 Profile 230
5.5.7 External profile 232
5.5.8 Simultaneousness 235
5.5.9 Selection 235
5.5.10 Feeder 236
5.5.11 Variant 237
5.5.12 Scenario 243
5.5.13 Specifics 246
5.5.14 Revision date 247
5.5.15 Note 248
5.5.16 Presentation Components 248

6 Calculations 249

6.1 Loadflow 250
6.1.1 General 250
6.1.2 Island mode 250
6.1.3 Calculation 252
6.1.4 Result 256
6.2 Unbalanced load flow 257
6.2.1 Unbalanced load flow: General 257
6.2.2 Unbalanced load flow: Calculation 259
6.2.3 Unbalanced load flow: Result 260
6.3 IEC 60909 262
6.3.1 General 262
6.3.2 Power Station Unit 270
6.3.3 Calculation 271
6.3.4 Result 272
6.4 Fault Analysis 273
6.4.1 General 273
6.4.2 Calculation 274
6.4.3 Result 275
6.4.4 Zero sequence test 276

6.5	Network load	277
6.6	Harmonics	277
6.6.1	Harmonics: General	278
6.6.2	Harmonics: Model	278
6.6.3	Harmonics: Calculation	282
6.6.4	Harmonics: Result	285
6.7	Costs	287
6.7.1	General	287
6.7.2	Calculation	288
6.7.3	Result	288
6.8	Reliabilty	289
6.8.1	General	289
6.8.2	Concept	289
6.8.3	Input	290
6.8.4	Modelling	291
6.8.5	Calculation	292
6.8.6	Result	293
6.9	Protection	294
6.9.1	General	294
6.9.2	Calculation	296
6.9.3	Result	298
6.9.4	Protection analysis	304
	General	305
	Calculation	306
	Result	307
6.9.5	Protection for Stedin	308
	General	308
	Calculation	308
	Result	309
6.9.6	Protection for Enexis	309
	General	309
	Loadflow	311
	Tactics	312
	Analysis	313
	Scheme	315
	Form	315
6.10	Voltage dip analysis	316
6.10.1	General	316
6.10.2	Calculation	316
6.10.3	Result	317
6.11	Failure analysis	319
6.11.1	General	319
6.11.2	Calculation	319
6.11.3	Result	321
6.12	Normal Open Point optimization	323
6.12.1	General	323
6.12.2	Calculation	323
6.12.3	Results	323
6.13	Pseudomonitor	323

6.13.1 Pseudomonitor 324
6.14 Outage simulation 326
6.14.1 General 326
6.14.2 Calculate 326
6.15 Stability analysis 328
6.15.1 General 328
6.15.2 Model and calculation 329
6.15.3 Results 329
6.16 Dynamic analysis 330
6.16.1 General 330
6.16.2 Model 330
6.16.3 Case and events 338
6.16.4 Calculation 339
6.16.5 Result 342
6.16.6 Workspace 343
6.16.7 Troubleshooting 347
6.17 IEC 61363 348
6.17.1 General 348
6.17.2 Model 348
6.17.3 Calculation 351
6.17.4 Result 352
6.18 Arc flash 352
6.18.1 General 352
6.18.2 Model 353
6.18.3 Calculation 354
6.18.4 Result 356
6.19 Netcheck 357
6.20 Power generating module 358
6.21 Switchability 360
6.22 Frequency disconnection 361
6.23 Data driven loadflow 362
6.23.1 General 362
6.23.2 Calculation 362
6.23.3 Result 363

7 Macros 365

7.1 Macro editor 365
7.2 Macros: calculations 366
7.3 Macro structure and syntax 367
7.3.1 Macro objects 367
7.3.2 Macro values 369
7.3.3 Macro variables 369
7.3.4 Standard objects 369
7.4 Macro attributes 370
7.4.1 Macro alterable attributes 371
7.4.2 Macro alterable attributes table 372

7.4.3 Macro non alterable attributes 376
7.4.4 Macro non alterable attributes table 377
7.4.5 Macro: table with attributes 381
7.5 Macro commands and parameters 393
7.5.1 Macro alteration commands 393
Macro command SetPQS 394
Macro command Set 394
Macro command SetSelection 395
Macro command Add 395
Macro command AddSelection 395
Macro command Subtract 396
Macro command SubtractSelection 396
Macro command Multiply 396
Macro command MultiplySelection 397
Macro command Divide 397
Macro command DivideSelection 397
Macro arrays 398
7.5.2 Macro selecting 398
Macro command Trace 399
Macro command Route 399
Macro command Direction 399
Macro command Feeding 399
Macro command AddSelectedToSelection 400
Macro command DeselectAll 400
7.5.3 Macro functions 400
General functions 401
Calculations functions 401
Power and logarithm functions 401
Goniometric functions 401
Logical functions 402
Text functions 402
Excel functions 402
Date functions 402
7.5.4 Macro procedures 402
7.5.5 Macro conditional commands 403
Macro command if 403
7.5.6 Macro loop commands 404
Macro command While 405
Macro command Repeat 405
Macro command Loop 406
Macro command For 406
Macro command ForSelection 407
Macro command Break 407
Macro command Exit 408
Macro command Pause 408
Macro command ForSelected 408
7.5.7 Macro calculating commands 408
Load flow 409
IEC 60909 410
Fault analysis 410
Selectivity 411
Ripple 412
Reliability 412
Macro command Protection 412
Macro command Simulation 413
Macro command FailureAnalysis 413

Macro command NetCheck 414
Macro command Pseudomonitor 414
Macro command DataDrivenLoadflow 415
7.5.8 Macro reporting commands 415
Macro format 416
Macro write to an object 417
Macro command View 417
Macro command Viewcolor 418
Macro write to a text 418
Macro command text 418
Macro command debug 419
Macro command SetDecimalSeparator 419
Macro write to a text file 419
Macro command TfOpenForWrite 419
Macro command TfWrite 420
Macro command TfWriteLn 420
Macro command TfClose 420
Macro write to Excel 421
Macro command create 421
Macro command open_2 421
Macro command close_2 421
Macro command addsheets 421
Macro command getsheets 422
Macro command title 422
Macro command gettitle 422
Macro command write 422
Macro command copy 424
Macro command bold 424
Macro command border 425
Macro command merge 425
Macro command fit 425
Macro command align 425
Macro command fontcolor 426
Macro command backcolor 426
Macro command SetScreenUpdating 426
Macro command ClearSheet 427
Macro command Get 427
Macro command Put 427
Macro command SaveAs 427
Macro command AddFormatCondition 428
Macro command CreateDir 429
Macro command ExportResult 429
Macro command FreezePanes 429
Macro command GetUsedRange 429
7.5.9 Macro input commands 429
Macro read from input dialog 430
Macro command input 430
Macro read from a text file 430
Macro command TfOpenForRead 430
Macro command TfRead 431
Macro command TfReadLn 431
Macro function TfEOF 432
Macro read from an Excel file 432
Macro command read 432
7.5.10 Macro network commands 433
Macro command savenetwork 433
Macro command SavenetworkAsIs 433

Macro command storenetwork 434
Macro command restorenetwork 434
Macro command ShowNetwork 435
Macro command OpenNetwork 435
Macro command ExportNetwork 435
Macro command ExportGeo 435
Macro command Import 436
7.5.11 Macro topological commands 436
Macro command SetSerialsAndFeedings 436
Macro command SetDirections 436
Macro command SetMeshes 436
Macro command SetGroups 436
7.5.12 Macro Python commands 437
Macro command RunPythonString 437
Macro command RunPythonScript 437

8 Appendix 439

8.1 Vision: info calculations 439
8.2 Vision: info components 441
8.3 Vision: info user interface 441
8.4 Vision: info subscriber 442
8.5 Software installation and hardware key 443
8.6 Network file format 444

1 General

1.1 Information

Vision is a high-grade tool for analysis of electricity networks. Vision can be used to carry out load flow calculations, short-circuit calculations and fault analysis. Vision has been used since 1991 by virtually all Dutch energy companies and a considerable number of industrial and consulting engineering firms for the planning, design and management of transmission, distribution and industrial networks.

User convenience and practical applicability of results have been central to the development of Vision. Regular updates and upgrades are published on the website: www.phasetophase.com. For updates in this version, see: What is new 12.

Georg Simon Ohm

User interface
The user interface comprises a fast one-line editor which is intuitive to use, thanks to carefully chosen edit functions. This makes Vision accessible both to frequent users and incidental users who only perform network calculations a few times a year.
The user interface handles the network modelling and presents the results. It is control through the ribbon menu and the mouse, see: Menu and mouse control 38. An number of control actions have predefined shortcut keys 39.
The interface can handle large networks, making it extremely suitable for linking to geographical information systems. Through the use of copy and paste functions networks can easily be joined or expanded. The presentation of the network and associated information, such as component data and calculation results, can be fully customised by the user.
Although Vision is easy to use, electrical engineering knowledge remains necessary to be able to correctly interpret the data and the results.
See also:

- User interface 441
- Calculations 439
- Structure 37

Component types
During construction or modification of a network, the user is supported by a component database consisting of commonly used cables, transformers, reactance coils, generators, motors, busbar systems and protection relays. The use of these databases increases efficiency and prevents incorrect data entry. The component database can be extended or modified by the user from Vision.

Results
Results of calculations are directly shown in the network based on a user-defined View 115. Through the use of colour coding possible problem areas in the network can be quickly identified. The results can also be exported in

user defined Reports[116]. Detailed information for each node or line can be easily accessed and visualised. By using graphics several nodes or lines can be readily compared.

Export
The exporting of the calculation results, network diagrams and network information for usages in other applications is important for the users. Therefore, in addition to the ability to print and copy these diagrams and data, custom reports can be defined and stored in Vision and all results can easily be exported to other packages with the object information intact.

Subscriptions
With a Vision subscription, you are always guaranteed the latest upgrades, and you will receive information on all developments in the Vision periodical. New developments are presented, and experiences with Vision exchanged, at the annual users' day for all subscribers. A Vision subscription also entitles you to front-line support via telephone or email.

See also:
- Subscriptions[442]

Vision
Language: English and Dutch
License: by PC or network key
Installation: by user
System requirements: PC with Windows 10 or 11

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1.2 Vision Updates

NEW IN VISION 9.6

New location for the options file
The options files Vision*.ini, the desktop file Vision.dsk, and the view and report definition files are now read from %Appdata%\Vision and stored there.
There is one exception for the options file. If an options file is located in the executable folder, then this options file will be used.

New MS cable types
The types file Types.xlsx provided contains Twenpower medium-voltage cable types. These are one- and three-core cable types with copper and aluminum conductor with sections from 16 to 1200 mm² at voltage levels from 6/10 to 36/50 kV.

Own load rate limits for cable and transformer
For a cable and transformer, own maximum load rate percentages can be specified on the Connection tab. These percentages override the general limits in the options.

Frequency protection
Frequency protection is available with the circuit breaker. This protection is not used in the ordinary protection calculations, but only in the frequency disconnection calculation.

Frequency Disconnection Calculation

This calculation 361 performs load flows at different frequencies, applying the available frequency protections to disconnect parts of the network. This principle is also known as "Low Frequency Demand Disconnection."

Cost calculation improved

Cost calculation performs loadflows for the four dayparts and sums the results.

Calling Python from macros

From a macro, it is possible to call a Python command 437 or Python script 437.

NEW IN VISION 9.5.1

Save network file as set

When applying variants and/or scenarios, the set network can be saved as the base network via **Variations | Save | Save as set**.

Change voltage level

The voltage level of some selected nodes can be changed collectively via **Start | Edit | Special | Voltage**.

NEW IN VISION 9.5

Data driven loadflow

The data driven loadflow determines the most probable grid condition (voltages, currents and powers) based on the measurements provided. In case of gaps in the measurement data, they can be filled in automatically using the built-in preprocessor.

Connection clock number at transformer

By connecting the phases to the terminals of a transformer differently than intended, the resulting clock number may be different from the type clock number. In this case, the connection clock number can be specified on the **Connection** sheet of the transformer form.

Measurement side of homopolar impedance at transformer type

For YY transformers, the measurement side of homopolar impedance can be w1 or w2. This can be specified at the transformer type. Automatic side determination has remained. Here Vision determines the most logical side.

Two additional set points in load-dependent voltage control for (special) transformer

The load-dependent voltage control has two additional set points: (P<<,U<<) and (P>>,U>>). The set points are now called (P<<,U<<), (P<,U<), (P>,U>) and (P>>,U>>). (P<<,U<<) and (P>>,U>>) can be (0,0) if not needed.

Capacities at three-winding transformer

The three-winding transformer has six capacities, to be filled in on the **Connection** sheet of the three-winding transformer form.

Related scenario(s) at variant

The related scenarios are automatically activated after user permission when the variant is activated.

Related variant(s) at scenario

The related variants are automatically activated after user approval when the scenario is activated.

Taking over variants

Multiple active variants can also be taken over into the base with **Variations | Edit | Take over variant**.

Taking over scenario(s)

One or more active scenarios can be taken over into the base with **Variations | Edit | Take over scenario**.

Contract at customer at node
Information about a customer's contract can be entered as text in the node form.

Q control in battery
The battery has a reactive power control with the sorts Q(U) and Q(P).

Five-minute profile
An internal profile can also be specified on a five-minute basis. There are two types: five-minute of one day and five-minute of weekday, Saturday and Sunday.

Changed behavior of scaling percentages
The four scaling percentages in the settings of loadflow and other loadflow-using calculations have a different behavior when specified as zero.
A scaling percentage of zero means that the element does not supply/absorb reactive power when it could possibly have done so at a real power of zero.
Practically, this means that the element is completely off at a scaling percentage of zero.
In a fault analysis or protection calculation, an element will also not contribute to the short circuit at a scaling percentage of zero.

NEW IN VISION 9.4.2

Extra output at network comparison
Comparing two (the same) networks via **Tools | Compare | Compare with network** has been extended to report the differences in an Excel file.

Open network file from web
A network file can be opened from a cloud location via **File, Open, Open from web**.
A default location has been added in the options.

Option "Assessment priority" in failure analysis
This option sets the assessment priority of recovery, overload and overvoltage/undervoltage during switching. This allows problems to be accepted, in favor of recovery. However, this does not result in proper resolution.

NEW IN VISION 9.4.1

Switchability calculation
The switchability 360 calculation is based on the failure analysis in afternoon and evening situation. The results focus on switching ("omschakelen" in Dutch, but there is no English word for).

Earth voltage at voltage protection
Voltage protection also has a earth voltage and corresponding time.

Variant and scenario items more visible
The input forms on the "Variations" tab show the active variant and scenario items selected.
In the input forms, switching positions and powers that deviate from the input values due to active scenario(s) are shown with a yellow label. These actual values are thus active.

NEW IN VISION 9.4

Icon at node
A node can be provided with an icon. This is a point symmetrical shape with a short text in it.

Export to Excel via an integrated Excel toolbox
All reports and exports to Excel go through an integrated Excel toolbox to an Excel file. So no more using Excel on your computer.
The Excel file is written in the temporary folder and then opened when you have Excel on your computer.

Reading in and importing from Excel via an integrated Excel toolbox
All imports from Excel are done via an integrated Excel toolbox. So no more using Excel on your computer.

One or two line header in the reports
This can be selected in the report settings. A one-line header has advantages when sorting.

Calculation Power park module renamed to Power generating module
The functionality has also been improved.

Macro command
Import 436: import an Excel file in the standard way.

NEW IN VISION 9.3.2

Comparison of two networks improved
More properties of common objects are compared.

Calculation Power park module
The power park module assessment helps demonstrate that the reactive power of a Type B park meets grid code requirements.

Result colors revised
The result colors in the options have been revised and expanded.

Motor start scenario
In the load flow settings, a scenario can be selected that is active during the motor start.

Total-external profile at the transformer load
An external profile for a transformer load is now the total of the three components load, generation and PV.

Macro commands
Pseudomonitor: Calculation of the pseudomonitoring
Netcheck: Calculation of the netcheck
ExportResult: Export calculation results to Excel file
GetUsedRange: Ask range of a work sheet
Create: Create a new workbook
Pause: Pause the execution of the macro

All P and Q controls of load, PV and wind turbine collectively editable
Via **Edit | Collective | Element**.

Display the colors of the remembered results in the graph as well
Previously gray. Now gray when no special color, else that color.

Results of other calculations optional additional report
In the report settings, the checkbox for this is "Other calculations".

NEW IN VISION 9.3.1

Improved result overview after load flow and network load
The results overview, accessed via **Calculate | Results | Overview**, has been expanded to include:
- Highest and lowest voltage by voltage category
- Highest voltage variation by voltage category
- Highest load rating per object type (cable, transformer, element and transformer load)
- Highest voltage exceedance (relative to the (individual) limit) by voltage category
- Highest voltage variance overshoot in medium voltage
- Highest load rate overshoot by object type (cable, transformer, element and transformer load)

NEW IN VISION 9.3

Vector-jump protection
The vector-jump protection detects a sudden change in the angle of the voltage.

Conductor temperature for PILC and non-PILC
Two conductor temperatures can be entered in the options.

Normal situation and fault situation
In the settings of the load flow and network load, a choice can be made for normal situation or fault situation.
In the normal situation synchronous generators with "emergency current" do not participate.
In the fault situation, non-preferred elements do not participate.
The objects are colored afterwards according to the limits of the selected situation.

Earthing for asynchronous machine
The star point of an asynchronous generator or motor can be grounded.

Inverter power of PV as apparent power
The inverter power is now the apparent power. Previously the real power.

NEW IN VISION 9.2.2

Copy and paste presentation properties
The presentation properties of one selected object can be copied to an internal clipboard using **Start | Presentation | Copy**.
Next, this clipboard can be applied to the presentation properties of selected objects using **Start | Presentation | Paste**.

Variant- and scenario-items importable
Variant and scenario items relating to an existing variant or scenario can be imported.

NEW IN VISION 9.2.1

Netcheck
The netcheck helps to assess a request for a new load or generation.
The functionality of this first set-up will be expanded in the near future.
See: Netcheck 357.

Adding elements when importing
Elements can be added by putting "Name+" in the header.

NEW IN VISION 9.2

Several variants and scenarios active at the same time
Several variants can be active at the same time.
Several scenarios can be active at the same time.
The date is detailed to date+time.

Adoption of one variant
One active variant can be copied into the base with **Variations | Edit | Take variant over**.

Third current transformer in the measuring field
The measuring field may contain three current measuring transformers.

Resistance symbol for line
The line can be drawn with a resistor symbol.

P(f) control for wind turbine, PV and load
The P(f) control can be used in load flow with islanding, where the frequency is calculated.

P(I) control for battery
The battery has a P(I) control.
Also, all P(I) controls have become directional.

t_{input} and t_{output} for most of the protections
Most protections have an input time and an output time.
The input time, also known as pickup time, is added to the setting time(s) and plotted as a result in the current-time graph.
The output time, also known as operation output time, is applied after tripping.
The $t_{>}$, $t_{>>}$ en $t_{>>>}$ may now be zero, if the current is filled in. Internally, a minimum of 1 ms is used.

Creation time and mutation date
New objects are given a creation date time. The resolution of the time part is 10 μs. No duplicate creation date times are issued, for example when pasting a number of objects. This makes the creation date time unique within a network (and probably outside of it) and can be used to identify objects.
Modified objects (except by moving) are assigned a mutation date. Changes made on the creation date are not considered a mutation.
The creation date and the mutation date can be found on the **Specifics** sheet of the object forms.
Selecting on these dates can be done via **Select | Special | Date**.

Fragmented loadflow with profiles
The load flow can be calculated at fewer, possibly non-consecutive, times. For example, not every week, not every day, not every hour.

Take over switchover suggestion from failure analysis
A switch proposal can be adopted with **Calculate | Results | Process**.

Asymmetric breaking currents in IEC 60909
The asymmetric breaking currents are shown with the detailed results.

NEW IN VISION 9.1.2

Protection tool improved
Improvements include automatic sequencing and the ability to remove a curve.

Colours suppressible according to normal limits
In the load flow settings, it is possible to skip result coloring according to normal limits, in case the network is configured according to a fault situation.

Macro commands
DeselectAll: deselect all objects
Break: jump out of a loop

NEW IN VISION 9.1.1

Regulating transformers against the voltage limit
In the load flow settings it is possible to select a tactic for all transformer controls. This can be "high voltage" or "low voltage".
At "high voltage" all voltage regulating transformers regulate to the stage where the control voltage is as high as possible within the band.
At "low voltage", all voltage-regulating transformers regulate to the stage position with the lowest possible control voltage within the band.
The network load calculation can also make use of this facility. This tactic is available in the options, at Calculation, Presets.

NEW IN VISION 9.1

Macro commands
SetSerialsAndFeedings: set serial numbers and feeding group numbers again
SetDirections: set direction numbers again
SetMeshes: set mesh values again
SetGroups: set group numbers again
FreezePanes: block titles in Excel
ExportGeo: export geografical data to Excel.

Accu control
The accu can be equipped with a controller to control charging and discharging. A P(U) control or P(t) control can be selected. The P(U) control overrides the commonly specified P and profile. The P(t) control also overrides these values, but only if the time is known.

Profile at PV of the transformer load
The PV in the transformer load has a profile. The profile scales the solar radiation.

Transfer tripping ability of circuit breaker depending on type of protection
The transfer tripping ability can be activated for each type of protection.

Load rate limits for PILC and non-PILC
PILC cables and non-PILC cables have their own load rate limits in the options at *Calculation, Limits* . Set these values right once!

Voltage variation checked
After a network load calculation or a load flow with profiles, the minimum and maximum achieved voltage per node are known. For medium voltage nodes, this variation is tested against a new value dU_{max} in the options, under *Calculation, Limits* . Nodes with an exceeded value get the high color.

U_{min}, U_{max} and dU_{max} at node
Per node, the voltage limits from the options can be overridden by specifying your own limits in the node form at *Diverse, Limits* .

NEW IN VISION 9.0.1

Non-preferred element
A non-preferred element is switched off during switching in the fault analysis.

The value is set on the *Reliability* sheet of the element form.

Macro commands
CreateDir: Make a sub folder.
ForSelected: Execute a piece of macro for selected objects of a specified sort.

Motor start via autotransformer in IEC 60909 calculation
The secondary rated voltage of the special transformer can be used as voltage of the voltage source in case of short-circuits.

Network export in order of routing.
Sorting has been added to the export settings.

Easily adjust the distance between the nodes of a rail system.
By using the rail system form *Temporarily graphically decoupled* .

Calculate only one time at load flow with profiles.
By setting *Choose timestamp* in the loadflow settings.

Phase shift of a transformer as a scenario item parameter.
By selecting *Phase shift* at parameter.

NEW IN VISION 9.0

Protection presence split into present and active
The protections at a circuit breaker have two "tick marks": present and active. The new possible status is therefore: present, not active. These protections are stored in the network file, but do not function.

P(I) control for wind turbine
The wind turbine has a new P-control, with which the power based on the current (actually load rate) in one, two or three branches can be regulated.
The P(I) control may occur at the same time as a P(U) control.

P-control for load
The load has two P-controls: P(U) and P(I). This allows the power to be reduced if the voltage drops or if the current becomes too large due to a selected measuring field.

Remembering and restoring switch states
The current switch states can be remembered and be reset a little later. This is done via **Start | Edit | Special | Remember**.

Even harmonics
Even harmonics can also be entered.

Vertical text at nodes
The text at a node can be set to vertical via the presentation sheet in the node form.

Better power output after load flow with profiles
P_{min} and P_{max} are reportable on elements. $P1_{min}$ and $P1_{max}$ are reportable on branches. The sign shows the power direction.
The P of branches and elements is also exported in the result export after load flow with profiles.

NEW IN VISION 8.15.2

Unique specific values in the network export
When exporting a network to Excel with **Tools | Data | Export** an additional last worksheet *Specifics* is created, where all the specific charasteristics with their sorted unique values are exported. Note: this sheet consists of independent columns. In other words: the values in one row have no relation to each other.

NEW IN VISION 8.15

Harmonics until the hundredth
The harmonics, contained in the harmonic type, can now be definied until the hundredth. Only odd harmonics are used in the harmonic calculations.

Harmonic voltage source at source
The source has a harmonic voltage source, where harmonic voltages can be entered.

k2, k3, k4 at differential protection
The differential protection has three new parameters, to add an extra threshold.

Operation output time at current protection
The current protection has an own time, that is applied after the tripping.

P(I) control at PV
The PV has a new P control.

Smin and Smax at source
The source has an optional Smin and/or Smax at which the by the loadflow calculated power is tested. The result is translated in a load rate between 0 and 200 %.

Notes quick (in)visible
In practice, notes are a a blessing and a curse. Notes could be made (in)visible via **View | Adjust appearance**, but now it can quicker via Ctrl+Alt+N.

Select at color
Objects can be selected at the color (of their presentation) via **Start | Select | Object, Presentation**.

Selecting modified
Selecting objects by dragging a rectangle with the mouse is changed when dragging from the left to the right. Objects have to be found completely inside the rectangle to be selected.

NEW IN VISION 8.14

Wind turbine simplified
The wind turbine model has been greatly simplified and has complete P- and Q-control.

New load behaviour
Three new built-in load behaviours are available: Industrie (90% const. P, 15% const. Q), Zakelijk (35% const. P, 10% const. Q) and Wonen (30% const. P, 5% const. Q)).

Arc protection
The arc protection has been added to the installation tab at a node. The installation only contains data for the arc flash calculation.
In the presence of an arc protection, the short circuit is switched off in a fixed short time.

Load-dependent voltage regulation with special transformer
The voltage regulation of a special transformer has been expanded from only compounding to also including load-dependent voltage regulation. The regular transformer already had this regulation.

Arc flash calculation according to new edition of IEEE 1584
The 2018 IEEE arc flash norm has been implemented.

More selection options
There are two new items at **Start | Select**:
Direction: The entire direction of the selected object or objects is selected. The sub-menu offers the possibility to select additional directions (on the other side of an open switch) as well.
Area: The entire area which is fed by the same source\transformer of the selected object or objects is selected.

NEW IN VISION 8.13.1

Adaption of IEC 60909
PV, wind turbine (lite and converter coupled) and accu are handled according to the new edition of the norm out 2016.

Isochronous control
Synchronous generators with isochronous control keep the frequency nominal in island mode (during the loadflow).

Active filter
The condensor can contain an active filter. An active filter injects harmonic currents (during the harmonic loadflow) to compensate the harmonic current through a measure field.

NEW IN VISION 8.13

LSI relais
The current protection is extended with a new characteristic sort: LSI.

Inverse differential protection
The differential protection can also be equiped with an inverse characteristic.

Transfer trip switches at transfer trip ability
At the already existing transfer trip ability, transfer trip switched can be entered.

Extended blocking ability
At the already existing blocking ability, flexible combinations of protections can be made.

NEW IN VISION 8.12.4

Alias for fuses
See Alias 78.

Symbols for remote control and remote indication of switches
The presence of remote indication and/or remote control is drawn with a small symbol on top of the load switch and circuit breaker.

Presets
In the options loading presets can be defined. For each preset the generation, load, PV and wind can be scaled independently of each other.

Normal open point optimisation with four presets
The optimisation of the normal open point estimate the energy losses with different loading situations. The four preset situations are night, morning, afternoon, evening.

Network load calculation
With a network load calculation a number of different loading situations are calculated for a single network..

NEW IN VISION 8.12.3

Select specifics based on value
Objects can also be selected based on the value of the defined specifics. **Start | Select | Specifics**.

NEW IN VISION 8.12

Additional properties for feeders
The enumeration of the feeders at a node has been extended with two new attributes per field: *to* and *information*.

Generation and PV at transformer load
The transformer load has been extended with two new generation items: *generation* and *PV*.
The specified generation is multiplied by the current generation percentage when performing a loadflow calculation.
The PV-power is multiplied by the current PV-percentage when performing a loadflow calculation.

Measurement unit on secondary side of a transformer load
A measurement unit can also be applied to the secondary side of a transformer load.

Own characteristics saved
The 'own' characteristics to be specified in **Extra | Compare | Protections** are now stored in the network file.

Generator and motor off as the generation percentage or the load percentage is equal to zero
If the generator or motor has a specified capacity, but in the load flow the generation percentage or the load percentage close to zero or zero, the generator or motor is also turned off.
Previously, reactive power control was still active.

NEW IN VISION 8.11.4

Additional settings for loadflow
An own scaling percentage for wind turbines can be specified in the load flow settings.
With the load flow with internal profiles, a specific day can be selected, in addition to a certain week.
In addition, a larger time step can be chosen for a potential time step of a quarter and a half hour.

NEW IN VISION 8.11.3

Select special extended
Two new items have been added to **Start | Select | Special**:
Remote indication: select nodes, circuit breakers and short-circuit indicators with remote status indication.
P measurement: select measurement fields with a power measurement.

Measurement graph in the measure field form has been improved
A choice can now be made between showing the graph as current or as power.
The graph can be shown as a bar graph or line graph (the line graph becomes a point graph, in case of a too large break).
The measurement data can be copied to the clipboard as text.

NEW IN VISION 8.11.2

Measurement files and the calculated profile values plotted together in one graph
This can be done in the form of the measuring field. See Measurement unit 222.

NEW IN VISION 8.11

P-control at PV
Het power can be controlled based on the voltage.

Fault resistance series for selectivity calculation changed
0 to 10000 Ohm and 0 to 1000 Ohm are deleted.
0 to 5 Ohm and 0 to 2 Ohm are added. Check your choice in the options!

Also measuring field as measuring point for differential protection
Except a circuit breaker, also a measuring field can be choosen at "Other measuring points".

Set simultaneousness with a power measurement
Except with a current measurement, also with a power measurement the simulaneousness via measuring field measurements can be set.

Formula of special current protection changed
The factor k is renamed to factor m. The extra time "e" is moved inside the brackets.

Sort field
At the enumeration of fields, at node, the sort can also be entered. There is a list to choose.

Sk" leading at source
The basic registration of the short circuit power is Sk". Formerly Ik". When copying a source to another voltage, the short circuit power is preserved.

NEW IN VISION 8.10

Arc flash calculation
The Arc Flash module determines the energy that is emitted by the arc in case of a short circuit in an installation. Based on the arc energy the category of Personal Protective Equipment (PPE) is chosen. The module contains two methods of the arc flash calculations: according to the IEEE 1584 standard and according to the closed box text method of International Social Security Association (ISSA).

Differential protection at circuit breaker
The differential protection, formely a loose object, is accommodated at the circuit breaker.
The rail differential protection is accommodated at the node.

Earth fault differential protection
An earth fault differential protection can be entered at a circuit breaker.

Customer data at node
Customer data can be entered at the node.

Extended transformer voltage control
The voltage control of the transformer is changed and extended.
Umin and Umax are replaced by Uset (the average) and Uband (the difference).
Compoundering can be switched off at an opposite power direction.
A "load dependent" control is added.

NEW IN VISION 8.9

Unbalance protection
An unbalance protection can be entered at the circuit breaker.

Thermal protection
A thermal protection can be entered at the circuit breaker.

Directional voltage protection
The voltage protection can be set power directional.

NEW IN VISION 8.8

Dynamic analysis
- Workspace: to analyze different scenario's or to validate simulation results with external (measurement) data, variables can be saved or imported to the workspace. Those variables can now be used during the session to be compared with the other workspace variables or with current simulation data.
- Building-up linear electrical network: internal adjustment to speed-up the process, mainly during analysis of large networks.
- Initialization procedure: time domain initialization for determining the initial operating point.
- Cable model: possibility to represent a cable by T-model or π-model consisting of one or multiple sections.
- Tan(Delta) snubber resistors of cable: possibility to set snubber resistances (parallel to shunt capacitances of a cable) based on tan(delta) value.
- Power System Stabilizer (PSS) model: the function of a PSS is to damp oscillations in the network by adjusting the excitation of the synchronous generator.

Stability Analysis
As consequence of a disturbance or a normal change of operating point in a system, the system will show a transient response. The system is considered to be stable if oscillations in this response damp out after certain time period of time and a new stationary state is reached. A system is unstable in case if these oscillations do not damp out or even continue to grow with time. This can have serious consequences and, in the end, result in a blackout. Stability Analysis module determines based on the eigenvalues whether the system is stable or not. In literature this type of analysis is referred as ‘small-signal stability analysis’.

NEW IN VISION 8.7

IEC 61363
The calculation of short-circuit current according to IEC 61363 standard: “Electrical installations of ships and mobile and fixed offshore units – Procedures for calculating short-circuit currents in three-phase a.c.”.

Improved inverter control at PV
The inverter at PV has and extended Q(P) control and also a Q(U) control is possible.

Dynamic Analysis

- zigzag grounding transformer;
- input form for control systems of synchronous generator;
- reactive power and power factor control (synchronous generator);
- turbine and governing system (synchronous generator);
- neutral point grounding of elements (choice between isolated, grounded and grounded via impedance neutral point).

NEW IN VISION 8.6.3

Reliability calculation improvements

The remote control is reviewed. This leads to extra phases in the restauration process: isolate remote, switch in remote, switch over remote.

Pseudomonitor improvements

Adding an external profile is possible. The format is the same as an external profile at the loadflow.
The correction algorithm works according to actual power instead of nominal power.
A second, extended export is generated.

Failure analysis improvements

Maze detection: Mazes are not allowed.
Automatic source behind subnet border: at "loose" nodes behind subnet borders an invisible source is added, during the calculation.
Not available use: report of the power of (transformer) load that are connected to not available nodes.
Switch actions colored: when calculating for one object, the switch over branches are colored in the attention color.

NEW IN VISION 8.6.1

More fault sorts at the same time at Protection - Selectivity

The protection selectivity calculation can calculate more fault sorts in the same run.

NEW IN VISION 8.6

Units in external profiles

The external profiles for load flow, need no longer contain only factors. Depending on the parameter, the values can be specified in V, kV, A, A, VA, kVA, MVA, W, kW, MW, var, kvar, Mvar, m/s, pu,% and ‰ percentage points.

Sun intensity in PV replaced by scaling

The property "sun intensity" in W/m² is replaced by "scaling" in ‰.
Because both variables have a nominal value of 1000, nothing changes in the input and calculation.

Load and generation scale collective in the load flow

Through three percentage in the load flow settings, all loads, generations and PVs can be additional scaled.

Link to Gaia

From a node in Vision, a Gaia-network can be opened in Gaia. The calculated short-circuit power in Vision is passed to the source in Gaia.
In the options, the Gaia network files folder must be specified.

Parallel processing

The load flow with n-1 / n-2 and the load flow with profiles are fitted with parallel processing.
This can optionally be disabled in the settings.

ArgDir at directional protection replaced by RCA
The to be specified direction angle is turned 90 degrees. The "relay characteric angle" is now asked. This is the direction in which the relay "maximal" works.
RCA := ArgDir + 90 for current protections. The default RCA is 45 °.
For earth fault protections, the direction is reviewed, leading to RCA := ArgDir - 90. The default RCA is 0 °.

Snom at accumulator replaced by C-rate
The C-rate is more or less equivalent to S_{nom}. The C-rate is the maximum rate at which the battery may be charged and discharged.

Loss split into no-load and load losses at the cost calculation
The energy loss is splitted into no-load and load loss.

Two blocks of text at elements: at the node and at the symbol
An element now has two text blocks: one initially at the node and one initially at the symbol. In the first block/line is only the field number. In the second block is any other text. Obviously the position can be adjusted by dragging the cubes.

NEW IN VISION 8.5.2

Zoom next selected object
With **View | Zoom | Zoom selected | Next selected object at this sheet** you can zoom in at the next selected object. The shortcut is **7**.

Scrolling while dragging
If you reach the border of the window, while dragging, the network automatically scrolls in that direction.

Harmonic wave graph
After the harmonic loadflow, a wave graph is available per object, reachable via detailed results, button **Graph**.

Decreasing short circuit contribution of engines
De contribution of generators and motors immediately after a short circuit is Ik".
This contribution decreases in the time.
In protection calculations, where the time is known, the admittances of generators and motors are recalculated at specific times, namely at 20, 50, 100 and 250 ms. The factors μ and q of IEC 909 are applied
So, the protection calculation generates extra sequences, at which no protection switches off. This is only done when necessary.

NEW IN VISION 8.5

Efficiency type at accumulator and PV
De effciency of the PV is taken into a efficiency type.
Also for the charge effciency and the discharge efficiency of the accumulator.
The efficiency type consists of a name with 5 input values in pu and 5 accompanying output values in %.

Date and time at PV removed
The specification of a certain time at a PV is removed.
The PV works maximal, scaled with the sun intensity.
During a loadflow with time related profiles, the time is still taken into account to calculate the radiation.

Separation at load switch
A load switch can be drawed as a load separator (load switch+separator(s)) or separator.
The new attribute "separators or separation" causes the drawing of the separator line.
If $I_{k,make}$ is zero, the load switch symbol is not drawn, if separator is checked.

Year and failure frequency at sleeve
The sleeves in the cable have extra attributes: year and failure frequency.

More fault sorts at the same time at Protection - Simulation
The protection simulation can calculate more fault sorts in the same run.

Changes in Types.xls(x)
The efficiency type is added.

NEW IN VISION 8.4.1

Some small improvements
- k-factor calculation, at the harmonic loadflow.
- "Function" added to node properties.
- "Z1 -> Z0" in the transformer form.
- Short circuit power of the source also as impedance.
- Drawing transformer load as load, via the options.

NEW IN VISION 8.4

Variable objecttypes filename
The name of the objecttypes file is no more limited to Types.xslx. The name of the file, instead of the folder, has to be specified in the options.

Transformer control at other node
A transformer control can control the voltage at another node.

Tangens delta
The diëlektrical losses in the cable can be calculated in the loadflow, because the tangens delta is added to the characteristics of the cable type.

Generous customers
A new customer category is available at the (transformer)load.

Dynamic analysis
The dynamic analysis is available.

NEW IN VISION 8.3.3

Report of specifics per characteristic
Specifics get their own column per characteristic in the reports if the item "Specifics per characteristic" is choosen in de report definition.

Scenario-items import
Scenario-items can be imported. See Importeren 103.

NEW IN VISION 8.3 AND 7.8

PV
A new element is added: PV, or solar panel.
A PV consists of maximal three panels and an invertor.
The current generation is calculated on the basis of the entered sunintensity and the date and time.

Solar panel tool
De proceeds of a solar panel is dependent of the placing of it and the actual sun situation. These two items are combined in a tool that can be started with **Extra | Tools | Solar panel**.

Parameter calculation indication
The component parameters are used by different calculations. The labels of the parameters are marked in the component forms by means of a blue color, when they are (optionally) used in the quick calculation.
The user is thus not busy discovering information that Vision does not require for the calculation.
This indication can be switched on or off in the options.

Subnet borders extended
The subnet borders have been extended with a recording of the two feeding sources on both sides of a border. This is free text in the input form of a cable, link or connection, in which the name of the supplying substation can be put, for example.
In the diagram the subnet border can be extended drawed by an attention triangle and mentioning of the supplies. This attention triangle can be switched on or off in the options.
The semi-automatic setting of subnet borders via **Edit, Special, Subnet border** provides support in detecting subnet borders and determining the feeding sources.
Potential subnet borders and associated supplies can be easily incorporated here.

Select feeding route
The shortest route (smallest number of branches) from a node or element to a source can be selecterd with **Start | Select | Feeding**. Select one node or element first.

Three macro-commands
Put: with Put a series of cells from one of the two-dimensional arrays is copied to a sheet of the workbook output.
Get: with Get a range of cells in a worksheet from one workbook is copied to an internal array.
Route: with Route all objects in a route between two nodes or elements are selected.

Reactive power limit tactic at synchronous generator
The boundaries of the reactive power of a synchronous generator can except Q_{min} and Q_{max} also be specified more variable. For this, the reactive power limit tactic is introduced, shown as 'Qlimit' in the form. Possible choices are: constant, automatic and own.
When selecting automatic or own an additional Control tab appears. When selecting "automatic", the curve is automatically determined from a number of input parameters. When selecting 'own' you can specify the curve yourself.

Current protection direction at a two phase fault improved
The determination of the current direction at a direction-sensitive current protection is improved.
Previously it was always determined per phase, based on U_f/I_f.
Now, first the fault sort is determined on the basis of a plurality of phase current and phase voltage comparison rules. When a two-phase error is detected, the direction is determined on the basis of the voltage difference divided by the current difference.
This works similarly to the direction determining of the distance protection. The distance protection has a fixed direction angle of -45 °, while the direction angle of the current protection must be entered.

NEW IN VISION 8.2 AND 7.7

Reactance coil only in R, X and I_{nom}
The type data of a reactance coil could be specified as S_{nom}, u_k, P_k or R, X, I_{nom}. Because first mentioned set is not usable, this possibility is extincted.

Earth response time at short circuit indicator
The earth setting of the short circuit indicator has a own response time. At protection calculation with one fault, this setting is used. This calculation shows indicating indicators.

Text color and style
Per object presentatiion the text color and the text style can be choosen at the tab ‘Presentation’ of the input form. For the text style all combinations of bold, italic and underlined are possible.

Note movable
The note is movable by dragging it with pressed left mouse button. The position is stored in the network file.

One and a half percent growth
A growth of 1,5 % per year is standard available.

Report to Word
A report can also be send to Word. This is more suitable for small reports, also in length as width.

NEW IN VISION 8.1.4 AND 7.6.4

Island detection changed
Parts of the network that are not connected with a source are normally "in island".
From now these parts are no longer in island if they are connected with a synchronous generator with voltage control and frequency power control (f/P static). They automatically attend all calculations.

NEW IN VISION 8.1.3 AND 7.6.3

Store
A network fragment can be stored 90 using: **Start | Store | Save**.
Stored fragments may repeatedly be retrieved from the store to add to any place in the network, using: **Start | Store | Take**.
These actions are similar to copy and paste, but the objects in the "store" are permanently available.

Types check
The available object types can be checked for basic errors. From the Type viewer 115, button "Check".

Selectivity graph
The protection selectivity 298 of an object can be presented in a graph, summarising selectivity and whether a fault will be switched off or not.

Macro command ShowNetwork
Using this command 435, a network that has been altered by a macro will be displayed in de graphical editor.

NEW IN VISION 8.1 AND 7.6

No short-circuit contribution from synchronous motor
It can be specified that a synchronous motor 178 does not contribute to a short-circuit. In that case, the motor behaves as a general load. This can be specified on the "connection" tab.

Fields at node
For nodes 138, fields/bays 236 can be defined, by specifying their names on the tab "specials". The fields names order should match the order of the real fields.
When the field names have been specified, each branch 144 and element 171 can be assigned to the fields. For a node with a complete field assignment, the bus bar currents can be calculated for a load flow and a protection calculation.

Reference earth point for external earthing
A node can contain an earthing point 138, that may serve as a common grounding point for star points of several components. Using this, the star points of a synchronous generator, synchronous motor, capacitor, shunt coil, zigzag coil (grounding transformer) and transformer can be connected to the common ground.

Voltage transformer as type
The voltage transformer parameters have been combined into a type. The parameters are: name, transformer ratio, class and rated power.

Second stage for differential protection
The differential protection 213 has a second stage for difference current and a time. The differential protection trips if the sum of the complex currents is larger than a threshold value. An optional additional condition is that the sum of the complex currents is a factor k1 larger than the sum of the absolute currents.

Extended protection indication
In the circuit diagram, each protection device on a circuit breaker 203 is represented by a little transverse line on the circuit breaker symbol. For directional sensitive relays, this line points into the corresponding direction.

Protection blocking ability
A protection device on one circuit breaker 203 may block another protection device on another circuit breaker. On the circuit breaker form "General" tab this can be defined by ticking the "Block ability" checkbox. On the "Tools" tab, the relation to the other circuit breaker protection devices can be defined.

Reserve switch ability
If a circuit breaker 203 does not open after a trip command, the protection device may select another "reserve" circuit breaker to open. On the circuit breaker form "General" tab this can be defined by ticking the "Reserve ability" checkbox. On the "Tools" tab, the relation to the other circuit breakers can be defined.

Directional sensitivity of a short-circuit indicator
Signalling a short-circuit current by a short-circuit indicator 221 can be implemented with a directional sensitivity. This is used by the protection calculation - single fault.

Font
For all objects the font can be specified on the tab sheet "Presentation 248".

Unbalanced load flow
The unbalanced load flow 257 module has been implemented. The network is supposed to be three-phase balanced, but the loads may be unbalanced.

Changes in Types.xls(x)
The voltage transformer type has been added.

NEW IN VISION 8.0

Windows-ribbon
The Windows 7 ribbon has been implemented. The new ribbon structure is in accordance with the new computer operating systems standard. As a consequence, Windows XP is no longer supported.

Graphical editor
The schematic single line diagram editor uses the Direct2D-technology. This strongly improves the network visualization. As a consequence, Windows XP is no longer supported.

NEW IN VISION 7.5

Load switch
The load switch has been provided with a type, containing rated voltage and current data.

Additional current transformer in the measure field
The measure field can contain two current transformers. The current transformer data are described by a type.

External grounding connection
A node may have an external grounding connection. This can serve as a common grounding point for the Wye-star-points of several components. For example, the star-poits of synchronous generators, synchronous motors, capacitor, shunt coil or transformer can be commonly grounded. This has consequences for the proper calculation of short-circuits with ground connection. See: Node 138.

Asynchronous starting of synchronous motors
Synchronous motors can start asynchronously. For the motor start calculation the parameters Ia/Inom and the R/X-ratio have been introduced. The short-circuit calculation still uses the synchronous machine subtransient reactance and the fictitious stator resistance.

Unbalanced load
In anticipation of the unbalanced load flow, the load has a form for definition of the unbalanced load.

Changes in Types.xls(x)
The load switch type has been added.
The current transformer type has been added..
The synchronous motor type has been extended with Ia/Inom and R/Xa for the motor starting calculation.

NEW IN VISION 7.4

Control
Check for abnormal values in the network model. See: Prepare 80.

Items visibility in forms
The visibility of items in the objects forms can be enabled or disabled in the ***Options*** . The visibility can be enabled for: Specifics, Note, Selection, Reliability and Variations. For each item a choice can be made from: never, if applied, always.

Measure field extra parameters
The next parameters have been added to the measure field 222: I_{nom} (relocated from the circuit breaker), $I_{k,dynamic}$, $I_{k,thermic}$ and $t_{thermic}$. The I_{nom} is tested in the load flow calculation. The $I_{k,dynamic}$ is tested in the IEC 60909 short-circuit calculation. The $I_{k,thermic}$ and $t_{thermic}$ are used to calculate the t_{max} in the IEC 60909 short-circuit calculation.

Hints
For all parameters in the component forms a hint will show up when moving the mouse pointer to a parameter name. The hint shows a short parameter description. The hint text is contained in the spreadsheet file *VisionHintsEN.xlsx* . See: Edit components 91.

Variants
A variant 237 describes modifications to a network model that will occur on certain specified dates (in the future). Using variants, all stages of commissioning and decommissioning of network components can be evaluated. A variant is a list of events, specifying the dates where the objects will be taken in or out of service.

Scenarios
A scenario 243 describes the settings and changes to objects parameters in the whole network. The changes can be independent of time but also a chronological table of events can be defined. The manipulable parameters are: switch state, transformer tap changer setting, real power, reactive power and apparent power. Several scenarios can be defined for a network. One scenario can be activated using the menu ribbon **Home**, ribbon group

Variations, item **Scenario**. Using the selected scenario and date, all calculations will be made for this network state.

State

In previous versions the state was a set of properties of selected objects, that were stored in the network file. The stored properties are: node (simultaneousness), branch (switch state, tap changer position), element (switch state, absolute power (MW/kW), relative power (%), tap changer position). The stored states will be converted to a scenario without date.

Time

A network study may be carried out for a moment in the future. The actual values of the loads depend on the load growth and the elapsed time from year zero. The load growth is defined in the load behaviour 227. The year for the load flow study can be set in the ribbon **Home**, ribbon group **Time**. As a result, all loads and transformer loads will be set according to their load growth and all calculations will be performed for that year.

Arc flash

An arc flash 119 will normally be accompanied with a large amount of energy. Personell, working on an installation, must therefore be well protected. The arc flash function calculates the amount of energy that someone may be exposed to. The maximum amount of energy determines the protection grade of protective clothing.

Capacitor and coil grounding

It has been made possible to ground the capacitor 192 and the coil 194 through a grounding impedance. This influences the unbalanced calculations.

Changes in Types.xls(x)

In the types file *Types.xls(x)* the Drop-out/Pick-up ratio has been added for fixed-time over-current protections.

Edit Special, Profile situation

This operation brings the network in a specific state for time-independent calculations (other than the load flow calculation) that normally do not consider profiles. See: Profile situation 93.

NEW IN VISION 7.3

Accumulator

The accumulator 198 has been added as an element for the storage of electrical energy. In a load flow calculation using load profiles 230, the accumulator stores or produces electrical energy, according to the specified accumulator profile. The state of charge depends on the starting value, the storage capacity and the accumulator profile. During the charging and the discharging processes, the state of charge does not exceed the physical limits.

Measure field

The presence of a current measuring transformer and a voltage measuring transformer can be specified for informative purpose. A measure field 222 can be placed in a node or in a bay on either side of a branch or to an element.

Zoom selected at the next sheet

The function 'Zoom selected at the next sheet' enables the user to browse through the network sheets for any selected objects. With this function, all multiple presentations of one object can be found quickly. The function is available through: **View | Zoom selected | At the next sheet** or with shortcut key **8**.

Details of detailed results presented in table of cells

The details of a detailed results form, mostly tables with values, are presented in tables, consisting of cells. Each cell is containing one value. These tables can also be converted into tables of text values an can also be exported into Excel. A selection of cells can be copied into the computer clipboard.

One fault resistance for a selectivity calculation

The choice for ranges of fault resistances for a selectivity calculation 294 has been extended with the choice of only one fault resistance. The choice can be made in the ***Options*** **, at Calculation | Protection**.

Exporting the results of a selectivity calculation

The results of a selectivity calculation can be exported to Excel in a fixed format, using: **Calculation | Results | Export**.

External profiles

The load flow calculation with profiles can be executed using a file of time related factors for loads, generators and accumulators. Unlike the profiles, the external profiles 232 have an absolute relation to the time. The external profiles can be defined using Excel.

Sheet names in the views

The names of all the sheets where nodes have a presentation, can be printed in the views 72. The printing can be enabled in the view definitions 115.

Cable type names extended to 40 characters

The cable type names have been extended from 30 to 40 characters.

Earth fault current and response time of a short circuit indicator

The attribute 'Current' of a short circuit indicator 221 has been split into a 'Phase current' and an 'Earth current'. Also, the 'Response time' has been added as a delaying time. The short circuit indicator actions can be monitored using the protection calculation with Single Fault.

Types.xls

There are no changes in the *types.xls* type file.

NEW IN VISION 7.2.1

Reconfiguration of a transformer load

A transformer load can be decomposed into a transformer, a secondary node and a load. All properties are transformed into the new configuration. Select the transformer load and choose: **Start | Edit | Split**.

Types identification and rated voltage

A component type will be identified by its name in combination with its rated voltage (Unom), falling within a range. As a result, in ***Types.xls*** object types may have duplicate names if their rated voltage are not in the same range. For example, LV cables and MV cables with the same name may occur.

Cable calculation steps close to nodes

The number of cable calculation steps can be defined for protection and network analysis calculations. An option has been added to simulate short-circuits close to the from and to nodes (1% and 99% of distance).

NEW IN VISION 7.2

Fault location estimation

After defining the cable type attribute ***Pulse velocity*** , the distance from a node to a short-circuit location can be calculated from a measured ***Pulse duration*** . The calculation can be made on the ***Reliability*** form of the cable 150.

Additional type file

The basic object types can be augmented with a user-defined additional type file 75. Its location can be specified in the ***Options*** , at ***File locations*** . If type names have been used more than once, the basic type will be used.

Second earth fault protection
A second earth fault protection 211 has been added to the circuit breaker 203.

Fault impedance
The impedance on the fault location can be defined for the impedance between the phases (Zpp) and te impedance between phases and ground (Zpe). These impedances are used by the Fault analysis 274 and Protection calculation 296.

NEW IN VISION 7.1.1

Protection, One fault
The protection sequence can be evaluated for a fault on a single object/location. This is principally the same calculation as the **Protection | Simulation** calculation, but always executed for one fault on one specific object/location only. With this calculation, more detailed results are available during the sequences of the protection actions. See: Protection, Calculation 296.

To add a network
A network can be added using **Tools | Compare | Add a network**. The network that will be added must be opened as a separate network. The addition is done by adding the network sheets 65. Possible identical objects will not be added.

Import function moved
The function to import 103 objects data from an Excel spreadsheet file has been moved to: **Tools | Data**.

Export
The network data can be exported 113 to Excel in a fixed format, using **Tools | Data | Export**.

NEW IN VISION 7.1

Profile sorts
The profiles 230 have been extended with a time related sort. This implies that profile values can be related to months, weeks, days, hours or quarters of an hour. The existing free profile sort remains for not explicitly time-related values. The profiles are used by the load flow.

Notes
All objects can receive a user-defined note 248, to indicate special circumstances. This note will be presented in a yellow frame close to the concerning object. The frame cannot be moved and its size does not depend on the zoom level, so that it is always visible.

Cables parallel circuits
Each cable 150 connection can be made up of parallel circuits. Inputting the number of parallel circuits replaces the need to model each circuit explicitly. The advantage is that commonly protected parallel cables do not need an extra dummy node and a link. Moreover, the one line diagram will be simpler.

Link electrical properties
The electrical properties of a link 149 are fixed. However, from this version the rated current I_{nom} and the maximum short-circuit current I_k(1s) can be specified. If specified, the loading will be presented in the results. If not specified, the link is assumed to be infinitely strong and its loading will not be presented.

Ripple control calculation in the macro’s
The ripple control calculation can be executed from a macro. See: Macrocommand Ripple 412.

Type for harmonics norm
The harmonic load flow results can be validated to a norm, defining the maximum values for each frequency. The norm is defined in the *Types.xls* . Starting the harmonic load flow the user chooses the desired norm.

NEW IN VISION 7.0

Ribbon
The Vision Main menu has been replaced by a 'ribbon': a set of toolbars on various tab pages. Microsoft introduced the ribbons in Office 2007 and consecutively in Windows 7 and Office 2010. Many programs will adapt the new ribbons structure.

Load behaviour and growth
The load behaviour has been split into load behaviour and load growth. Load behaviour defines the voltage dependency of the load power. Load growth defines growth percentage and scale factors. The latter has been enhanced with a 30 years definition. When opening a previous version network, the load behaviour automatically will be split into the new definition.
Six fixed load growth scenarios have been programmed: No growth, 1%, 2%, 3%, 4% and 5%, exponentially per year. Besides, a user defined growth scenario can be selected.
Standard the load flow calculates the load situation at the end of the specified time period (in years). From this version, the load flow also calculates the grow path during the specified time period. Each year will be calculated separately and the results can be examined graphically as a function of the time.

Motor start in the view
In the views definition the user can choose for either presentation of the results before, during and after the motor start or for the presentation of only the results during the motor start.

Cost calculation
The cables investments cost have been introduced in the cost calculation. The specific cable investment cost has been included in *Types.xls* .
For each year a load flow will be performed and the cost of losses will be calculated. Also non-continuous growth will be taken into account.

Zero sequence impedance of MV/LV transformers
The Ro and Zo of standard transformers in *Types.xls* have been specified for MV/LV distribution transformers.

Preferred types
All component types in *Types.xls* have been supplied with a column ‘Prefer’. For each type a ‘true’ or ‘false’ indicates whether it is a preferred type.
Preferred types appear on top of the type selection lists in the component forms.

Ripple control
One or more ripple control sources can be placed in the network. The sources are specified on the tab page 'Specifics' of the node form.
The specification are: frequency, voltage and angle. The function calculates the ripple control voltage propagation through the network. The results are presented in graphs and tables.

1.3 Vision: introduction

Vision is a high-grade tool for analysis of electricity networks. Vision can be used to carry out load flow calculations, short-circuit calculations and fault analyses. Also the proper working of your over current protection can be simulated and selectivity analysis can be carried out. Vision can be used to carry for planning, design and operation of electrical transmission, distribution and industrial networks.

Vision compromises of the software and a PC or network key.

Introduction
Vision is designed for both frequent and occasional users. To ensure a high degree of familiarity, the functionalities offered by Windows were used as much as possible in the development. All general functions associated with this are therefore not described in this introduction.
However, Vision has a number of specific features and functions which one needs to know to be able to work with Vision. This introduction describes the installation procedure as well as the key features and functions.

Installation
Vision can be installed on a computer as follows:

- download the latest version of Vision from www.phasetophase.com
- install Vision *Network analysis*
- For the installation of the network key: see Hardware key 443. In this case, nothing needs to be installed at the client.
- For the PC key: plug the PC-key into the computer's USB port. For a SuperPro key: install the driver. See: Hardware key 443.

Startup
Click on the Start button and choose **Vision Network analysis**.
When using the network key, activate the network key option in the **Application menu | Options | Network Key**.

Network representation
The network is represented as a single-line diagram comprising of the nodes (busbar systems), branches (for example cables or transformers) and elements (for example generators or loads).

Selections
Many actions within the editor only relate to the selected components. Selected components are shown in the selection colour (default: white). A specific selection of components can be saved (to create: **Insert | Miscellaneous | Selection**; to select: **Start | Select | Object, Selection**).

Edit mode and Result mode
The network editor has an Edit mode and a Result mode. The presentation of data and results differs between the two modes. The Result mode is only available after a calculation has been carried out. With **View | Mode | Edit** and **View | Mode | Result** one can switch between the two modes.

Views and Reports
Definition of Views enables the user to determine the presentation of information for themselves in the single-line diagram (to create/change: **Tools | Definitions | Views**; to select: **View | View | <View>**).
Reports enable the user to compile custom reports (to create/change: **Tools | Definitions | Reports**; to print: **Application menu | Print | Report**).

Type
Addition and modification of network components is supported by component database. This database contains type data for busbar systems, cables, transformers, reactance coils, generators, motors, circuit breakers and protection relays. The component database is an Excel-file with the default name *Types.xlsx.*

Options
Vision can be configured by the user via **Application menu | Options**. Through these options the settings for both the editor and the calculations can be altered.

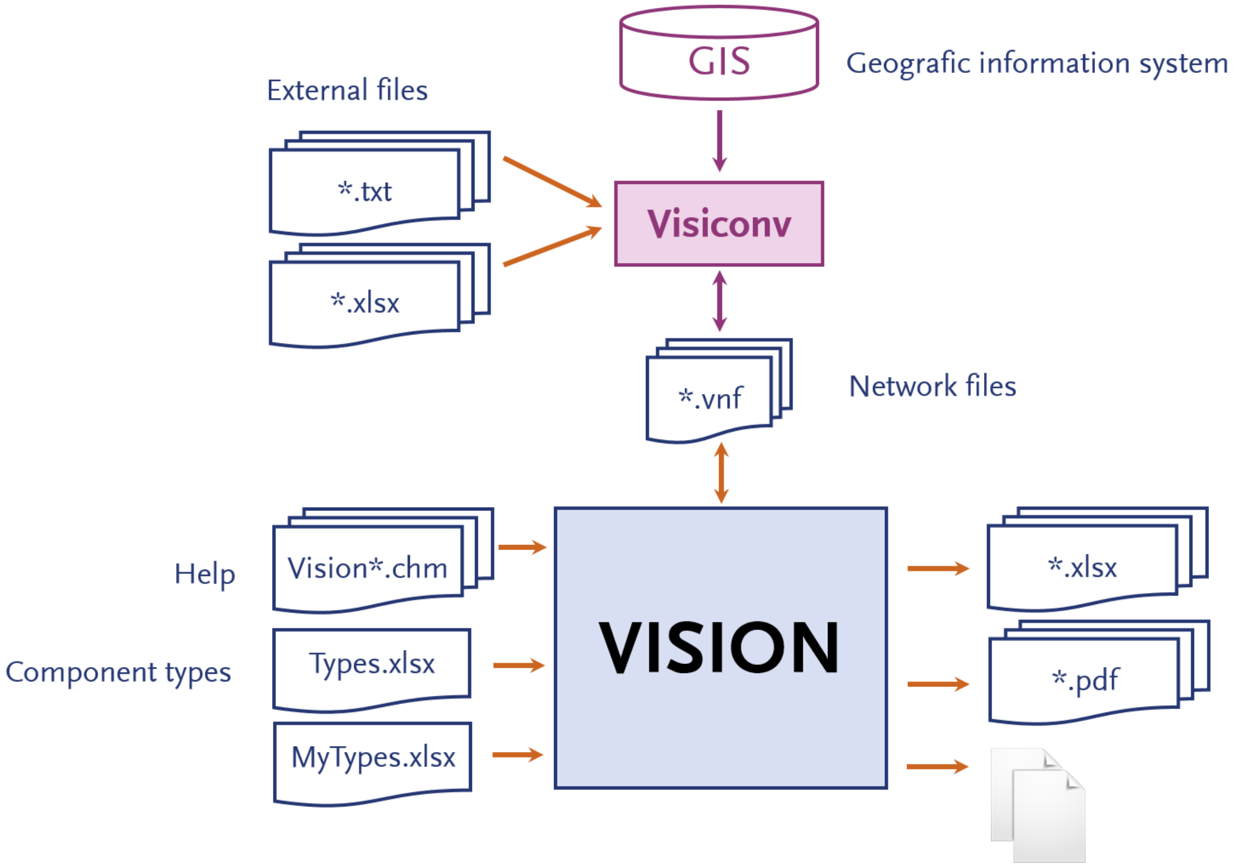
Help
Extensive support is provided via the help function, which is called with **F1**. The help function contains a description of all the editor functions, components and calculations.

Menu and mouse control
Most of the control actions are performed through the use of the ribbon menu and the mouse. The most important functions are explained in: Menu and mouse control 38.

1.4 Vision: structure

Vision *Network analysis* uses network files to store all the information of a network. A Vision network file can be recognized by the extension VNF (Vision Network File) . These network files are in plain text format. Network files are generated by Vision, but can also be generated by data from a (geographical) information system. Network files can be exchanged by e-mail.
For a description of the network file, see: www.phasetophase.nl/downloads.
When modelling a network with the Vision user interface, the type data can be obtained from the type file *Types.xls* .

When modelling a network through the Vision user interface the types database is used. In the types database the information of the different types of components is stored.
Vision supports exporting data to Excel, PDF or via the clipboard. This is shown in the illustration below.



The Vision user interface is based on a ribbon menu structure, with a set of different tabs. On a tab the different commands are ordered in groups according to their function. The tabs are ordered based on the kind of activity one wants to perform using Vision, e.g. the inserting and editing of objects is shown on the Insert tab. The main tabs are:

- Application menu 78: ("Bestand" in the upper left corner) file handling, print, prepare, send and options
- Start 91: clipboard, library, presentation, edit, select, memory and time
- Insert 85: adding objects

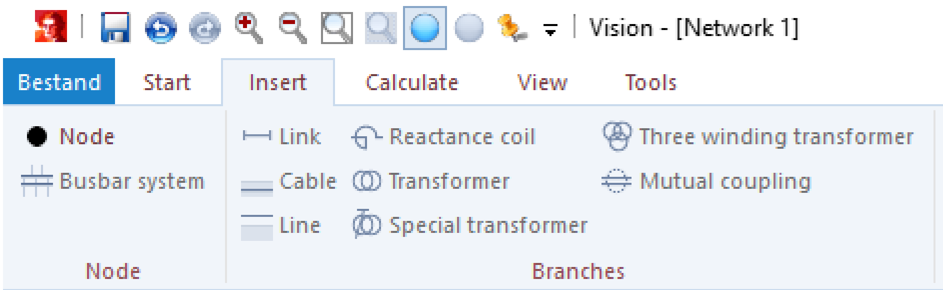
- Calculate 249: executing calculations and assessing results
- View 63: zoom, appearance of the network and the calculation results
- Tools 99: compare and take over, data import and export, geography, report definitions, change options file, various tools and macro editor.

1.5 Menu and mouse control

Most control actions take place using the ribbon menu and the mouse. Conveniently, most of the functions have been grouped according to their usage and are accommodated in different ribbon tabs. In most cases one can chose between using the ribbon menu or the right mouse button. Some functions can only be performed through the use of either the menu or the mouse.

Most Network file operations 78 are collected in the "**bestand**" menu in the upper left corner.

Actions that can be executed via the menu, i.e. the ribbon, the ribbon groups and the associated items, are indicated in bold letters in this manual. The consecutive actions are separated with vertical dashes. For example, a transformer can be inserted with **Insert | Branches | Transformer**, which means: first select the "Insert" ribbon tab and then select the item "Transformer" in the ribbon group "Branches".



The selection concept is the same as the Windows-standard. This means the selection of one object by means of mouse-clicking automatically de-selects the previously selected objects. Selecting additional objects can be done by selecting an object while holding down the Ctrl-key.

Function	Menu	Work area
Add node (busbar)	Click on desired location with left mouse button Choose **Insert | Node | Node**	Click on desired location with right mouse button Choose **Node** from pop-up menu
Add element (e.g. generator or load)	Select one node using the left mouse button Choose **Insert | Elements | <Element>**	Select one node Click on free work area using the right mouse button Choose **<Element>** from pop-up menu
Add branch (e.g. cable or transformer)	Select two nodes using the left mouse button Choose **Insert | Branches | <Branch>**	Select two nodes Click on a free work area space using the right mouse button Choose **<Branch>** from the pop-up menu
Add switch or protection (e.g. fuse or separator)	select one branch or element and one connected node using the left mouse button Choose **Insert | Switches and protections | <Switch** or **Protection>**	select one branch or element and one connected node using the left mouse button Click on free work area using the right mouse button Choose **<Switch** or **Protection>** from the pop-up menu
Select	Choose **Start | Select | Component ... All**	Select an area by dragging with the left mouse button pressed or Click on component using the left mouse button or Ctrl-Click on components using the left mouse button
De-select	Choose **Start | Select | Component not, Special, Inverse**	Ctrl-Click on the selected component using the left mouse button Click on free work area using the left mouse button (deselect all)
Change component	Select component Choose **Start | Edit | Parameters**	Click on component using the right mouse button (in Edit mode)
Change node length		Move the end of a node while holding down the left mouse button
Scroll through network	Cursor buttons	Pressed the Alt-key and the left mouse button
Zoom in and out	Choose **View | Zoom | Zoom in ... Zoom rectangle**	Make a window by pressing Shift + holding down the left mouse button (zoom in)
Centre		Hold down shift and click in work area using the left mouse button
Move a component		Select the object and move it while pressing the left mouse button
Move several components		Select components to be moved Move the components while pressing the left mouse button
Put a bend in a branch	Click on the desired bend location on the branch using the left mouse button Choose **Start | Edit | Bend** Move the desired part of the branch while holding down the left mouse button	Click on the desired bend location on the branch using the left mouse button Click on a free work area using the right mouse button Choose Bend from the pop-up menu Move the desired part of the branch while holding down the left mouse button
Delete components	Select components to be deleted Choose **Start | Edit | Delete | Selected**	Select the components to be deleted Press **<Delete>**
Perform calculation	Choose **Calculate | Basic ... Special | <Calculation>**	
Present results	Select the desired components Choose **Calculate | Results | General ... Detailed graph**	Click on an object using the right mouse button (in Result mode)

1.6 Shortcut keys

In Vision a number of shortcut keys are defined. With these shortcut keys frequently applied actions can be performed with a single push of a key. An overview of the shortcut keys is given below:

Shortcut	Function
F1	Help
F2	Edit arameters
F3	Report
F9	Repeat previous calculation
F10	Grid Navigator
F11	Options
Ctrl+O	Open Network
Ctrl+S	Save Network
Ctrl+N	New Network
Ctrl+P	Print
Del	Delete selected
Ctrl+X	Cut
Ctrl+C	Copy
Ctrl+V	Paste
Ctrl+Z	Undo
Ctrl+Y	Redo
Ctrl+F	Find object
Ctrl+A	Select all
Ctrl+E	Select island
Ctrl+G	Select group
Ctrl+M	Select mesh
Ctrl+R	Select route
Ctrl+T	Select all connected objects
Ctrl+Alt+T	Select all connected objects (same voltage level)
Ctrl+I	Select inverse
Ctrl+J	Select memory selection
1	Zoom towards upper left corner
2	Zoom towards upper right corner
3	Zoom towards lower left corner
4	Zoom towards lower right corner
7	Zoom a next selected object
8	Zoom selected at the next sheet
9	Zoom selected
0	Zoom whole network
-	Zoom out
=	Zoom in
cursor keys	Pan a network diagram
shift-cursor keys	Pan a diagram fast
PgUp	Next sheets
PgDn	Previous sheets

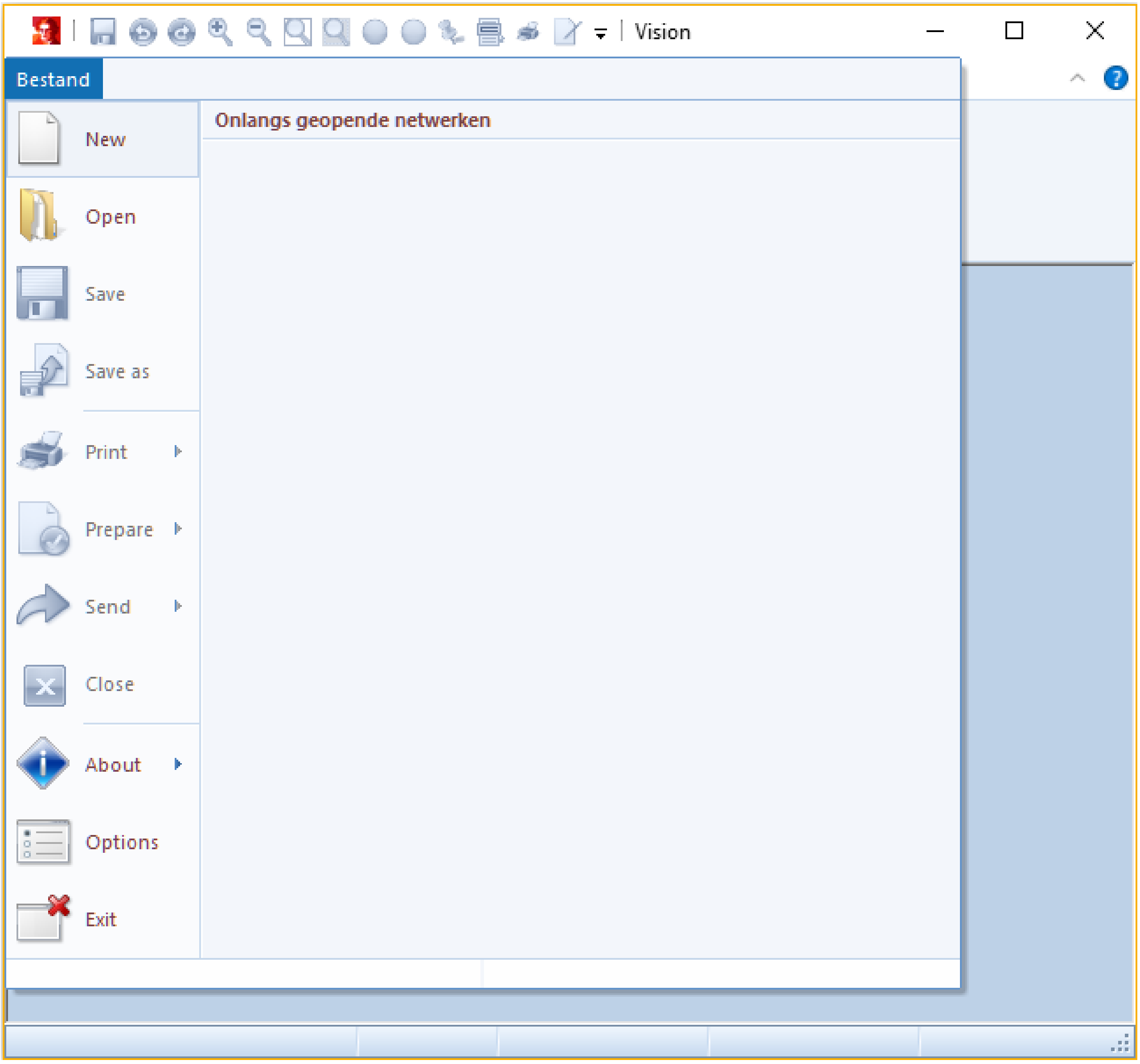
2 Getting started

Vision has been equipped with a clear and efficient graphical user interface. The grid planning engineer can become familiar with all the functionalities in a very short time.
This Getting Started shows in six steps how to perform the first load flow and short circuit calculation from scratch.

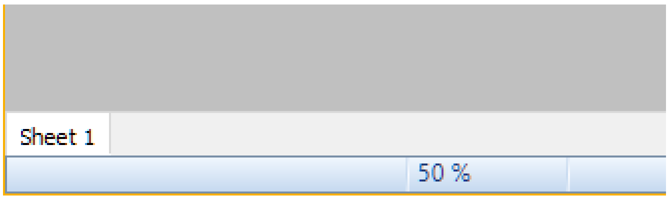
1. Creating a new empty workspace 41
2. Adding new nodes 42
3. Adding new connections 46
4. Adding an external grid and loads 52
5. Computing a load flow 55
6. Computing the short circuit current 59

2.1 Creating a new empty workspace

From the Application menu, choose: **New**:



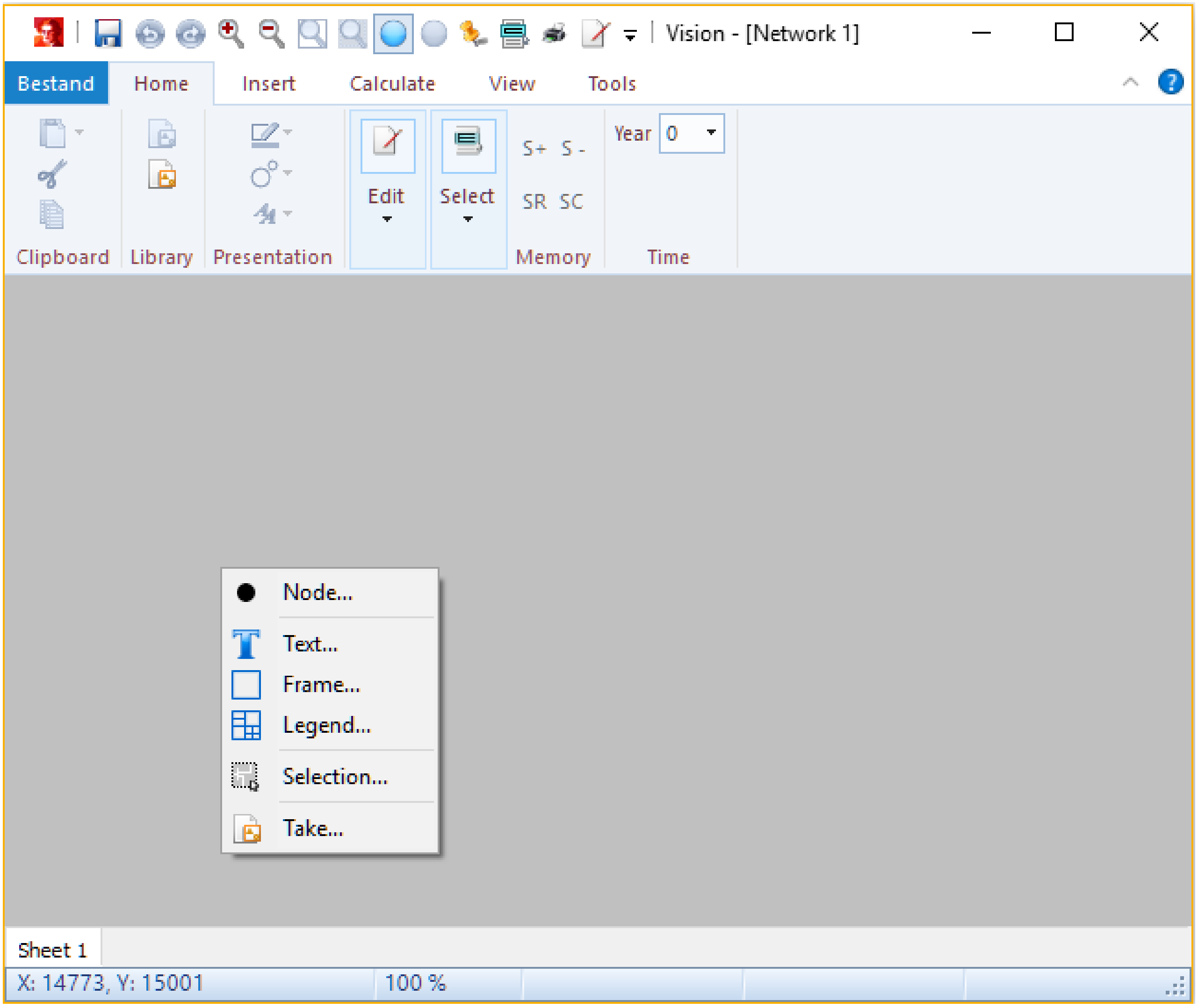
In the lower left corner the new automatically generated sheet is shown: Sheet 1.



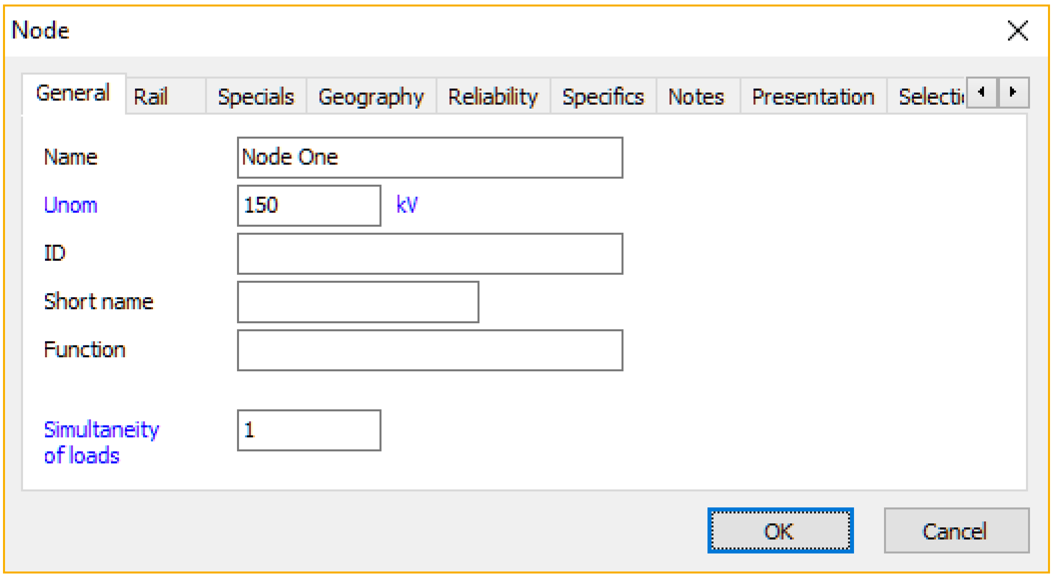
The worksheet has now been opened and the network can be constructed. The next step will be Adding new nodes 42.

2.2 Adding new nodes

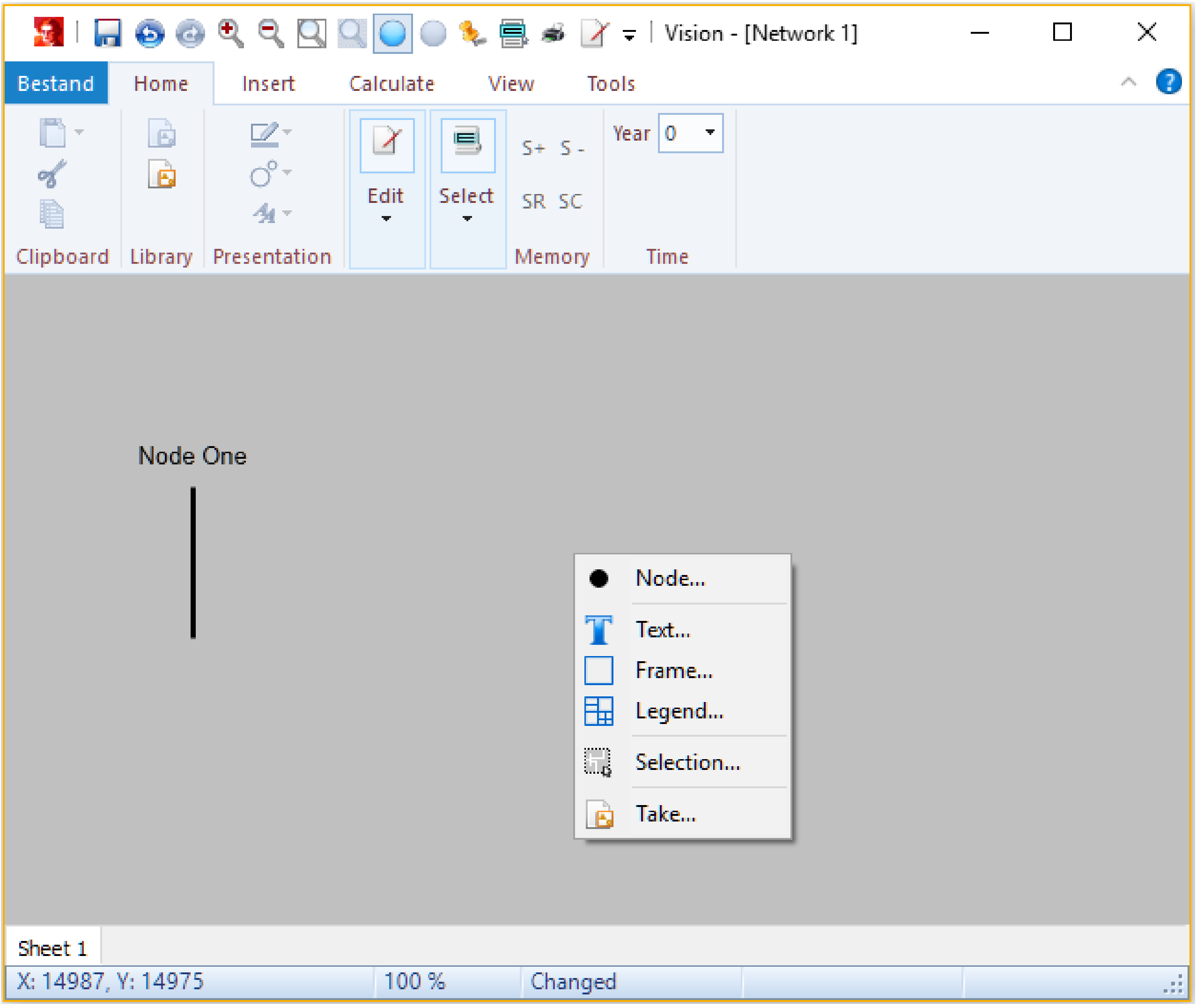
To add a new node, first click on the worksheet using the right mouse button. A pop-up menu will appear in which a **Node** should be selected (using the left mouse button).



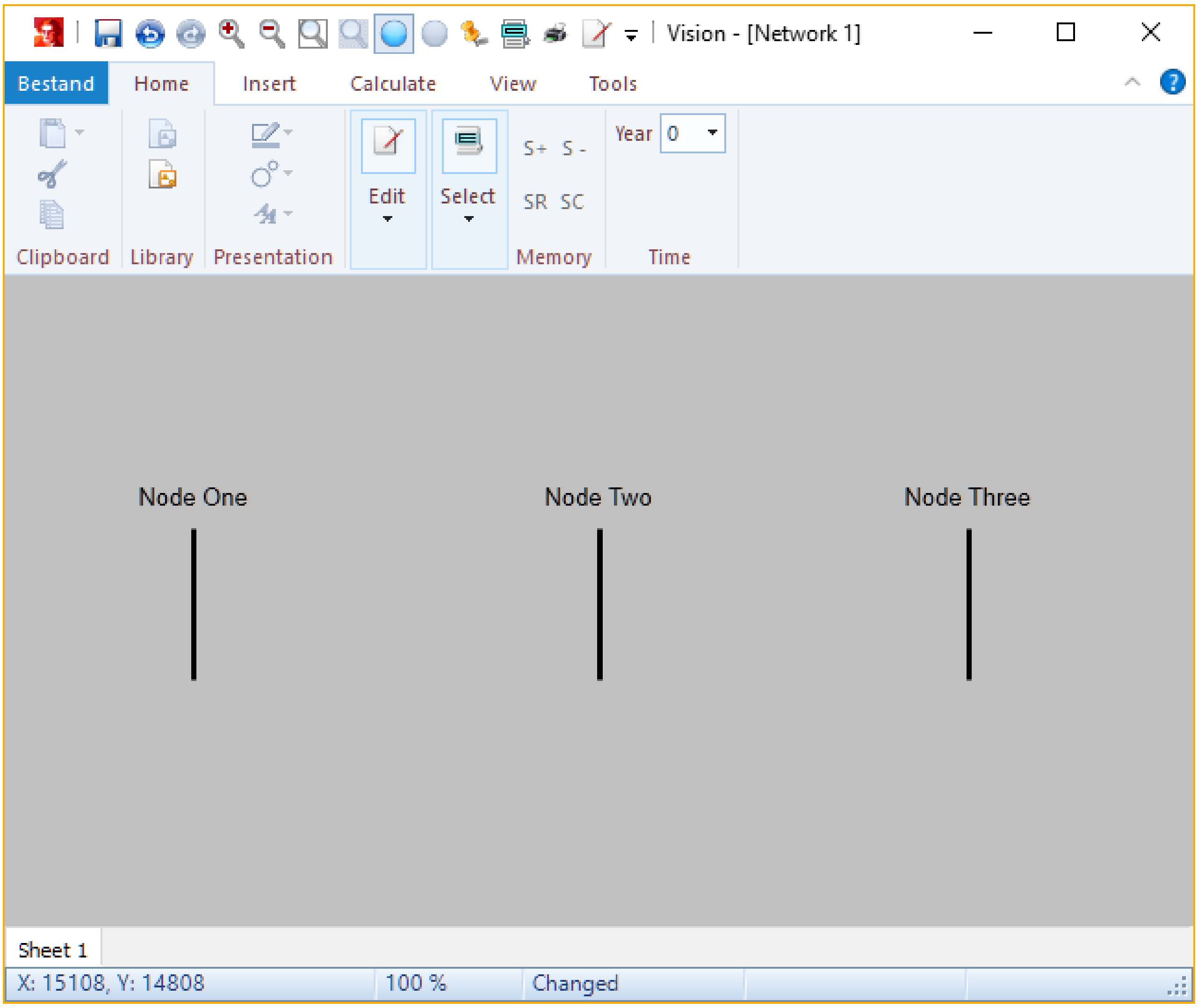
Hereafter, the **Node** input form pops up, with a number of tabs. The first tab contains the general data, like the **Name** of the node and its **Rated Voltage**. In this example an node will be added with the name *Node One* and a rated voltage of *50 kV* .



The default presentation of a **Node** is a vertically oriented bar. The presentation of the node can be customised using the **View** tab in the node pop-up menu.
Subsequently a second node will be added by right clicking on the worksheet, to the right of the first node.



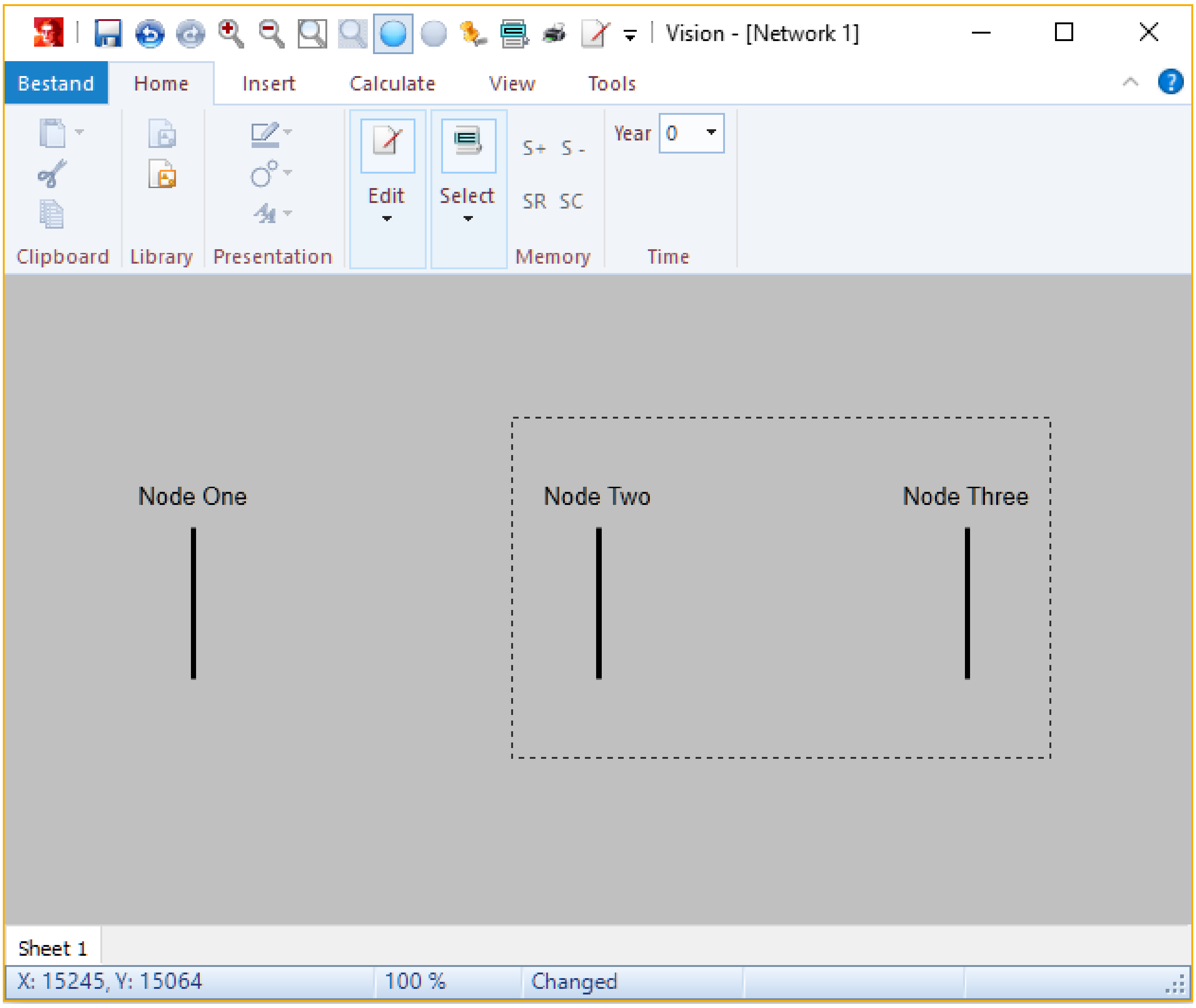
On this spot, an MV node will be added with the name *Node Two* and a rated voltage of *o kV* .
In the same way a third node will be added, to the right of the second node. The name will be *Node Three* and it has a rated voltage of *o kV* .
The network under construction is depicted in the next illustration:



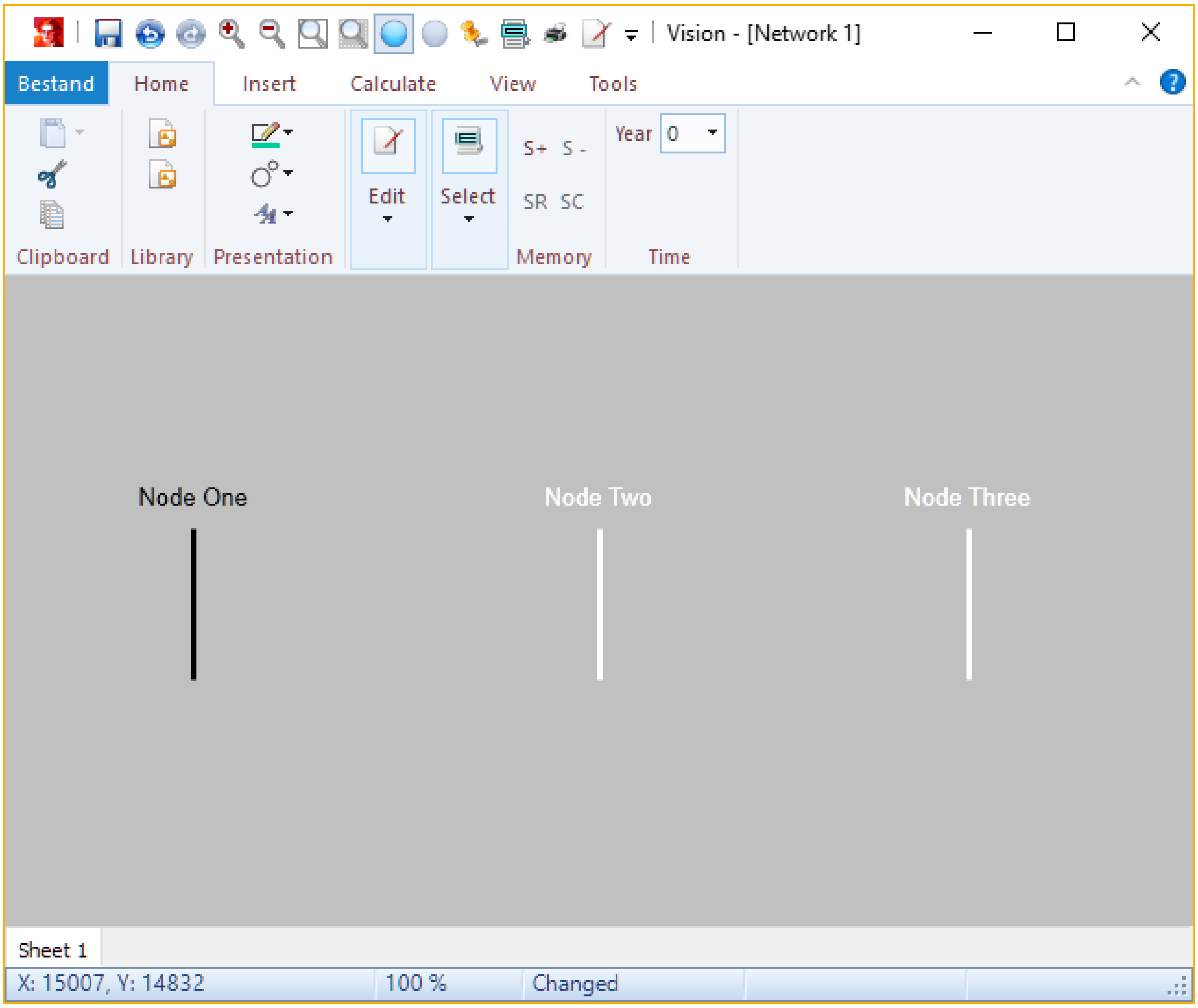
The next step will be Adding new connections 46.

2.3 Adding new connections

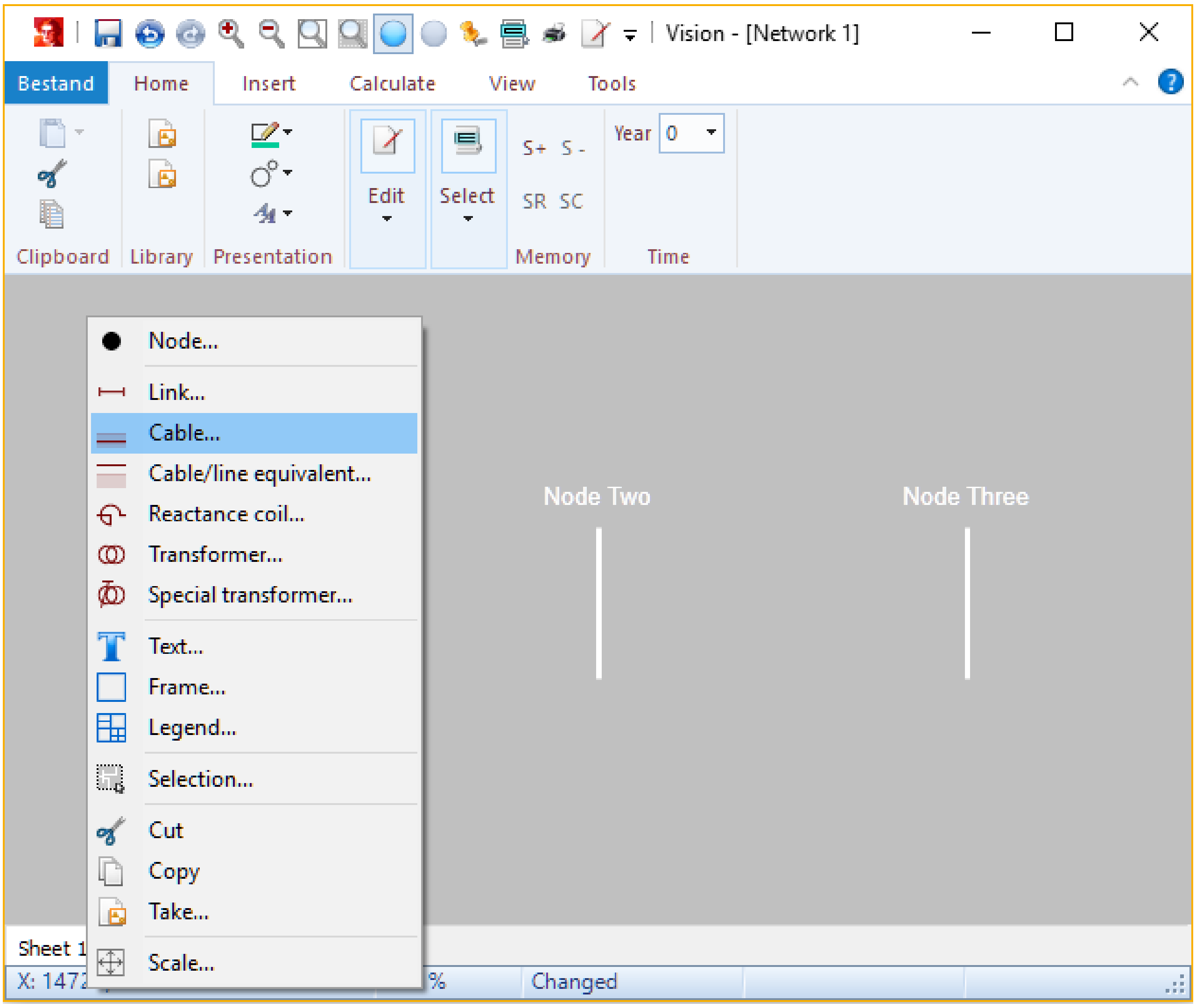
Between nodes *Node Two* and *Node Three* a cable connection will be added. This can be done after the two nodes have been selected. To select the two nodes, draw a rectangle while holding down the left mouse button.



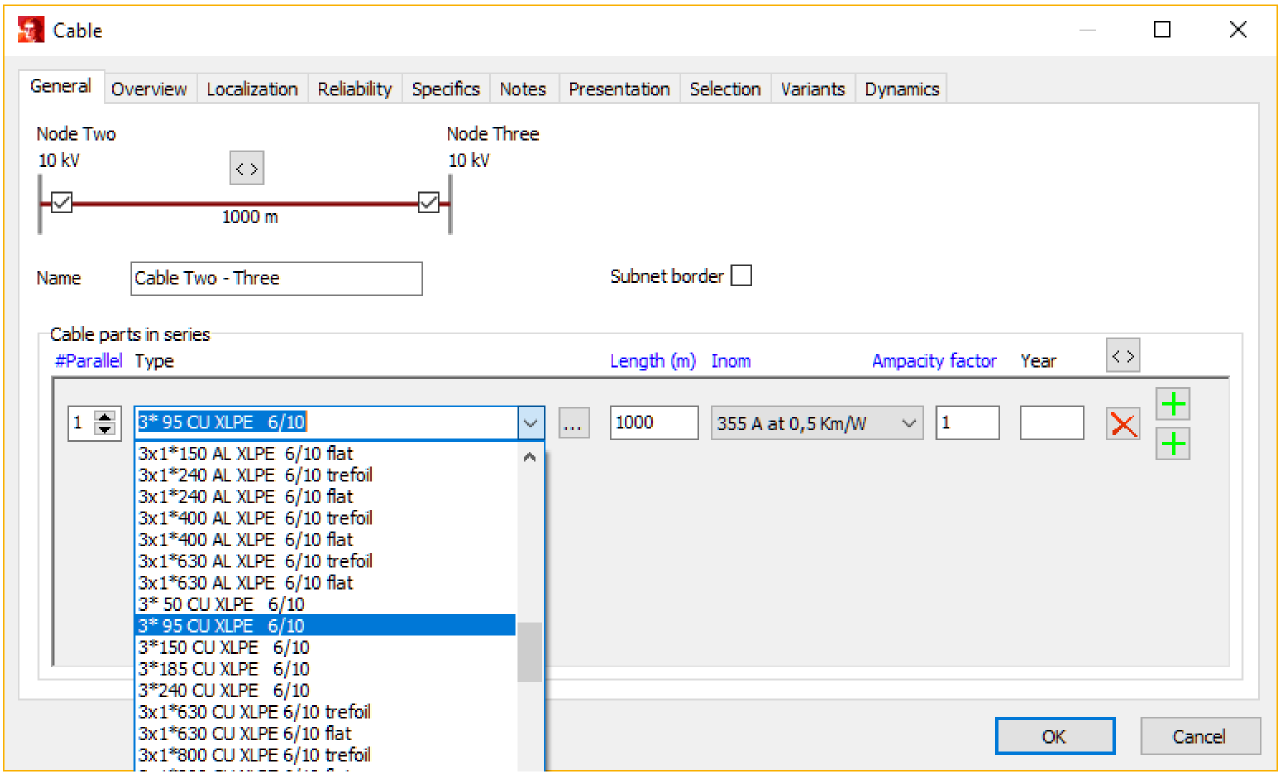
After releasing the left mouse button, the two nodes are selected. This is shown by the white colour of the nodes.



Now the cable can be added by right clicking on the workspace. A pop-up menu will appear with multiple choices. On the pop-up menu choose **Cable**.

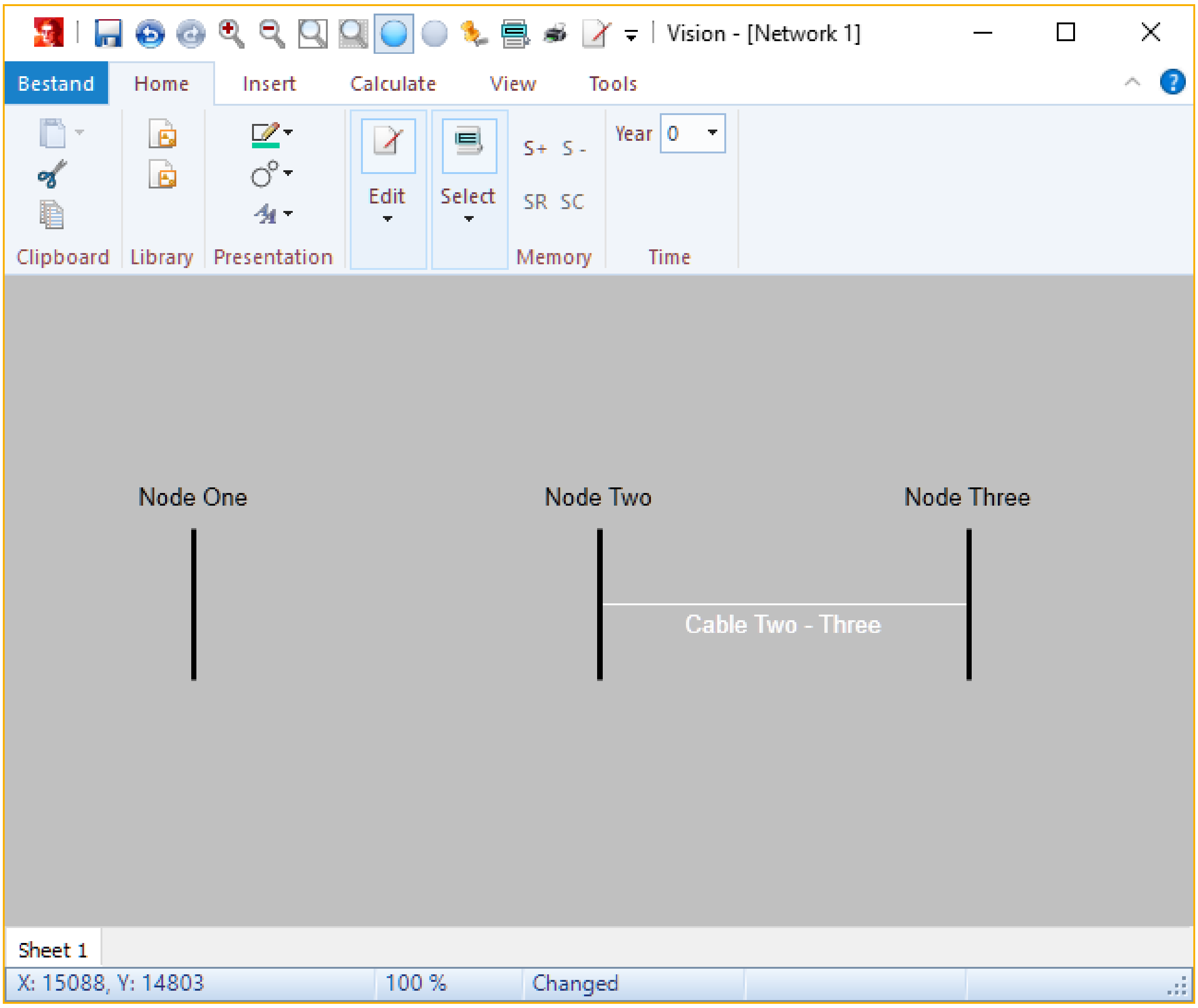


The **Cable** input form pop-up. On the first tab general information like the Name of the cable, the Cable type and the Cable length can be specified.



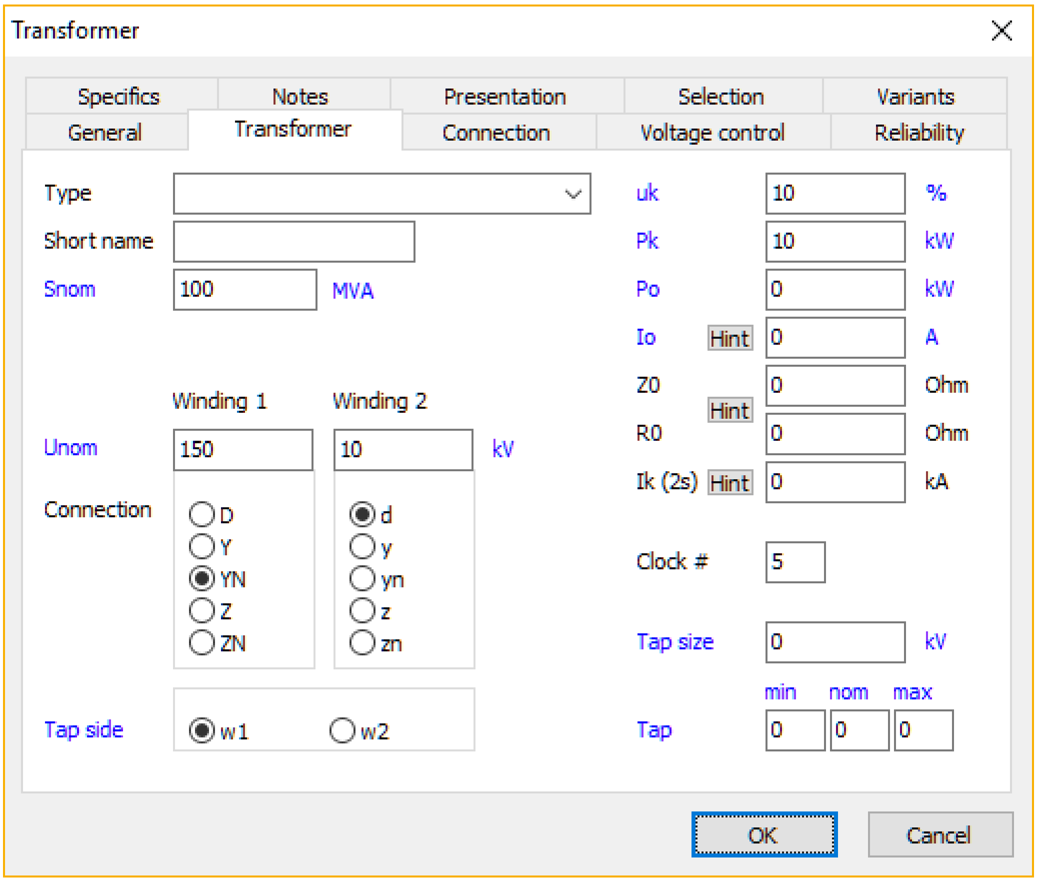
The cable type data will be specified using the pull-down menu. In this example *3x95 Cu XLPE 6/10 kV* cable will be used. The detailed cable data can be examined and altered using the button **...**. The length of the cable should be specified and is *1000 m* in this tutorial. The cable ampacity is *355 A* for the chosen ground specific heat resistance of *0.5 Km/W*. An ampacity factor of has been chosen. The form can be close by pressing **OK**.
The input form is closed by pressing the **OK** button.

As a consequence the cable has been inserted between the two selected nodes.



Hereafter, a transformer will be inserted between the left two nodes. To do this, only the two left nodes should be selected. First, to de-select any other objects, click with the left mouse button on a free spot on the worksheet. Secondly, draw a rectangle around the left two nodes (hold down the left mouse button). Hereafter the nodes *Node One* and *Node Two* should be selected. Subsequently click with the right mouse button on the workspace. A pop-up menu appears, where one can choose to add a **Transformer**.
Hereafter, the Transformer input form pops up. On the first tab, specify the name, for example *Trafo 1*.
On the Transformer tab specify the name plate data, for example:

- *Snom: 100 MVA*,
- *uk: 10 %* and
- *Pk: 10 kW.*

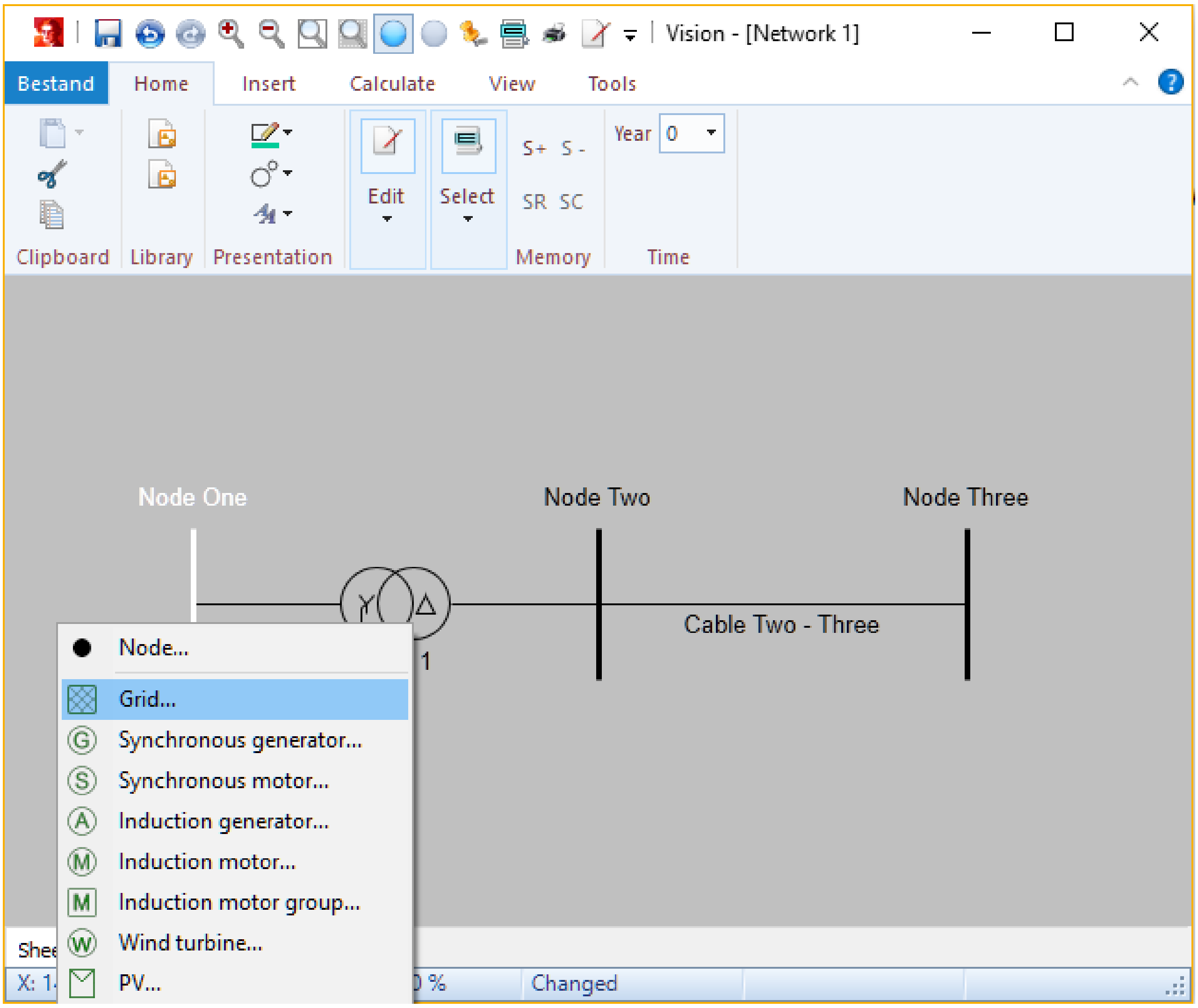


The rated primary and secondary voltages have been specified by default. These values can be altered if needed. The input form can be closed using **OK**.

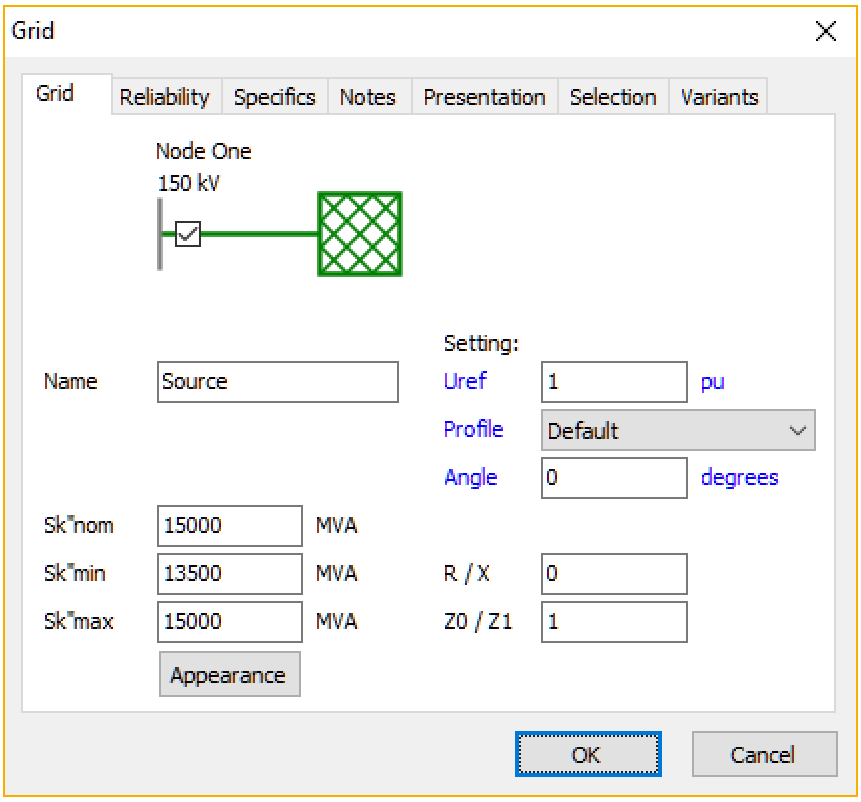
The next step is Adding an external grid and loads 52.

2.4 Adding an external grid and loads

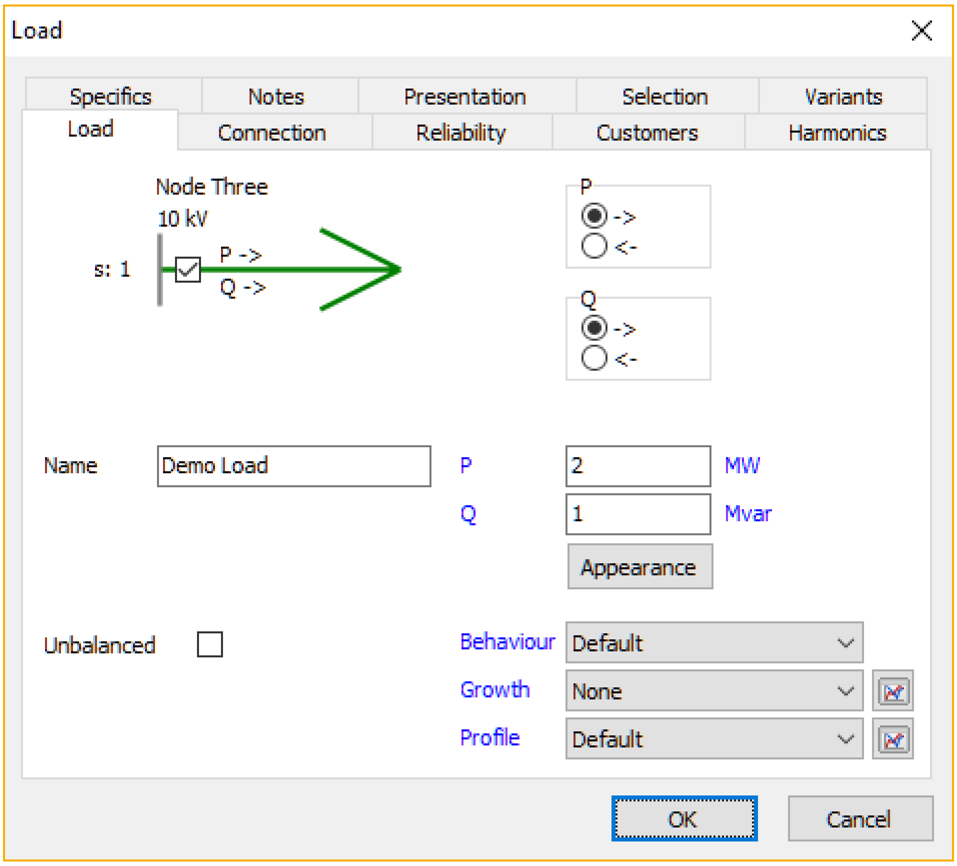
To add a network source, only the concerned node should be selected. Firstly, click with the left mouse button on the workspace to deselect other objects and secondly, select the most left node by left clicking on it. Hereafter, only *Node One* is selected. Now, click with the right mouse button on the workspace and to reveal the pop-up menu and choose **Grid**.



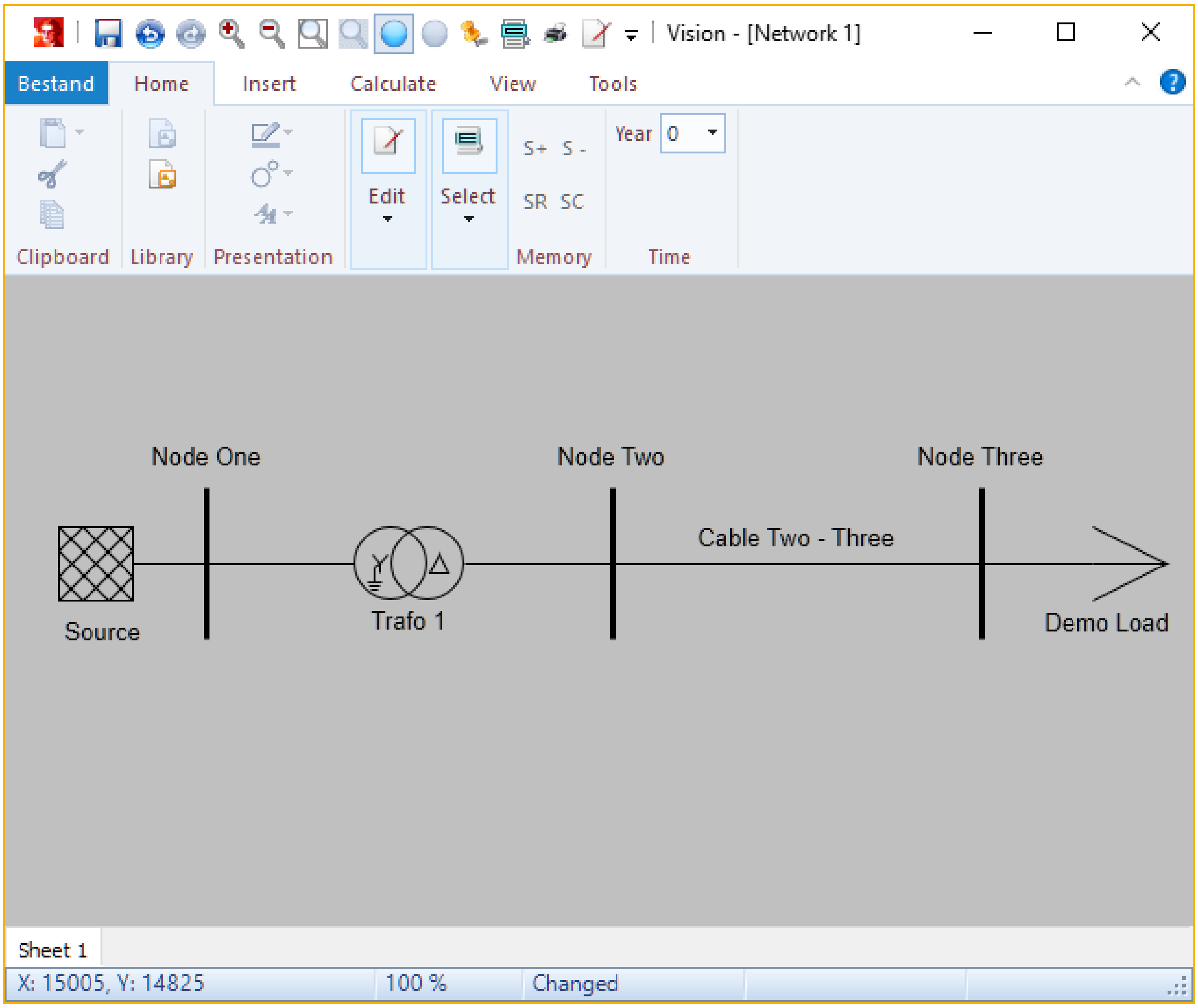
Hereafter, the grid input form shows up. Many inputs are specified by default.



To add a load, only the relevant node should be selected. Firstly, use the left mouse button on the workspace to de-select all other objects and secondly, click with the left mouse button on the most right node. Hereafter, only *Node Three* will be selected. Use the right mouse button to click on the workspace and from the pop-up menu choose **Load**.
Hereafter, the **Load** input form shows up. In this example a load of 2 *MW* and 1 *Mvar* will be added. Using the **Appearance** button the units can be switched between P, Q, S, I and/or cosine phi.



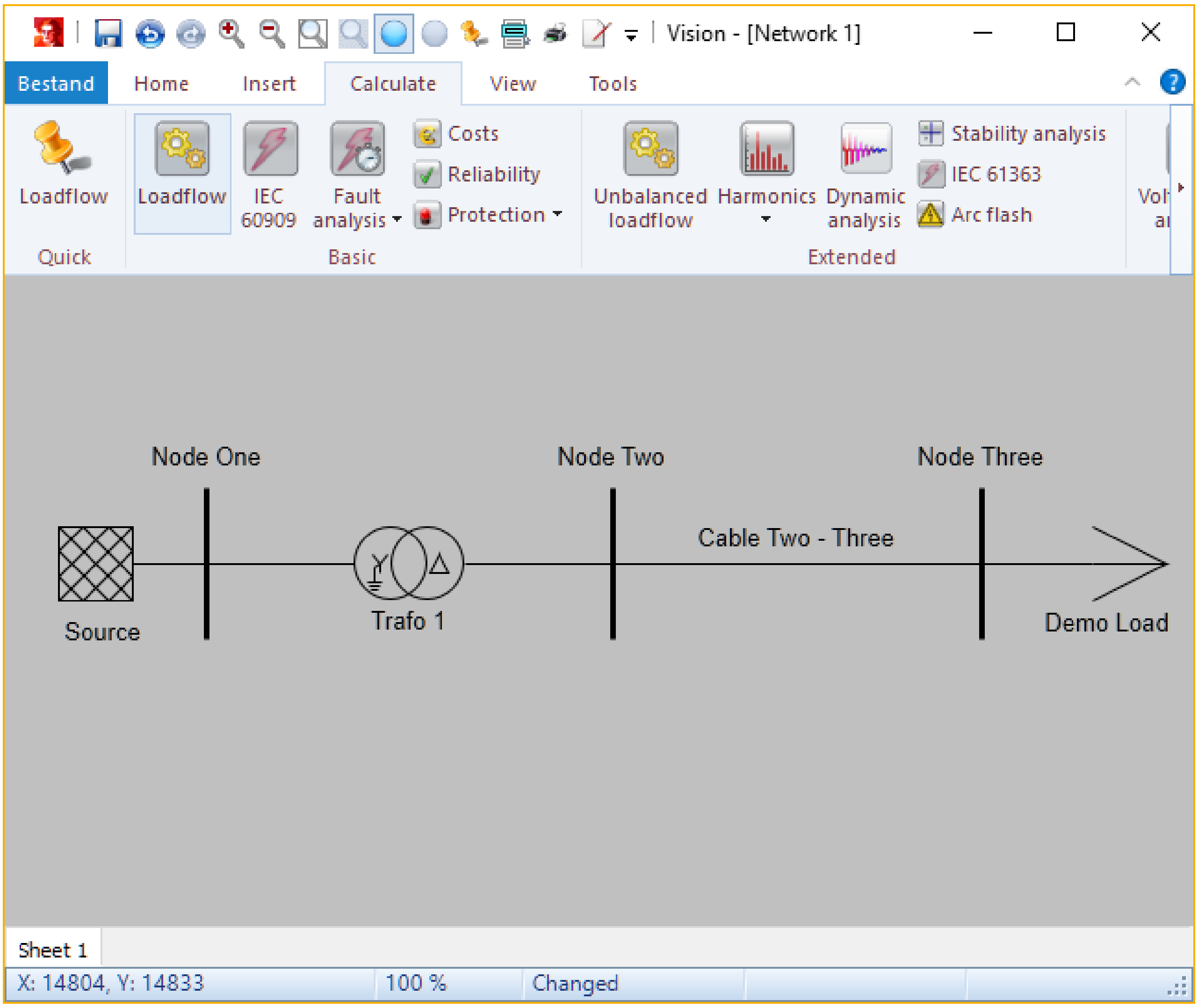
Now that the network has been specified, calculations can be carried out.
If you are not in the demo-mode, you can save the network using **Application menu | Save**.



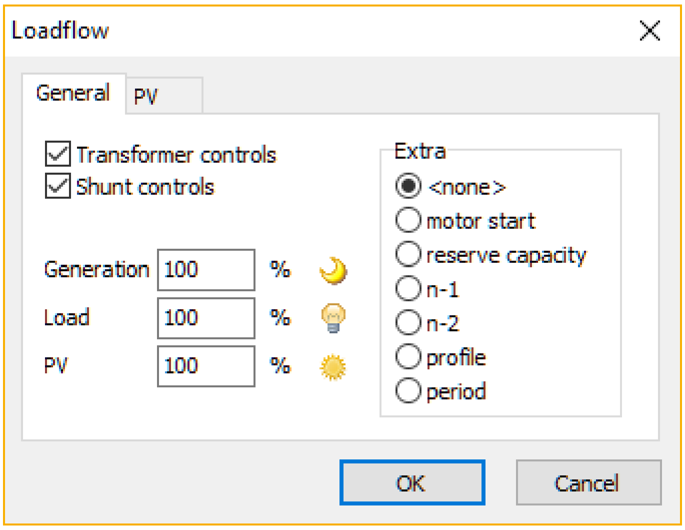
The next step will be Computing a load flow 55.

2.5 Computing a load flow

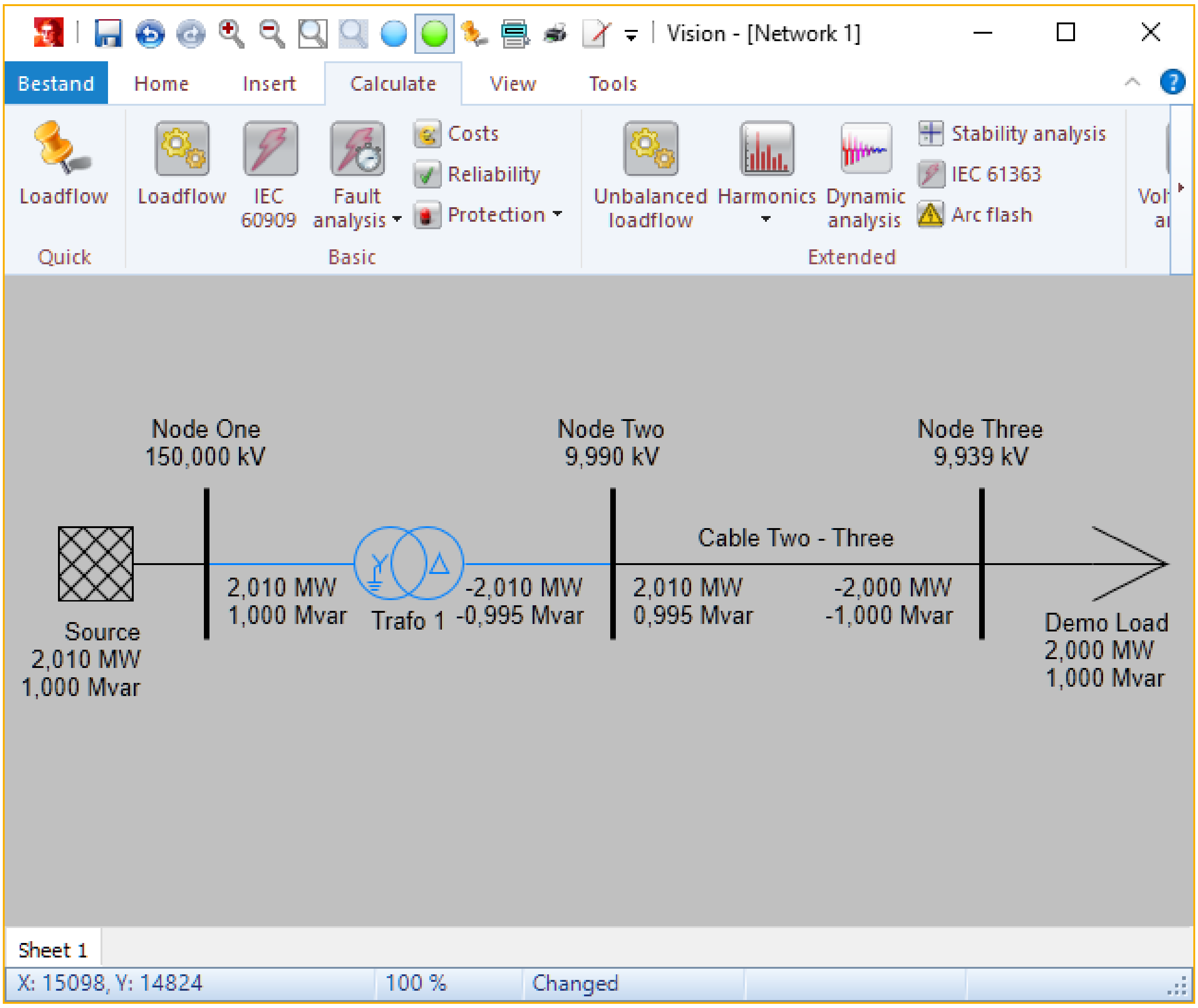
From the main menu choose **Calculate | Basic | Load flow**.



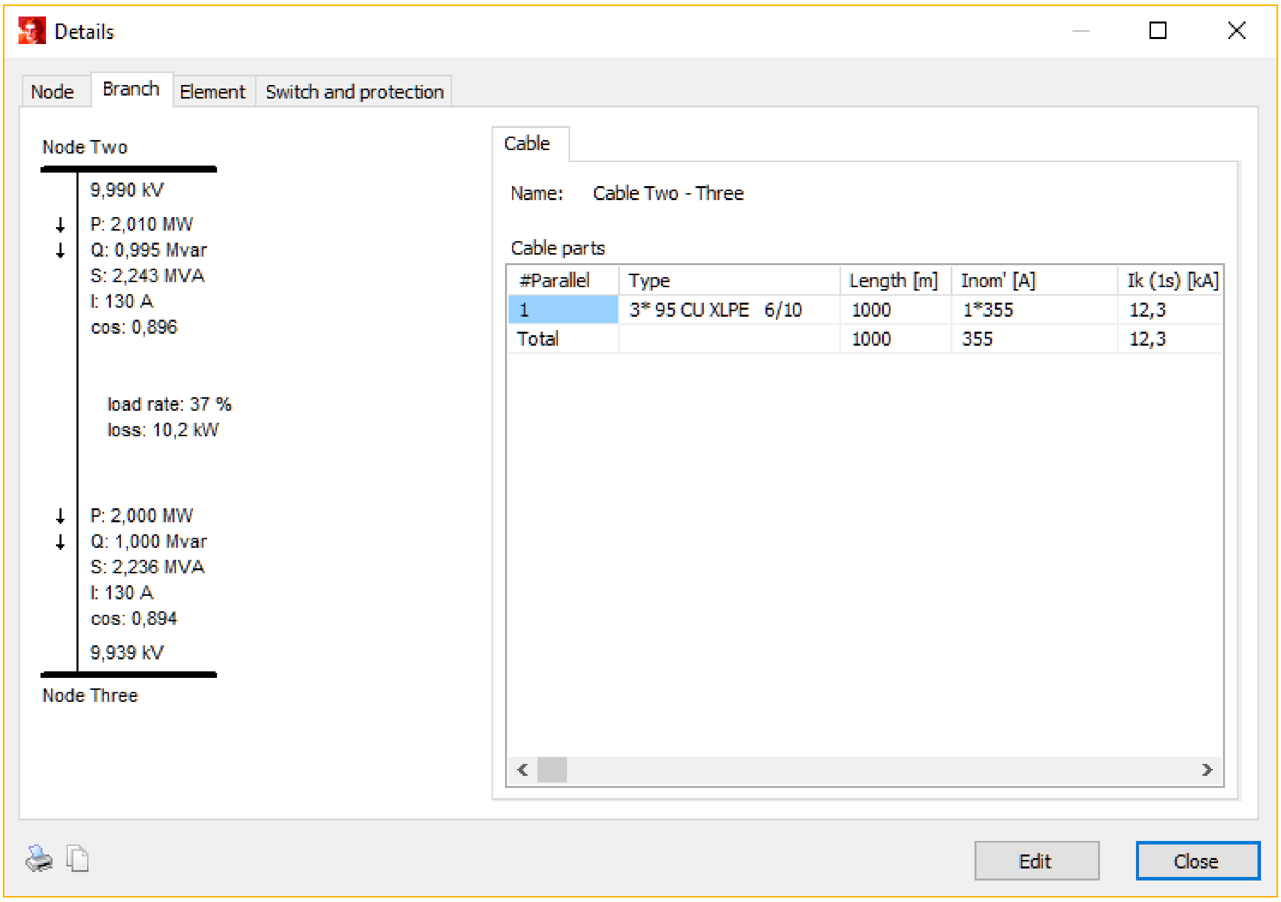
Hereafter, a form pops up in which the loadflow settings can be further specified.



In this example, no special settings will be chosen. The calculation can be performed by pressing the **OK** button. The illustration below shows the result.



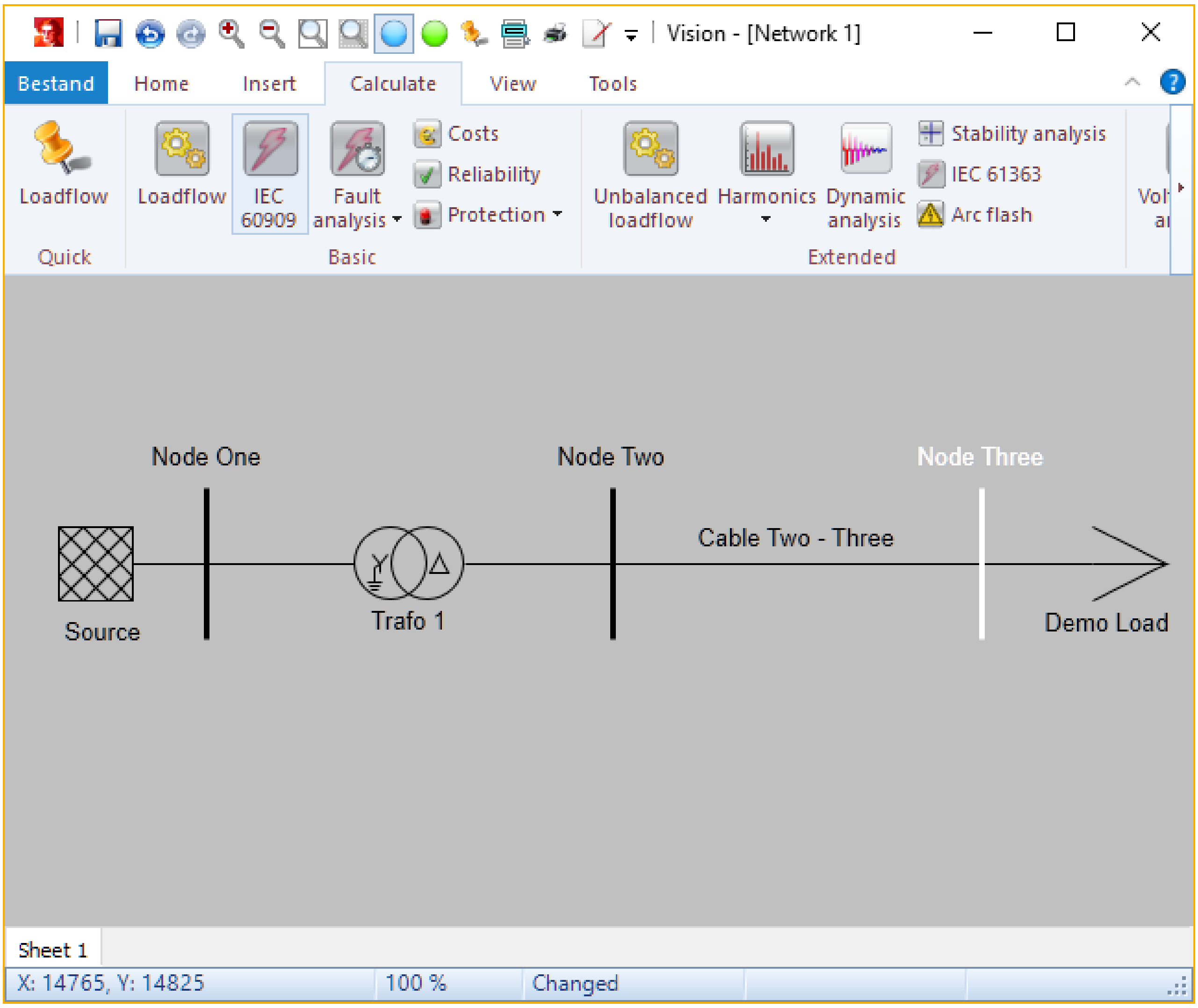
By using the right mouse button on a component, detailed results can be shown. For example, the detailed results of the cable are shown below:



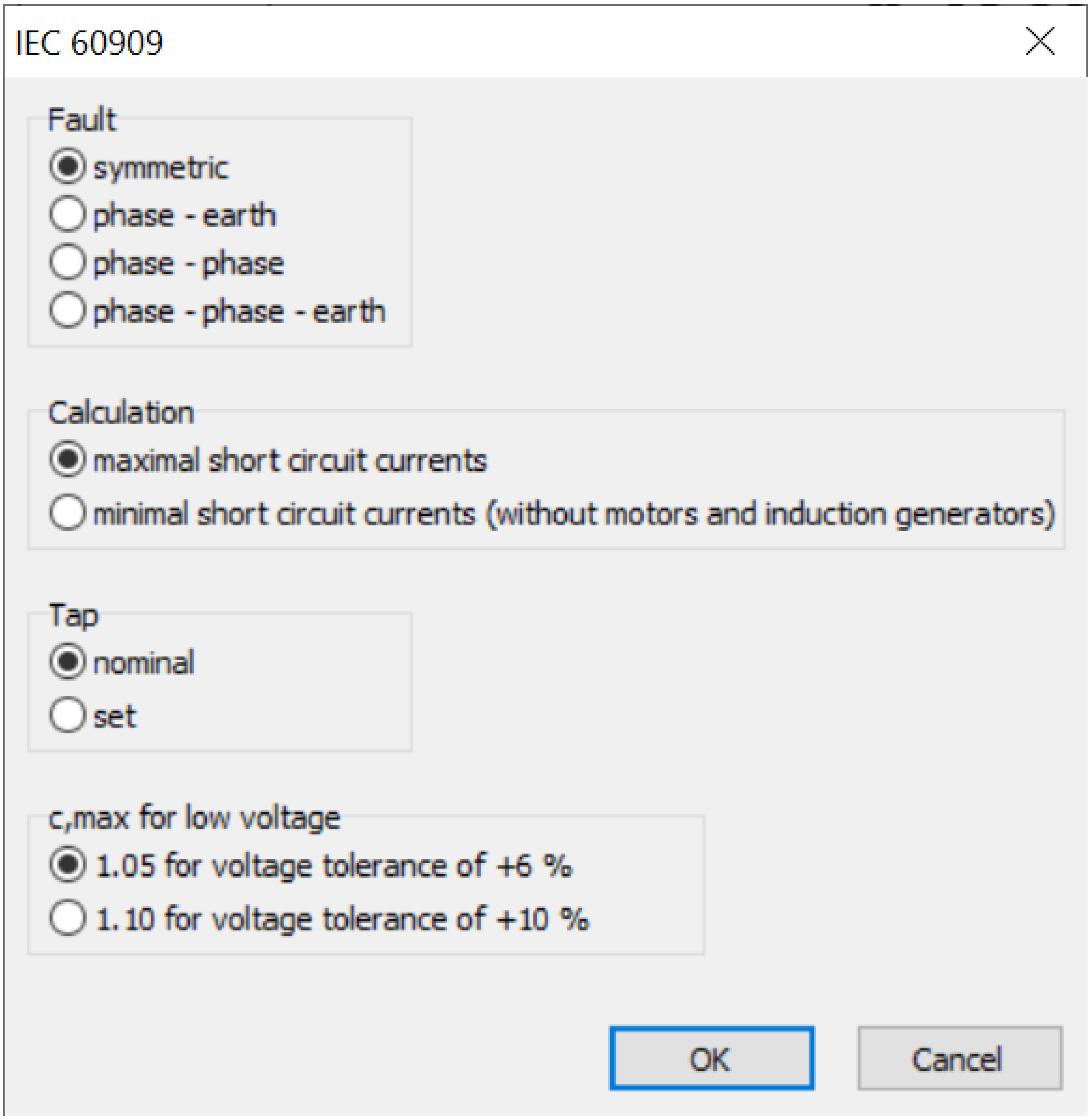
The next step will be Computing the short circuit current 59.

2.6 Computing the short circuit current

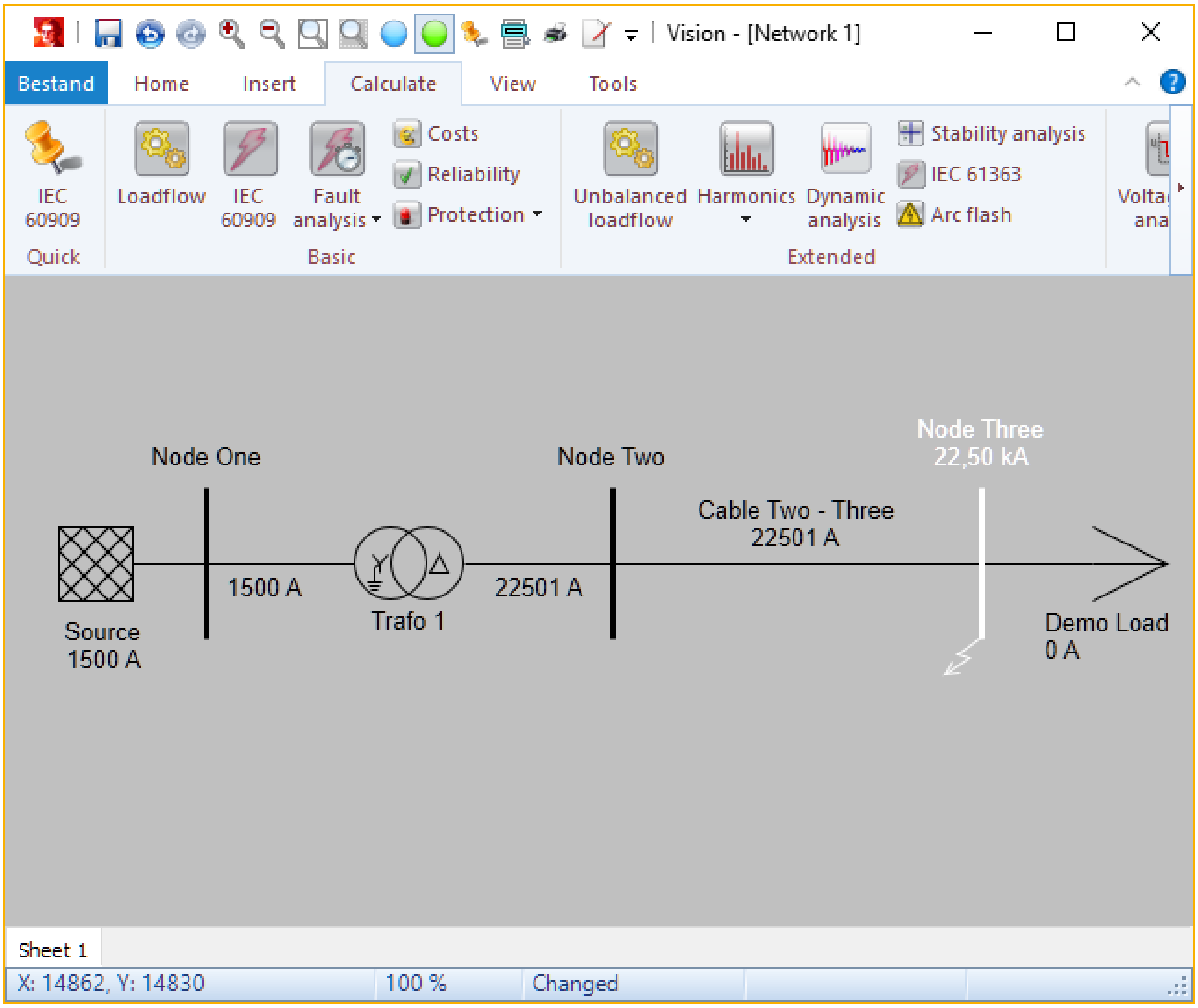
In this example, the short circuit current for *Node Three* will be computed according to the IEC 60909 standard. To do this, first select only *Node Three*. Secondly, from the main menu choose **Calculate | Basic | IEC 60909**.



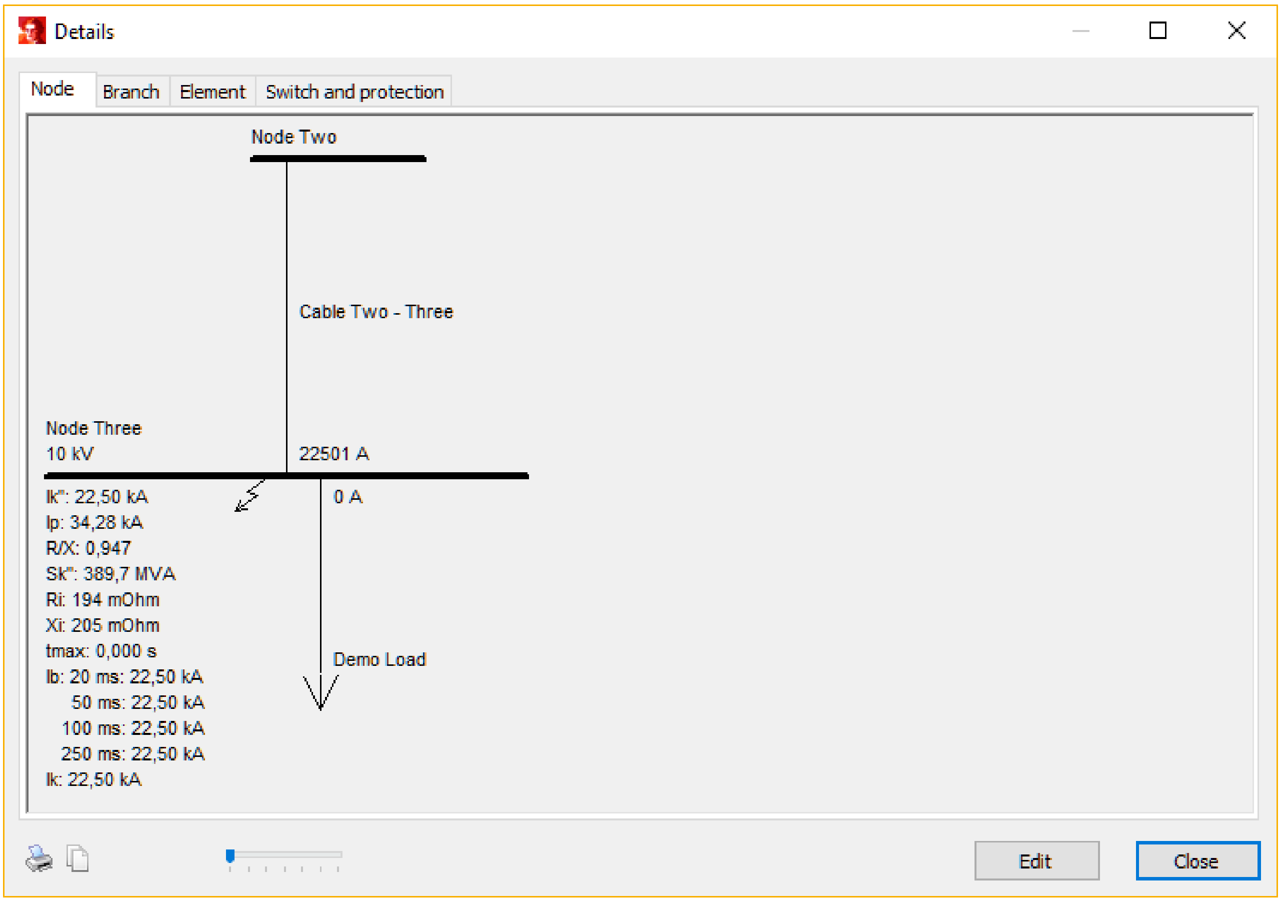
Hereafter, the **IEC 60909** calculation settings form shows up.



In this example we choose a symmetrical short circuit calculation. After closing this form by pressing the **OK** button, the calculation will be performed. The illustration below shows the result.



The symmetrical short circuit current on *Node Three* should be *22,50 kA*. Detailed information can be examined by clicking on *Node Three* with the right mouse button.



This “Getting Started” is only a very short introduction to Vision, but from this point on the user should be ready to discover all of Vision’s functionalities on its own.

3 User interface

The user interface handles modelling of the network and the presentation of the results. It is controlled by using the ribbon menu and the mouse, see: Menu and mouse control 38. An number shortcut keys 39 are defined for particular control actions.

3.1 Network

In power engineering, a one-line diagram or single-line diagram is a simplified schematic notation for representing a three-phase power system. Network objects such as circuit breakers, transformers, capacitors, bus bars, and conductors are shown by standardized symbols. Instead of representing each of three phases with a separate line and terminal, only one conductor is represented. It is a block diagram which graphically depicting the paths the power flows flow between objects within the system. Objects on the diagram do not represent the physical size or location of the electrical equipment. It is common to organize the diagram in such a way that the left-to-right and top-to-bottom sequence of components represents the logical sequence of the actual switchgear and other devices.

The network objects are represented using predefined symbols. The colour and style of these symbols can be defined for each of the individual objects on the tab **Presentation**. The default values can be defined in the options menu: **Bestand | Options, Editor, Presentation defaults**. See: Options 127

3.1.1 Network presentation

The network is the representation of the power system wherein calculations can be performed. A network is build up with objects. Objects are the network components, like nodes, branches (cables, lines, transformers), elements (loads, motors, generators), switches and various graphical objects:

- nodes 138
- branches 144
- elements 171
- switches and protection devices 201
- other objects 223.

The network model is object-oriented. As a consequence, the way the objects are graphically interconnected determines the resulting power system model. All the components are objects. All components in the network are graphically represented at least once. (Parts of) the network can appear graphically on more than one sheet, see Sheet 65. Every component can be represented on multiple sheets, from which the network can be further expanded, see: Multiple object presentation 67.

The user can define views 72 that give a customised presentation of the text on the sheets. This same customised presentation will also be shown on the graphical print 98. Network data, including results, can be viewed in reports and can be printed. Reports 116 can be defined by the user.

Together with the network data, also the properties, comments and hyperlinks can be saved. These can be consulted and printed. See Prepare 80.
Comments enable the user to add the necessary background information to the network file.
Besides comments, also links to documents, spreadsheets, pictures and web addresses can be attached to the network file. These links are implemented as hyperlinks. By clicking on a link, the matching program is started and the file is opened.

Graphical presentation of objects
Each object has its own graphical properties, defined on the tab *Presentation* of the particular object. The graphical presentation properties of selected objects can be modified collectively by means of the menu: **Start | Edit | Collective, Presentation**. Here you can change the: **colour, size, thickness, style, text style, font, text size** and **text visibility**.

Nodes
Nodes in the network are, for example, busbar systems and stations. Nodes are connected through branches.

Branches
Branches can be lines, cables, links , reactance coils or transformers. Transformers link nodes with different voltage levels.

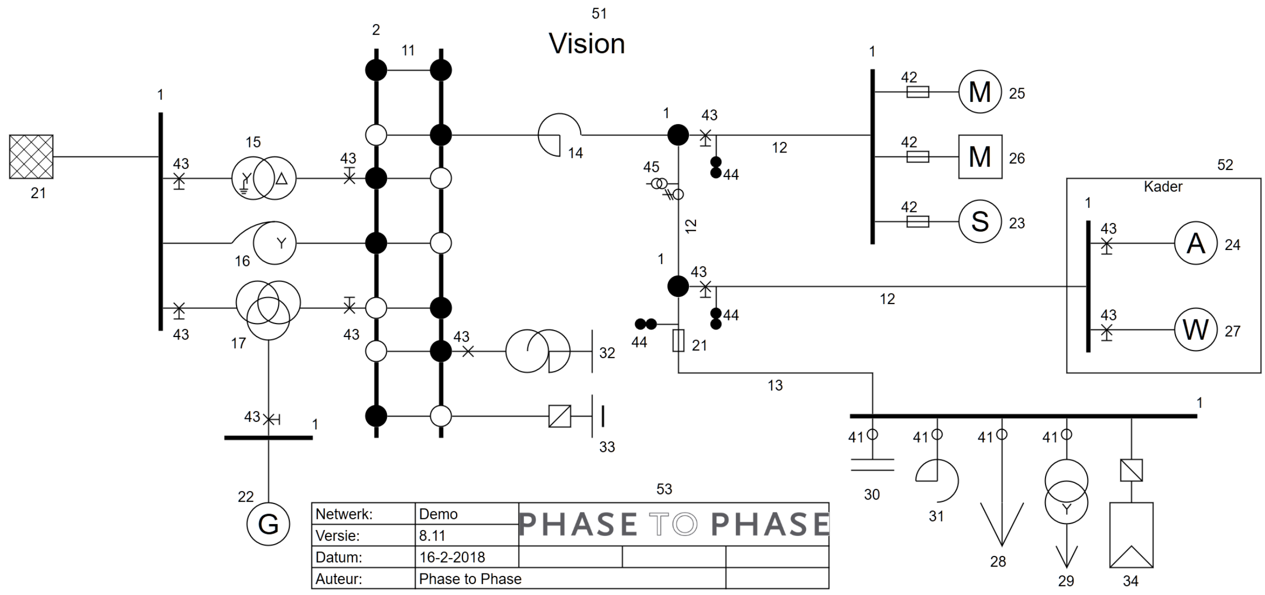
Elements
Elements represent the supply and absorption of electrical energy. Elements are always linked to a node. Possible elements in Vision are:

- External grid
- synchronous generator
- synchronous motor
- asynchronous generator
- asynchronous motor
- asynchronous motor group
- wind turbine
- PV
- load
- transformer load
- shunt capacitor
- shunt reactor
- zigzag transformer
- battery

Switches, breakers and protections
Each branch and element can be equipped with switches, circuit breakers and protection relays. The state of the switches have to be changed in the pop-up form of a branch or element.
The representation of the circuit breaker, open switches and protection devices can be changed in through **Bestand | Options | Editor, Drawing**
The possible switches and protection devices are:

- load switch
- fuse
- circuit breaker
- short-circuit indicator
- measurement unit

Symbols
The following symbols are used to depict the various components in Vision.



1 node
2 busbar system
11 link
12 cable
13 line
14 reactance coil
15 transformer
16 special transformer
17 three-winding transformer
21 External grid (V)
22 synchronous generator (G)
23 synchronous motor (S)
24 asynchronous generator (A)
25 asynchronous motor (M)
26 asynchronous motor group (M)
27 wind turbine (W)
28 load
29 transformer load
30 shunt capacitor
31 shunt reactor
32 zigzag transformer
33 battery
34 PV
41 load switch
42 fuse
43 circuit breaker with or without protection relay
44 short circuit indicator
45 measurement unit
51 text
52 frame
53 legend

3.1.2 Sheet

A network may consist of more than one sheets, each containing a part of the network.
A sheet has a name, comments and a colour. The order of the sheets can be altered:

- Move a tab to the left: Shift+PgUp

- Move a tab to the right: Shift+PgDn.

The connection between two sheets can be made by using the multiple object presentation 67 of a node on two different sheets.

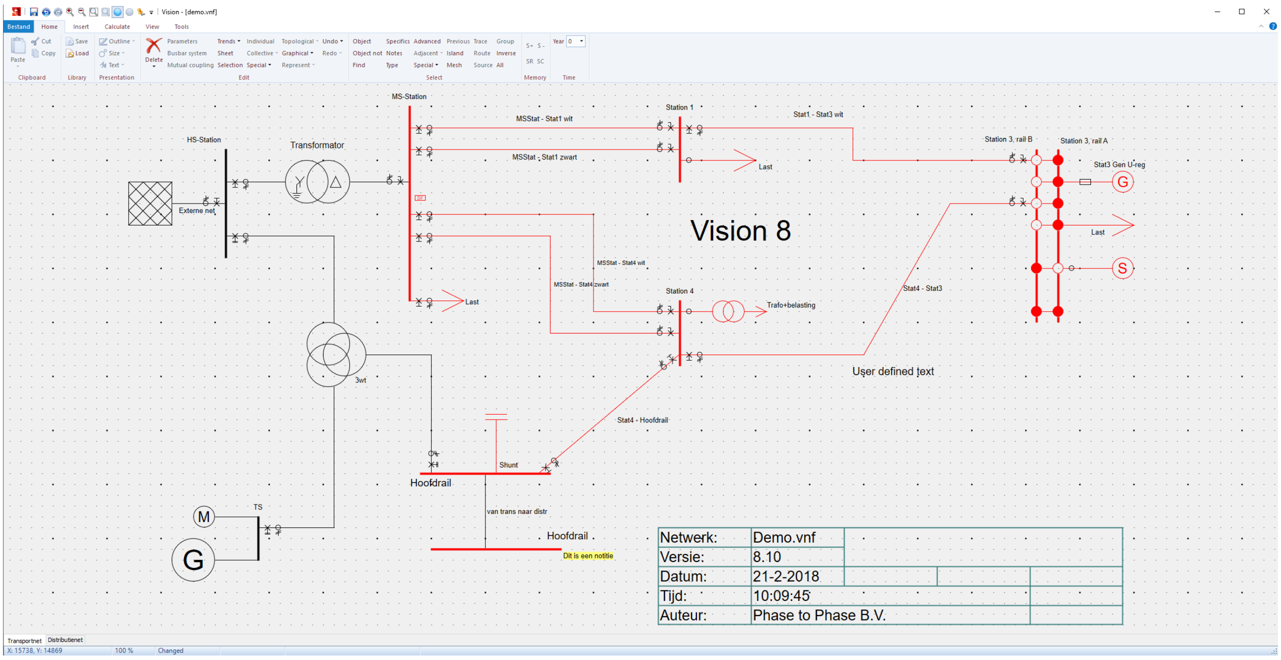
A new sheet can be created using **Insert | Miscellaneous | Sheet**.
The editing of a can be done by using **Start | Edit | Sheet**.
An empty sheet can be deleted using **Start | Edit | Delete | Sheet**. If a sheet still contains components, these first have to be deleted, before the sheet can be deleted.

Grids

Next to a fine grid (20 pixels), a major grid and a mapping grid can be defined for each sheet. The size of the grid can be altered as follows:

- Major grid: height and width defined in the number of fine grid points
- Mapping grid:
  - o sheet width and height defined in the number of fine grid points
  - o grid width and height defined in number of maps
  - o grid offset left and above: mapping offset of first map, if not in the very left upper corner of the worksheet; defined in number of maps

The visibility of the grids can be set trough **Bestand | Options | Editor, Drawing**



The mapping grid makes it possible to split a large network in a number of grid maps, which for instance can be used to facilitate the printing of a large network on A4 paper. To print a mapping sheet, right click somewhere on the sheet and chose **print mapping sheet.** The maps will be automatically numbered, from left to right or from top to bottom. The numbering starts at the first map, located at the top left. This first map obtains the number 1, plus the **Number offset**.

Modifications

All modifications are only performed on the active sheet. However there are two modifications which can take place on all all the sheets:

- Collective editing, when the box **on all sheets** is checked
- Updating of component types, when the box **on all sheets** is checked

3.1.3 Multiple object presentation

An object can have multiple graphic representations on different sheets. This makes it is possible to represent a specific group of objects on one sheet, to keep a good overview of the important objects in a large network. Links and cables which connect the nodes on two sheets do not have to be represented on each of these sheets. Nodes can be always represented on several sheets. Elements and branches can only be represented together with their associated nodes.

Each object, always remains a unique object in the network model, independent of the number of graphical presentations. Modifying the technical model parameters of a specific object is possible from all the graphic presentations of that object. The graphic parameters (form, size, colour, etc.) of a specific object can vary between sheets and can be established independently for all presentations of the object.

A new presentation of an object is created by first selecting that object on a certain sheet and then pasting it graphically on another sheet by using **Start | Edit | Represent | Selected objects at sheet ...** . Hereafter the graphical properties of the represented object can be modified. Each object can only be presented once per sheet.

The status 'selected' is a property of an **object**. As a consequence, selecting an object on one sheet, selects the object on all sheets where it is graphically represented. All presentations of an object are therefore selected at the same time or not selected at all.

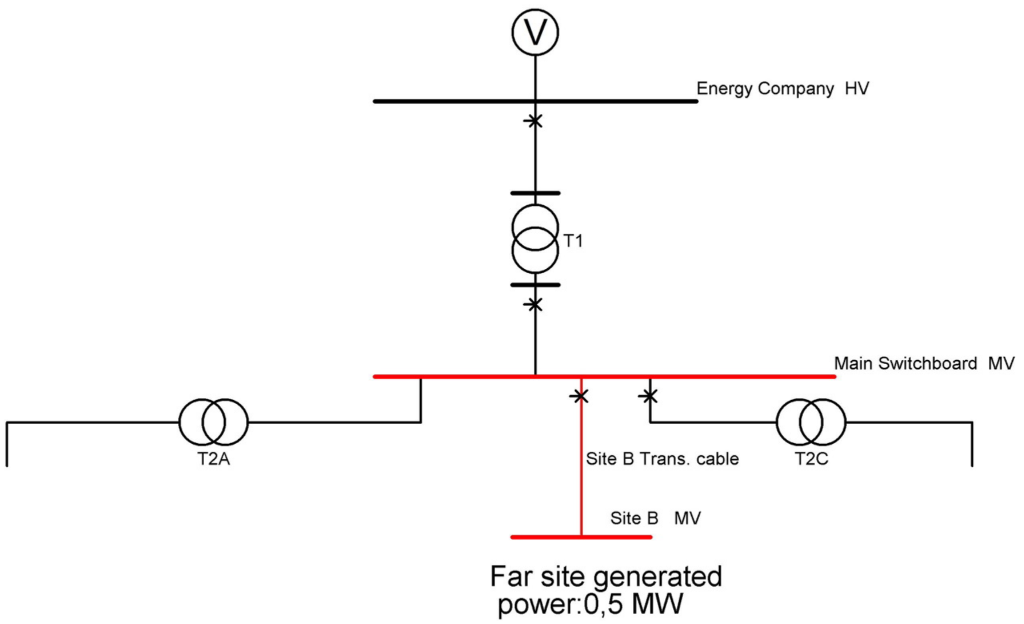
The status 'removed' is linked to the **object presentation**. Thus the object will only be removed after all presentations are removed.

Objects with multiple presentations can be easily distinguished in the network by altering their colours through **View | Appearance in Edit mode | Colour, Multiple presentation**

In case a node has multiple representations, the sheet names the node is represented on can be shown through an user-defined view115

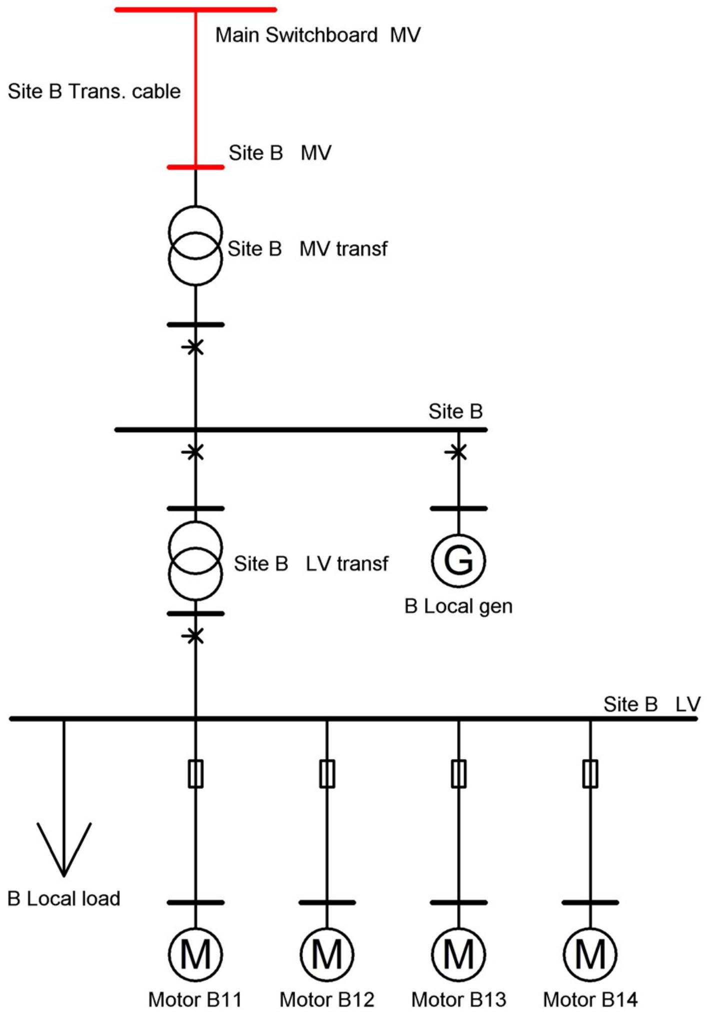
EXAMPLE

The next example shows a network, modeled on two sheets: "General plan" and "Far site". The node "Main Switchboard MV" feeds the node "Site B" (plus the network downstream) through the transformer "Site B MV transf". These objects are marked in red on the sheet "General Plan". The other network components and the network source are shown in black.



Sheet "General plan"

The details of site B are presented on sheet "Far Site". The nodes "Main Switchboard MV" and "Site B" have a presentation on this sheet as well and are also marked in red.



Sheet "Far site"

3.1.4 View

GENERAL

A number of functions influence the presentation of objects. These functions are:
- zoom functions
- special views
- edit mode and result mode
- views

ZOOM FUNCTIONS

One can zoom in and zoom out on the network in the following ways:
- by creating a window by pressing the left mouse button while holding down the Shift key down
- by using the mouse wheel
- by using the Shortcut keys 39
- by using **View | Zoom** in the ribbon menu.

Zoom functions in the ribbon menu

Zoom in : zoom in
Zoom out : zoom out
Zoom window : zoom to a part of the network contained within a window defined by clicking and dragging the left mouse button
Zoom network : display the whole network
Zoom selected : ***All selected objects on this sheet*** : display all selected components in the network on the current sheet
All selected objects on next sheet : display all selected components in the network at the next sheet (multiple object presentation 67)
Next selected object at this sheet : display the next selected component in the network

Zoom and scroll using the keyboard

Shortcut key	Function
1	Zoom towards upper left corner
2	Zoom towards upper right corner
3	Zoom towards lower left corner
4	Zoom towards lower right corner
7	Zoom next selected object
8	Zoom selected at the next sheet
9	Zoom selected
0	Zoom whole network
-	Zoom out
=	Zoom in
cursor keys	Scroll through the network diagram
shift-cursor keys	Scroll network diagram with factor 10
PgUp	Go towards the next sheet
PgDn	Go towards the previous sheet

Scroll and zoom using the mouse wheel

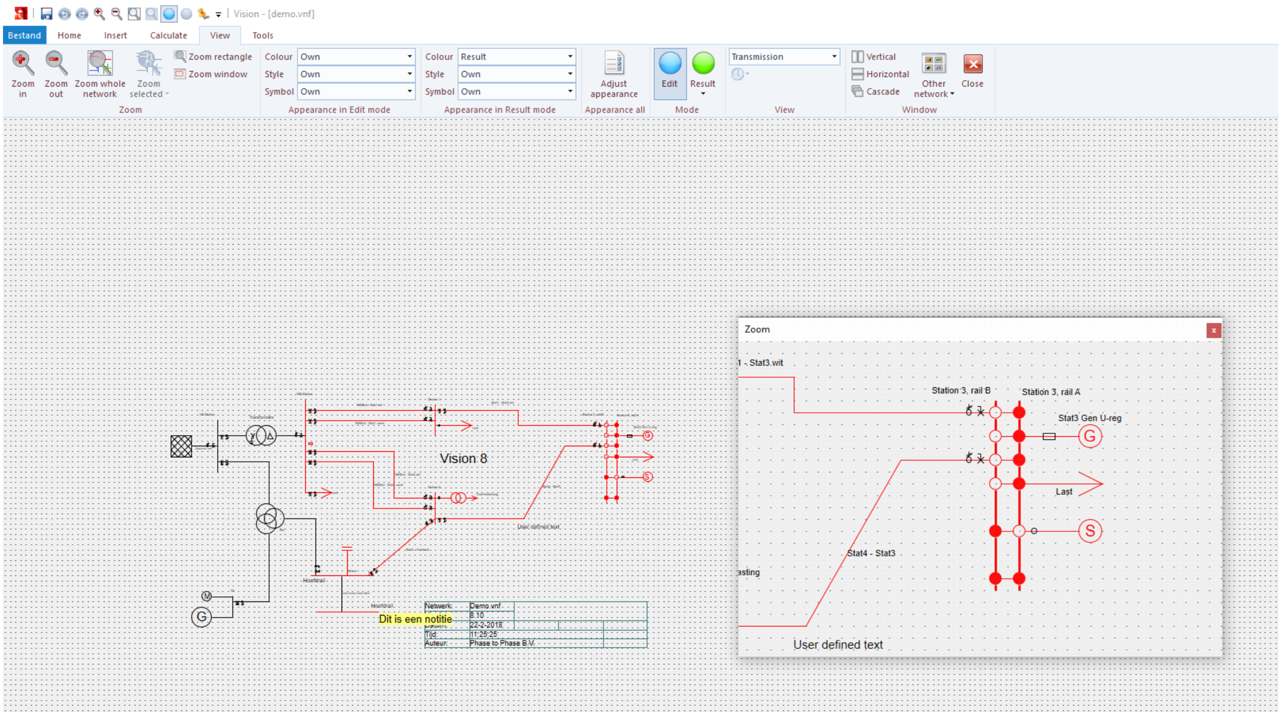
Next to the scrolling with the cursor keys it is also possible to scroll using the mouse wheel
Mouse wheel : scroll vertically.
Shift + mouse wheel : while pressing the shift-key, scrolls horizontally.
Ctrl + mouse wheel : while pressing the ctrl-key, zooms in or out.

Panning

By pressing the Alt-key and the left mouse button, one can pan trough the network

Zoom window

The Zoom window function, **View | Zoom | Zoom window** activates the zoom window. This function displays a zoomed in representation of the area around the mouse pointer in a sub-window.



EDIT MODE AND RESULT MODE

The network editor has two modes: Edit mode and Result mode. In Edit mode, data can be modified. In Result mode, calculated data is displayed. After performing a calculation, Vision automatically switches to Result mode. The appropriate mode can be activated by selecting **View | Mode | Edit** or **View | Mode | Result**. In the Result mode the network colour representation can be set in Edit colours or Result colours.

Transmission and Distribution

View | Transmission, Distribution is used to display network information using default views.
Up to 10 user defined views are listed. See: Views 72.

VIEW ADAPT

View | Adapt is used to display the network in ***special views*** , dependent on the components properties, separately for Edit-mode and Result-mode. The object colours can be chosen for a number of pre-defined situations in the ***Options*** . This object colour can be overruled in other specific situations. A branch with an opened switch can be presented with another line style and elements can be presented with a symbol, depending on the power or current.

Colour

Object colour

Result :	colour depending on the result of a calculation; to be defined in the ***Options*** , with **Calculation** on tab sheets **General** and **Limits**.
Own :	the standard network representation
Draw :	the standard drawing colour
Voltage :	components are drawn in the colour dependent on the nominal voltage (colour definition in **Editor | View** in the ***Options***)
Open switch :	branches and elements are drawn in a different colour when their switches are opened (colour definition in **Editor | View** in the ***Options***)
Island :	islanded components are drawn in the island colour (colour definition at ***Island*** in **Editor | Drawing** in the ***Options***)

Mesh : branches that could be removed without isolating any nodes and affecting the delivery of energy will be coloured (colour definition at ***Other*** in **Editor | View** in the ***Options***)

Group : components, that are delimited by protections and opened switches, will be coloured groupwise (colour definition at ***Automatic colours*** in **Editor | Drawing** in the ***Options***)

Direction : a trace, starting from a Source node and going through a cable, connection or reactance coil or a trace, starting a transformer low-voltage node through a cable, connection or reactance coil (colour definition at ***Automatic colours*** in **Editor | Drawing** in the ***Options***)

Area : a trace, starting from a source or a trace, starting from a transformer in the direction of high-voltage towards low-voltage (colour definition at ***Automatic colours*** in **Editor | Drawing** in the ***Options***)

Multiple presentation : components that are represented on multiple sheets will be coloured (colour definition at ***Other*** in **Editor | View** in the ***Options***).

Overrule object colour

The chosen object colour scheme can be overruled another colour scheme in cases of objects with an open switch, objects in island, objects in a mesh or objects with a multiple presentation.

Style

Object style

Own : the object own style

Open switch : branches and elements are drawn in a different line style when their switches are opened (style definition in **Editor | View** in the ***Options***)

Element symbol

Own : the object own symbol

Power (P) : elements are drawn as a closed circle dependent on the defined or calculated active power (colour definition at ***Other*** in **Editor | View** in the ***Options***)

Current : elements are drawn as a closed circle dependent on the defined or calculated current (colour definition at ***Other*** in **Editor | View** in the ***Options***)

Visibility

In the Edit-mode the presentation of the auxiliary lines of differential protections can be set as permanent visible or only visible when moved.

The presentation of (transformer)loads, switches and protections can be suppressed optionally.

The presentation properties, which do not depend on a result, can be defined in the ***Options*** , with **Editor** on the tab sheets **Drawing** and **View**.

3.1.5 Views

Various information can be displayed for each network component. These include the components name, type and operating voltage. The items to be displayed are defined in a view. Vision has two predefined views and can have up to 10 user-defined views.

By using **Tools | Definitions | Views** a new view can be defined, or an existing view can be modified or deleted. This feature allows the user to specify for each component which data is displayed in the Edit-mode and in the Result-mode.

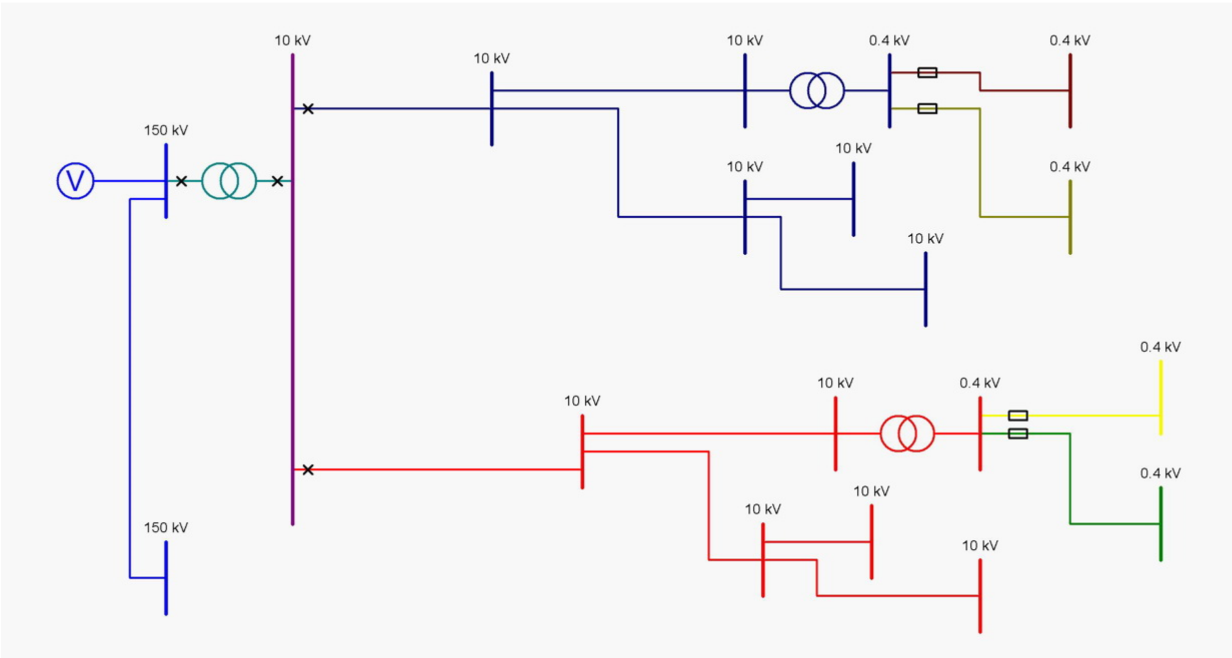
Through **View | View | <View>** a view can be selected.

See also: Define views 115

3.1.6 Group

A group is a set of components that is bounded by protection devices and/or open switches. Failure of a component in the group leads to an outage covering the whole group.

The network below has the following groups:
- 150kV network with source
- 150/10kV-transformer
- 10kV node at the secondary side of the 150/10kV transformer
- both 10kV feeders from the secondary side of the 150/10kV transformer up to the 0.4kV fuses
- all 0.4kV feeders starting at the secondary side of the 10/0.4kV transformers

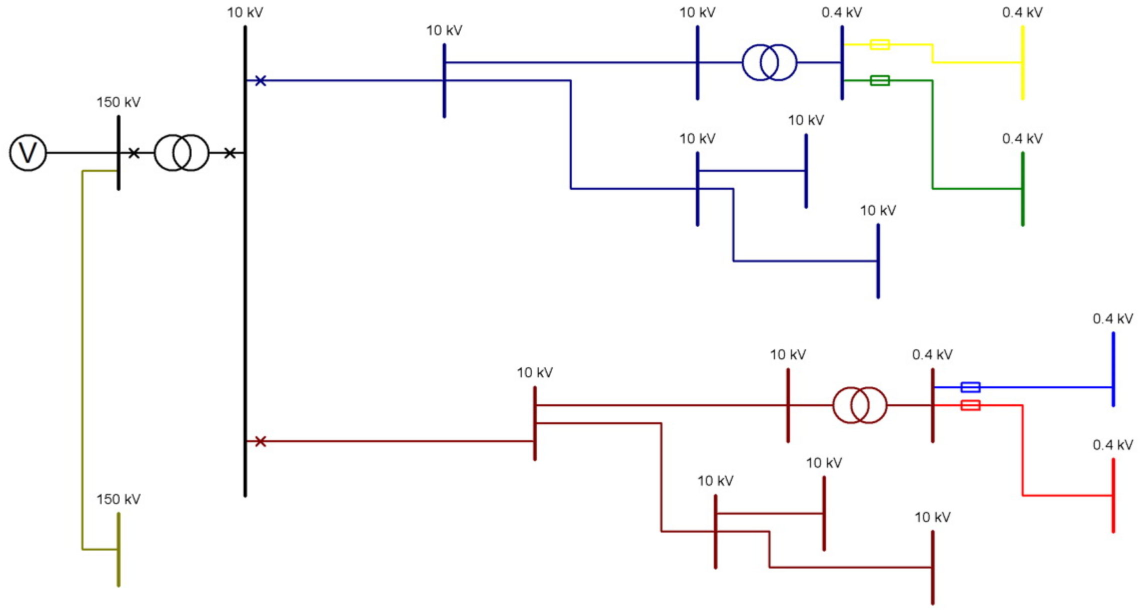


Example of a network with 9 groups

3.1.7 Direction

A direction is:
- a trace, starting from a source node and going through all the downstream cables, connections and reactance coils it can reach or
- a trace, starting from the secondary side of a transformer through all the downstream cables, connections and reactance coils it can reach.

The network below contains:
- one 150kV direction, from the source to the other 150kV node
- two 10kV directions, from the secondary side of the 150/10kV transformer down to the 10/0.4kV transformers
- two times two 0.4kV directions starting from both 10/0.4kV transformers



Example of a network with 7 directions

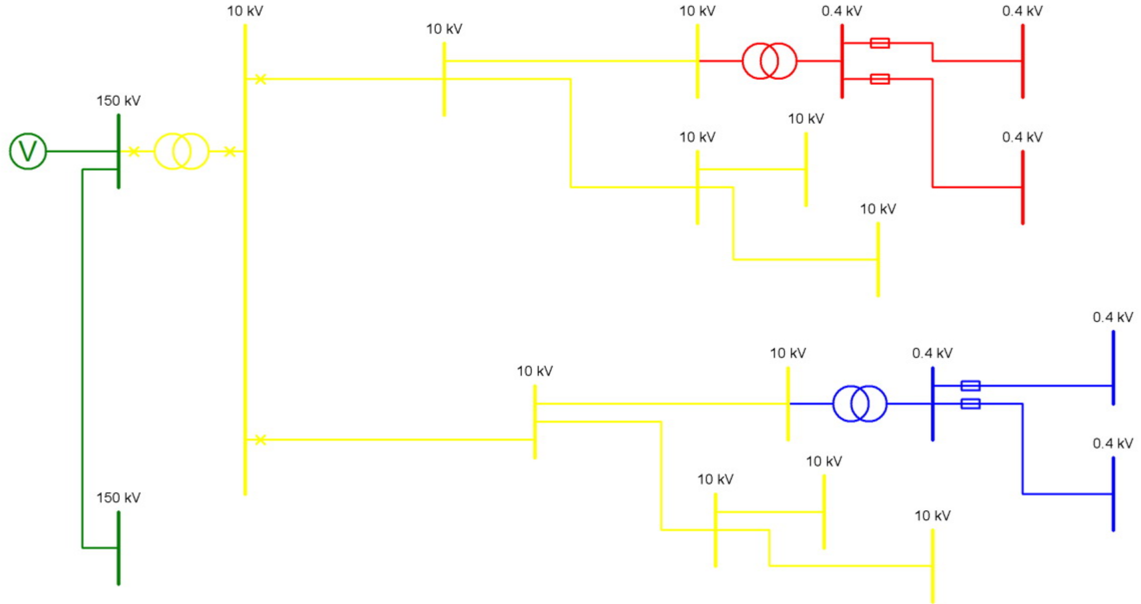
3.1.8 Area

An area is:

- a trace, starting from a source or
- a trace, starting from a transformer in the direction of high-voltage towards low-voltage.

The network below contains the following areas:

- source with 150kV network
- 150/10kV transformer with 10kV network
- two 10/0.4kV transformers with their respective 0.4kV networks.



Example of a network with 4 areas

3.2 Object types

In Vision, a database of component type data is used to support building a network. This type file database, containing all the different components, is named *Types.xls* or *Types.xlsx*. This file has to be a non-protected Excel spreadsheet file. When starting Vision, the component type data is read into the memory. The contents of the type file can be examined with the Type viewer 115.

Creating and updating type data

In the type file, data on components are recorded, these data can be modified and supplemented by the user. Making changes to the object type database can be done trough Microsoft Excel.

Examining and exporting component type data

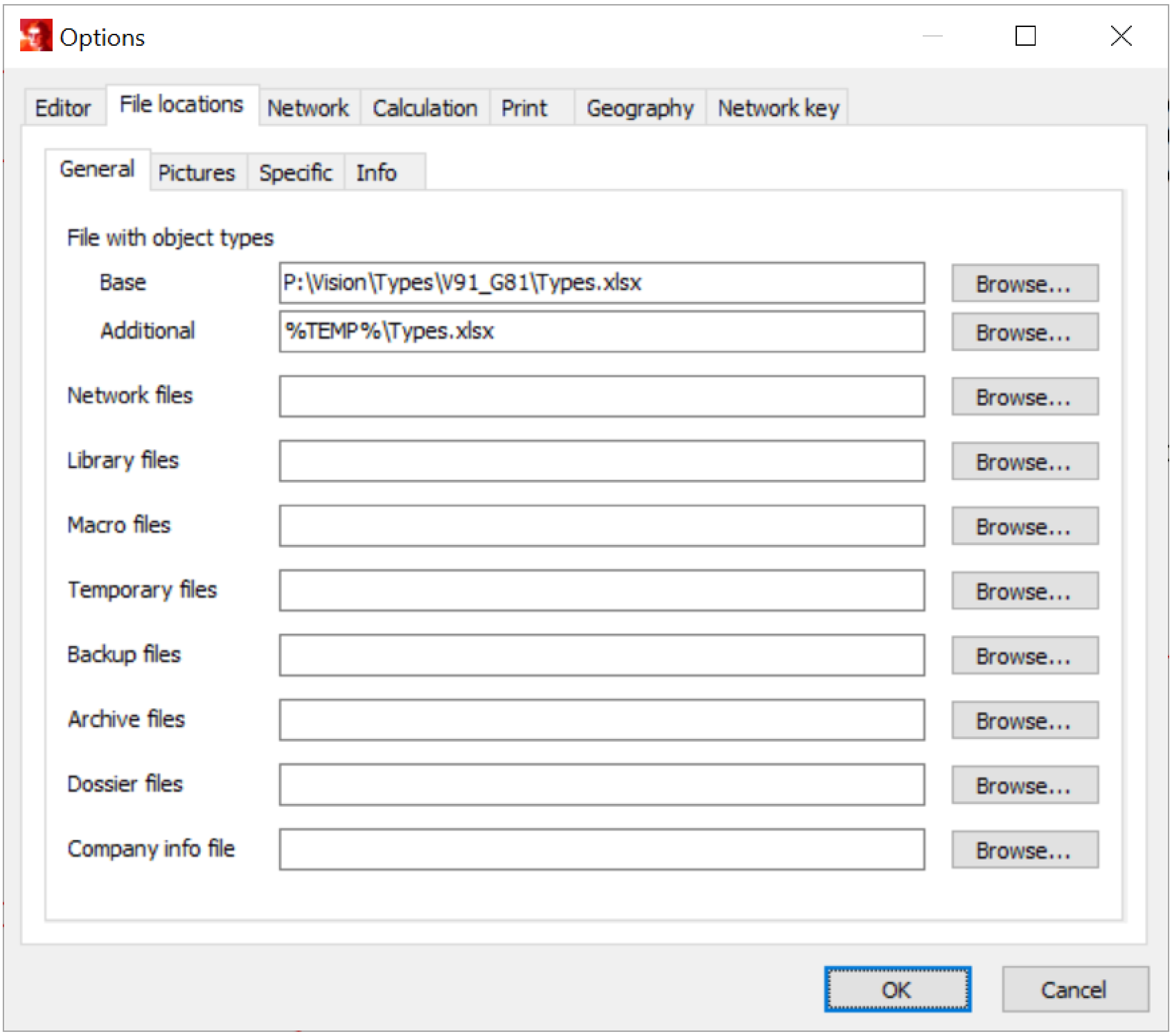
The type data of all objects in a specific network can be examined and can be exported to a spreadsheet. By doing this, it becomes easy to make additions or modifications to the standard type file. See: Type viewer 115.

Component type file location

By default Vision uses the component type files from the directory where the software has been installed, for example *C:\Program files (x86)\Vision*. The component type file can also be located in a different directory, either on the PC or on the network. In that case, the path to that directory should be defined in the **Options**, at: **File locations | General**.

Additional type file

The basic object types can be augmented with a user-defined additional type file. If the type names in the additional type file are not unique, the basic types will have preference. In this case, the types from the additional type file will not be read into the memory.



After changing the file location, Vision prompts whether the component database should be read again, making the data directly available for use.

See:

- Type 76
- Alias 78

3.2.1 Type

The following component types are used in Vision:

Tab in Types.xls	Object type	Applied in object
Cable	Cable type	Cable
Trafo	Transformer type	Transformer and transformer load
Specialtrafo	Special transformer type	Special transformer
Coil	Reactance coil type	Reactance coil
3wt	Three windings transformer type	Three windings transformer
Rail	Rail type	Node
Sg	Synchronous generator type	Synchrone generator
Sm	Synchronous motor type	Synchrone motor
Asg	Asynchronous generator type	Asynchrone generator

Asm	Asynchronous motor type	Asynchrone motor
Zigzag	Zigzag transformer type	Zigzag transformer
Wind	Wind turbine type	Wind turbine
Fuse	Fuse type	Fuse
Switch	Load switch type	Load switch
Breaker	Circuit breaker type	Circuit breaker
Current	Overcurrent protection type	Circuit breaker
Voltage	Voltage protection type	Circuit breaker
Distance	Distance relay type	Circuit breaker
Vt	Voltage measurement transformer type	Measurement unit
Ct	Current measurement transformer type	Measurement unit
Profile	Load and generation profile type	Profile
Harmonic	Harmonic source type	Asyn. motor, load, battery and PV
Harmonic norm	Harmonic standards type	
Lineconductor	Conducter type of lines	
Efficiency	Efficiency type	Battery and PV

Vision read the the object types from the Excel-file with the default name **Types.xlsx.** Each different component type is shown on a different tab in the Excel-file.

When a component is added or modified in Vision through the use of the object types, all of the parameters are copied and saved in the network file.

Types identification and rated voltage

A component type is identified by its name in combination with its rated voltage. The rated voltage of should fall into a certain range in order to be able to select a specific component type. As a result, the component database may have multiple objects with the same name, as long as their rated voltage, $U_{nom,}$ is not in the same range. This allows, for instance, LV cables and MV cables with the same name.

When adding an object to your network which has associated component types, a drop-down menu will appear in which all possible object types are indicated. These are not all the object types which may exist.
If the nominal voltage U_{nom} is part of the component, only component types with a U_{nom} in the same range will be shown. This range differs depending on the object:

Object	**Typefilter**
Node	Alle railtypen or
	0.75*node.U_{nom} railtype.U_{nom} 5*node.U_{nom}
Cable	0.75*node U_{nom} cable type.Unom 3.5*node U_{nom}
Reactance coil	0.75*node U_{nom} reactance coil type U_{nom}
Transformer	0.8*from node U_{nom} transformer type U_{nom},1 1.2*from node U_{nom} and
	0.8*to node U_{nom} transformer type U_{nom},2 1.2*to node U_{nom}
Generator	0.8*node U_{nom} generator type U_{nom} 1.2*node U_{nom}
Motor	0.8*node U_{nom} motor type U_{nom} 1.2*node U_{nom}
Fuse	0.8*node U_{nom} fuse type U_{nom} 1.5*node U_{nom}
Switch	0.75*node U_{nom} switch type U_{nom} 4.1*node U_{nom}
Circuit breaker	0.75*node U_{nom} circuit breaker type U_{nom} 4.1*node U_{nom}

MODIFICATION

The file *Types.xlsx* can be modified using Microsoft Excel.

The type data of all components in a network can be exported to a spreadsheet. In this way it becomes easy to modify the component database. See: Type viewer 115.

With **Start | Edit | Update types** the parameters of the selected components are overwritten with the values from the component type files. In order for this to work, the type must occur in the component type file.

See also: Object types 75

3.2.2 Alias

As many names for (the same) cable type and transformer type can exist within large companies, a system of aliases has been produced to keep the number of types manageable. In the type file, only the data of the 'official' types are kept. A table in the type file indicates how the 'unofficial' types (aliases) are converted to the 'official' types, based on their name.

When opening a network, all known alias types are replaced by their standardized type, including corresponding object type data.

The alias system is present for cable types, transformer types, reactance coil types and rail types. An alias table always consists of two columns: the alias name ('alias') and the new name ('name'). The four alias tables can be included in Types.xls tabs, 'Cable alias', 'Trafo alias', 'Coil alias', 'Rail alias' and 'Fuse alias'.

3.3 Application menu

The application menu at the top left of the ribbon is called **bestand.**
By clicking on it the following menu items become visible
- File handling 78 (New, Open, Save)
- Printing and reporting 98
- Prepare 80 (Information, Properties, Comments, Hyperlinks, Variables, Check)
- Send network 79
- About Vision
- Options 127.

3.3.1 File handling

New
Creates a new (empty) network.

Open
Open an existing network file.
When opening a network file Vision checks if the component data in the network are consistent with the data in the component type file. Any inconsistency will be flagged and may be synchronised with the data in the active component type file, using **Start | Edit | Special | Update types**.

Save
Saves the network as a network file. If the network file has not been saved before, a file name will first be requested.

Save as
Saves the network in a network file, after choosing a (different) file name or choosing to save it as an older version network file.

Close
Closes the active network. With new and modified networks, Vision asks whether the network should be saved before closing the network file.

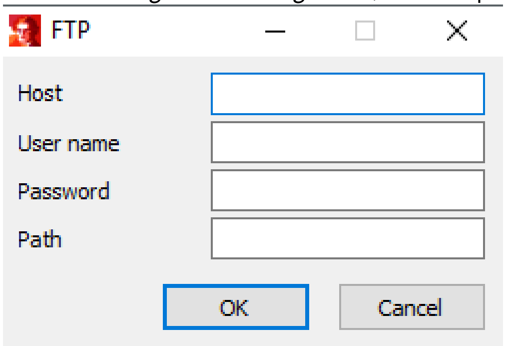
Exit
Exits Vision, for new and modified networks, Vision asks whether the network should be saved before exiting.

3.3.2 Sending

A network file can be sent by e-mail or via FTP.

When sending a file by email, the active network is temporarily saved as a zip file. This file is attached to a new outlook email. The use of outlook is thus required.

When sending a file through FTP, the FTP parameters should first be specified:



3.3.3 Prepare

Information
Bestand | Prepare | Information gives an overview of the size of the current network.

Characteristics
Some properties of the network can be saved with the network file with **Bestand | Prepare | Characteristics**.

General
General characteristics are: customer, city, region, country, project, description, version, state, by and date.

Invisible specifics
A list of the detailed characteristics of object that are not shown in views and reports. It is possible to fill in the characteristics manually or to select the characteristics from the list of characteristics which have already been applied.

History
A very short description of what has been changed in the network on which date and by whom. Moreover a check box can be selected that will make Vision automatically asks for updating the history when saving the network.

Users
A list of users who are authorized to save the network file. The user names are the Windows user names.

Comment
Bestand | Prepare | Comment offers the possibility to store necessary background information of a network as text.
A text field is available for this purpose. If in **Options** at **Editor**, **General** the option 'Show comment after opening' is checked, each time the network file is opened, the comment will be shown on screen. The comment can also be printed.

Hyperlinks
Bestand | Prepare | Hyperlinks offers the possibility to include a number of references to documents, spreadsheets, images or web addresses in a network file. These references have been implemented as hyperlinks.
In the form a new hyperlink can be inserted by placing the cursor in the text field or in the last already defined field and pressing the cursor key 'down' once. A new line will appear, where the characteristics and location to which the hyperlink should point can be entered.
By clicking on a hyperlink with the right mouse button a drop-down menu appears. With 'Browse' explorer is started and a file can be selected. With 'Go to' the corresponding program is started to show the information the hyperlink points to.
Characteristic is a description of the link in text.
Location is the reference to a file or a web address.
Examples:

```
'C:\My documents\documentation.docx',
'C:\My images\substation.png',
'www.phasetophase.nl'.
```

Variables
Bestand | Prepare | Variables offers the possibility to define network variables with a name and a value.
These variables can be used by means of their name between percentages in:
- the value of a specific attribute of an object
- the file name of a measurement file of a measurement field

Check
Checking the network for abnormal values is done with **Bestand | Prepare | Check**.
Abnormal values which do not lead to errors when performing calculations generate a warning or an information notification.

Information notifications are generated by:
- Multiple islanded nodes
- Element with a current> 1000 A
- Cable with an ampacity> 1500 A

- Cable with a length <10 m
- Parallel cables with different lengths
- Connection as modelled as link
- Switch with load capacity> 1500 A

Warnings are generated by:
- Node with simultaneity <0.1
- Node with simultaneity> 1
- Many islanded nodes
- Power supply without short-circuit power
- Element without rated power
- Element with bad cosinus phi
- Transformer load with many small consumers
- Transformer load with a power > 2*transformer rated power
- Cable with a length > 4 times the straight line distance
- Cable part with a small nominal voltage
- Cable section with a resistance <0.01 Ohm / km
- Cable section with a resistance> 10 Ohm / km
- Cable section with a reactance> 1 Ohm / km
- Cable with an amapacity <10 A
- Cable with geographic coordinates which are not continuous
- Cable with a different geographical length
- Branch with no or incorrect zero sequence impedance
- Meshtransformer
- Load switch type different from the rail type
- Power switch type different from the rail type
- Switch or protection in element with low load capacity
- Protection with a trip current> 1.5 * cable load
- Duplicate IDs
- Unknown field
- Field connected more often

Error messages are generated by:
- Cable with length < straight line distance
- Inconsistent clock numbers

By double-clicking on a line in the list of error messages with the left mouse button, the object is selected shown in the network diagram.
Once checked and approved, the checking messages can be suppressed per object and per message, by including a line in the specific tab with the 'checked' attribute.
The following texts can be used as values: simultaneity, current, power, cos, consumers, length, geo, main conductor, earth screen, auxiliary, resistance, load capacity, parallel, mesh, protection, type, ID and field.

3.4 Finding and selecting components

It is necessary that objects are selected, for almost all operations. There are various ways to do this. By using the search function objects can be found based on their name, ID, text, type and details. Next to this, there are several more specific selection options available, see:
- Select and Search 82
- Memory selection 85

3.4.1 Select and search

GENERAL

Selecting objects

It is necessary that objects are selected, for almost all operations. Selecting and deselecting can be performed in the following ways:

- by clicking on the component using the left mouse button
- by making a rectangle while holding down the left mouse button; when dragging from left to right, the objects that completely lie in the rectangle are selected; when dragging from right to left, the objects that partly lie in the rectangle are selected
- via the menu **Start | Select**

By selecting a object, the previously selected objects are deselected. Additional (de)selecting is done by selecting an object while pressed the Ctrl-key.
The status 'selected' is linked to the **object**. As a result, when an object is selected on a single sheet, the object is also selected on all other sheets where it is graphically represented. All representations of an object are thus selected simultaneously or not selected at all.

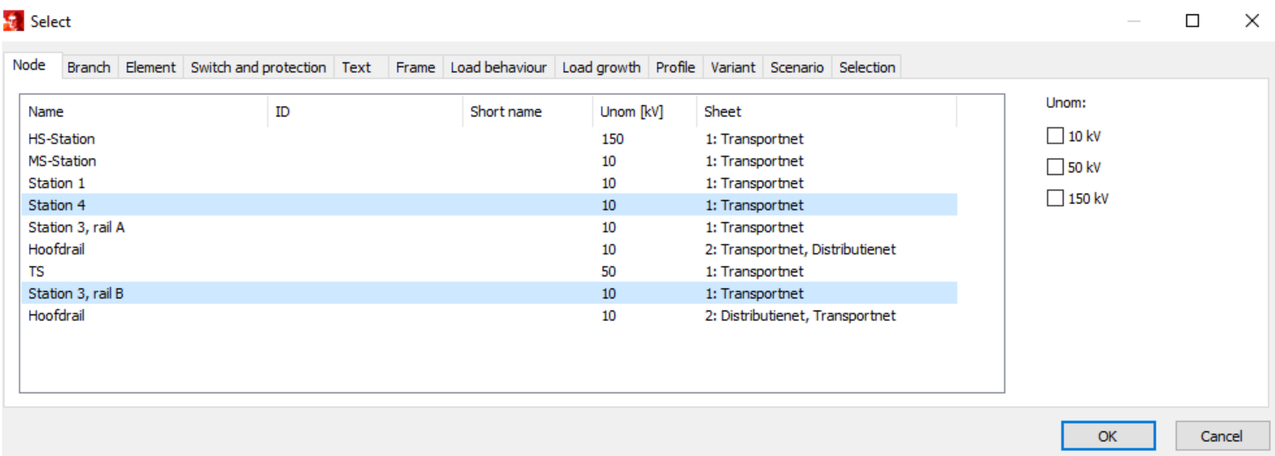
A selection of objects can be temporary stored to the memory. This selection can also be modified. See: Memory selection 85.

Selected objects can be saved as a selection in the network file.
Insert | Miscellaneous | Selection is used to add a selection to the network file.
Start | Edit | Selection is used to change the name, colour and content of the section.
Start | Edit | Delete | Selection is used to delete a selection. The selected objects are not deleted.

MENU

Object

Start | Select | Object can be used to indicate which components are selected. A subdivision has been made between Node, Branch, Element, Switch and protection, Text, Frame, Load behaviours, Load growth, Profile, Variant, Scenario, Selection and Presentation. With ***Load behaviour*** all (transformer) loads which have a specified load behaviour are selected. With ***Profile*** all the elements with the specified profile are selected.
For node, nodes can also be selected based on their voltage level.
All branches of a chosen species can also be selected for branch.
With element, all elements of a chosen type can be selected.
All switches and protection devices of a chosen type can also be selected for switch and protection.
In **Options | General | Select mode**, you can set whether only objects on the active sheet are selected or objects on all sheets the sheets are selected.
Before applying a selection all objects currently selected are deselected.



Object not

Start | Select | Object not can be used to deselect components.

Find

It is possible to find components by their Name, ID, Text, Type and Specifics, using **Start | Select | Find** or the shortcut key **Ctrl-F**. The asterisk is used as wildcard. The found objects will be selected. Another selection will be lost.

Specifics

For all components the user may input specific remarks 246. With **Start | Select | Specifics** all user defined specifics can be viewed in a summary. Using this objects may also be selected.

Selecting specifics by text

Objects can be selected by means of a text, appearing in the characteristic or the value of a specific (remark). The functionality optionally uses case-sensitivity and wildcard characters.
Objects can also be selected based on the presence of a characteristic. The available characteristics are shown in a list.
Objects can also be selected based on the value of a particular attribute. The available characteristics and (after selecting) associated values are shown in a list.
Objects can also be selected based on the presence of a value. All available values are shown in a list.
All objects are deselected beforehand.

Type

Start | Select | Type is used to select all components of particular types.

Advanced

With advanced selection it is possible to select or deselect objects based on any parameter or calculation result, according to the mark-up of a report, to be selected.
Choose **Start | Select | Advanced**
Choose the tab of the component type to be selected
Choose a report containing the parameter or result
Click on the specific parameter or result column header to sort the values
Select a range of components from this list based on this parameter
Press **OK**.
The selected rows can also be copied (by right clicking on them) and pasted into Excel.

Adjacent

With **Start | Select | Adjacent** adjacent components can be selected:

- node connected to a selected branch
- node connected to a selected element
- branch connected to a selected node
- branch in between two selected nodes
- element at a selected node
- switch in a selected object.
- object of the selected switch

Special

Use **Start | Select | Special** to selects objects with special characteristics:

- branches in which one or more switches are open
- objects with a double ID
- branches that are part of a subnet border
- connections with a mutual connection
- objects with a certain revision date
- cables with a 0.1 Hz measurement file in the specified folder
- nodes, circuit breakers and short-circuit indicators with remote status indication
- measurement fields with a power measurement.

Previous

Start | Select | Previous is used to select the components that were selected previously.

Island

With **Start | Select | Island** or **Ctrl-E** all the network components which are not connected to a source or a special synchronous generator can be selected.

Mesh

With **Start | Select | Mesh** or **Ctrl+M** all branches part of a mesh will be selected. In a mesh a branch can be opened without islanding any nodes.

Trace

A trace is a continuous path of nodes and branches, which starts at a certain starting point and ends at a net opening or at the end of a radial network. The functionality depends on the **Options | select mode**. If All sheets is chosen, the function will selects the trace in the whole network. If not, the function selects the traced objects only on the active sheet.

- select:
  - a node with a branch in the desired direction or
  - a switch/protection of
  - a node or an element
- choose **Start | Select | Trace** or **Ctrl-T**

The electrically connected network from the selected node in the direction of the selected branch is selected.

Route

The shortest route (smallest number of branches) between two selected nodes/elements can be selected using **Start | Select | Route** or **Ctrl-R**. The functionality depends on the **Options | select mode**. If All sheets is chosen, the function will selects the shortest route in the whole network. If not, the function only selects the objects part of the shortest route on the active sheet.

Source

The shortest route (smallest number of branches) between a node/element and a source can be selected with **Start | Select | Source**.

Group

Using **Start | Select | Group** or **Ctrl+G** the whole group 73 of one or more selected components will be selected. A group is enclosed by a protection device or an open switch.

Direction

With **Start | Select | Direction**, the entire direction of one or more selected objects is selected.

Area

With **Start | Select | Area** the entire area of one or more selected objects is selected.
An area contains all objects with the same power supply (if multiple power supplies are linked through the same voltage level, all of these power supplies are selected).

Inverse

Start | Select | Inverse or **Ctrl+I** is used to invert the selection.

All

Start | Select | All or **Ctrl+A** is used to select all components.

3.4.2 Memory selection

The current selection can be saved in a memory selection. This is a temporary selection to which other selected objects can be added. It works similar to the memory on a calculator, which is operated with the M +, M-, MR and MC functions. The memory selection buttons ***S+*** ***S-*** ***SR*** and ***SC*** are located in the menu **Start | Memory** .
- ***S+*** adds the selected objects to the memory selection
- ***S-*** removes the selected objects from the memory selection
- ***SR*** selects the objects from the memory selection
- ***SC*** clears the memory selection

The **Selection mode** in the **Options** is applied to S+, S- and SR

3.5 Adding components

Components can be added by inputting them individually or by copy and paste actions.

See:

- Insert 85
- Place 87
- Copy and paste 88
- Represent 89
- Library 90

3.5.1 Insert

GENERAL

New components, texts, frames, legends and selections can be added in the following ways:
- in the network form using the right mouse button
- via the menu item **Insert**.

NETWORK FORM

Adding a node:
- choose the desired location using the right mouse button
- choose **Node** from the pop-up menu.

Adding a branch:
- select the nodes which the new branch should connect
- click using the right mouse button
- choose the desired branch from the pop-up menu.

Adding an element:
- select the node where the new element should be connected to
- click using the right mouse button on the place the element should be drawn
- choose the desired element from the pop-up menu.

Adding a switch or protection device:
- select a node and a connected branch or element where the new switch or protection device is to be placed
- click on a empty place in the workspace using the right mouse button
- choose the desired switch or protection from the pop-up menu

Adding a text:
- select the desired location using the right mouse button

- choose **Text** from the pop-up menu

Adding a frame:
- select the desired location using the right mouse button
- choose **Frame** from the pop-up menu

Adding a legend:
- select the desired location using the right mouse button
- choose **Legend** from the pop-up menu

Adding a selection:
- select the network components which you want to added to the new selection
- click on an empty place in the workspace using the right mouse button
- choose **Selection** from the pop-up menu

RIBBON MENU

Adding a node:
- choose the desired location using the left mouse button
- choose **Insert | Node | Node**.

Adding a busbar system:
- select the nodes that have to be combined into the new busbar system
- the nodes must have the same orientation and may not be too far away from each other; see busbar system 143
- choose **Insert | Node | Busbar system** from the menu

Adding a branch:
- select the nodes which the new branch should connect
- choose the desired branch from the menu from the menu item **Insert | Branches**.

Adding an element:
- select the node where the new element should be connected to
- choose the desired element from the menu item **Insert | Elements**.

Adding a switch or protection device:
- select a node and a connected branch or element where the new switch or protection device is to be placed
- choose the desired switch or protection device from the menu item **Insert | Switched and protections**.

Adding a text field:
- select the desired location using the left mouse button
- choose **Insert | Illustrations | Text**

Adding a frame:
- select the desired location using the left mouse button
- choose **Insert | Illustrations | Frame**

Adding a legend:
- select the desired location using the left mouse button
- choose **Insert | Illustrations | Legend**

Adding a load behaviour:
- choose **Insert | Trends | Load behaviour**

Adding a load growth:
- choose **Insert | Trends | Load growth**

Adding a profile:
- choose **Insert | Trends | Profile**

Adding a sheet:
- choose **Insert | Miscellaneous | Sheet**.

Adding a selection:
- select the network components which you want to added to the new selection
- choose **Insert | Miscellaneous | Selection**

3.5.2 Place

ADDING GRAPHIC INFORMATION

A Vision network file where graphic information is missing or partially present can be opened normally with **Bestand | Open**. If no graphical information from the objects is present, nothing is displayed on the screen. If some graphical information is present, then:
- all nodes with graphical information are displayed
- all elements of these nodes are displayed and missing graphical information is automatically added
- all branches, of which all adjacent nodes are placed, are displayed and missing graphical information is automatically added
- all switches and protections devices in placed objects are displayed
- all other components are not displayed.

Nodes of which graphic information is missing can be placed as follows:
- Click with the left mouse button on the place where the node should be placed
- Select **Start | Edit | Graphical | Place | Place node**
- choose the desired node

or

- Right click on the place where the node is to be placed
- choose **Place node** from the pop-up menu
- choose the desired node

The selected node is placed at the indicated location. Elements and branches connected to this node are automatically placed.

Neighbour node
When nodes are placed via **Place node**, all nodes whose graphical information is missing are shown in a list. With large network files, this list is often too long to quickly find the desired node. Vision can limit this list by showing only neighbouring nodes.
Neighbouring nodes are all nodes connected to a branch with a single branch in between. In short: neighbours. The placing of neighbouring nodes of an already placed node can be done as follows:
- select the node from which a neighbouring node is to be placed
- right-click on the place where the neighbouring node is to be placed
- choose **Place neighbour node** from the menu
- choose the desired neighbouring node

or

- select the node from which a neighbouring node is to be placed

- Right click on the place where a neighbouring node is to be placed
- choose **Place a neighbour node** from the menu (one of the neighbouring nodes is placed)

or

- select the node from which all neighbouring nodes should be placed
- Right-click on the place where all neighbouring nodes should be placed
- choose **Place all neighbour nodes** from the menu (all neighbouring nodes are placed step by step)

In this way, graphical information can quickly be added to the network.

Select neighbouring nodes
Start | Edit | Graphical | Place | Selecting neighbour place nodes will select all the nodes from which additional nodes can be placed.

USE EXISTING GRAPHIC INFORMATION

When reading a network file that lacks graphical information, graphical information can also be added based on another network file. A prerequisite for this is that the identification of the components (in particular the nodes) and the sheet names of both network files are the same.
The identification of a node consists of the ID and the name.

Using existing graphic information to add the information to a network is done as follows:
- First open the network of which all the objects are placed
- Then open the network with the unplaced objects
- Select **Start | Edit | Graphical | Place | Place unplaced objects according to the other network**

All the nodes of the last network file whose identification and sheet name correspond to the identification and sheet name of the nodes in the first network are placed along with their associated branches and elements. Nodes for which no graphical information is known can be placed according to the method described above.

3.5.3 Copy and paste

COPY

You can copy a selected network section to the clipboard using **Start | Clipboard | Copy** or **Ctrl-C.**
The section is copied to two clipboards:

Windows clipboard
A graphical copy is transferred to the Windows clipboard. This copy is object-oriented.

Vision clipboard
The network section is transferred to the Vision clipboard as a data structure.
The copy usually contains a number of components, these can subsequently be pasted on the basis of the nodes contained in the copy. Without nodes, it is not possible to have branches or elements.
There are, however, four special types of copies:
- one or more elements all connected to the same single node;
- one or more parallel branches between two nodes;
- a network section containing one branch and one node, while the other node has not been selected and copied (the branch is 'open' at one end)
- one switch/protection device.

When a copy is made, a file is created in the temporary directory: the graphical representation of the network in the enhanced metafile format(*Vision.emf*). These images can be imported to various Windows programs.

CUT

You can cut the selected network section using **Start | Clipboard | Cut** or **Ctrl-X.**
Cut is the same as copy, followed by deleting the network section.

PASTE

Windows clipboard
The graphical copy on the Windows clipboard can be pasted in various Windows programs, including MS Office products. After pasting, the image can still be edited.

Vision clipboard
During the Vision session, the copied network section can be pasted into the same network, or into another network. There are two ways of doing this.

From the network form:
- move the pointer to where you want the top left-hand corner of the copy to go, then click the right mouse button.
- select **Paste** from the menu.

From the menu:
- move the pointer to where you want the top left-hand corner of the copy to go and click here using the left mouse button.
- select **Start | Clipboard | Paste**.

When you paste, components are added in their entirety.

When pasting copies from the four special kinds of copies using the Vision Clipboard as referred to above, the following components have to be selected:
- the node to which the element(s) are to be pasted
- the two or three nodes between which the branches are to be pasted
- the node to which the open branch is to be pasted
- the field to which the switch/protection has to be pasted (a field is a combination of node and branch or node and element).

Paste Special

Paste multiple elements
One or more copied elements that are connected to one common node can be pasted together to other selected nodes using **Start | Clipboard | Paste | Paste special**.

Paste multiple switches
The special coping of switches and protection devices also offers the opportunity to paste the copied switch/protection into more than one fields in a single pasting action. Select all the fields where the switch/protection has to be pasted and choose **Start | Clipboard | Paste | Paste special**.

Do not paste selections
When pasting all the objects parameters are copied. By selecting **Don't paste selections**, the selections of the copied objects are not copied to the pasted components.

3.5.4 Represent

An object can have multiple graphic presentations on several sheets. Nodes, text fields, frames and legends can be always represented on several sheets. Elements and branches can only be represented together with their associated nodes. Switches and protection devices can only be represented together with their accompanying node and branch/element.

A new presentation of an object is created by selecting that object on a certain sheet first and then paste it graphically on a another sheet by using **Start | Edit | Represent | Selected objects on sheet ...** . Hereafter the presentation properties can be modified.
In this way, a number of objects can also be represented in one go
An object can only be represented once per sheet

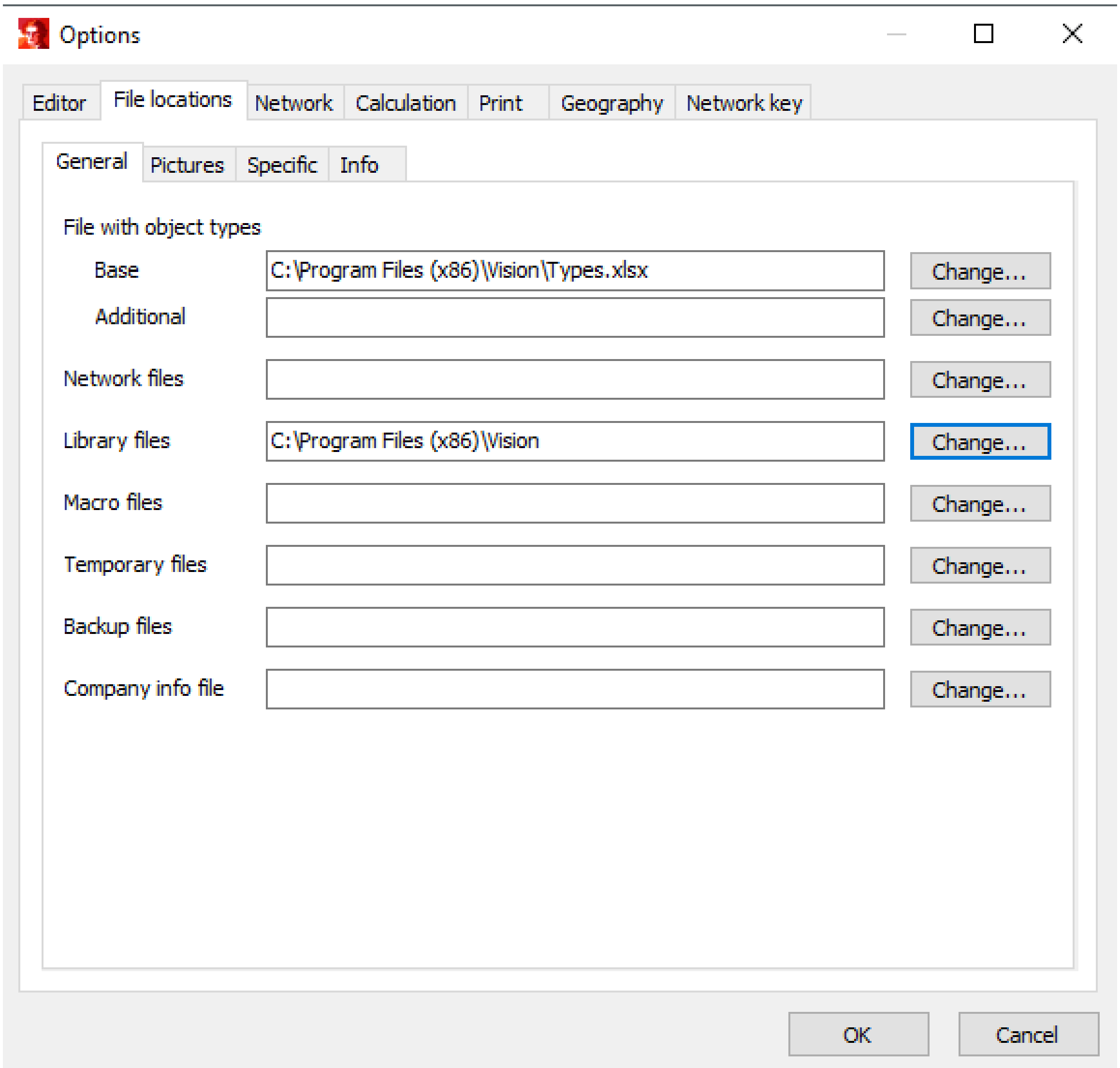
See: Multiple object presentation 67

3.5.5 Library

A fragment of a network can be stored using: **Start | Library | Save**. This action is similar to the copy-function in order to paste multiple objects at any desired location.

Fragments in the library can repeatedly be retrieved from the library to add them to any place in the network, using: **Start | Library | Take**. This action is similar to the paste-function in order to paste the objects at any desired location.

The library is similar to clipboard, however the objects in the library are stored in a file and are thus permanently available. The library location can be defined in the options menu.



An example of the library application is creating a library for several sub-stations configurations.

3.6 Edit components

Components can be edited both based on their graphical characteristics (their position in the network diagram) and their electro-technical characteristics. The network is object oriented, meaning that the network electro-technical structure is determined by the how the components are connected. This corresponds with the graphical representation.

Editing an object
Selected objects can be edited using the menu-items under the ribbon-item **Start | Edit**. In edit-mode, an object can also be edited by right-mouse clicking on it. After a successful calculation, Vision switches to the result-mode, in this mode right-clicking on an object will show the calculation results for this object.

Hints
For almost all parameters a hint will show up in the component form when the mouse pointer is hovering over a parameters name. The hint shows a short parameter description.

3.6.1 Edit individual

The parameter form can also be opened by clicking on the object using the right mouse button.
When clicking on **Start | Edit | Parameters** the parameter forms of all selected objects will be opened. This function can also be activated with the **F2** key.
The opening of the parameter forms can be interrupted by putting the mouse on the title bar of Vision and pressing the **Esc** key.

Certain parameters of a selection of components can also be changed using a table form by applying the function **Individual**.
The process is as follows:

- choose **Start | Edit | Individual**
- modify the values
- leave with **OK**

Hereafter only the components which are modified are selected.

Copy and paste
Copy and paste is made possible by clicking with the right mouse button.
A range of cells may be selected using the cursor keys while pressing **Shift**.
The value of one copied cell can be pasted into a range of selected cells.
If a range of cells has to be copied, the range of cells where it has to be pasted should have the same size.

Sorting
A number of rows of the table can be sorted by the values of one column. Select the range of cells in one column using **Shift** and the cursor keys. Then click with the right mouse button and choose **Sort**.

3.6.2 Edit collective

A selection of components can be changed in one go with the use of collective edit. Normally, this function only works for the objects on the visible sheet. If the checkbox **All sheets** has been checked, the collective edit will apply to all selected objects throughout all the sheets.
Depending on the type of components (node, branch, element, switch/protection or all) collective editing goes as follows:

- choose **Start | Edit | Collective | { Object, Node, Branch, Element, Switch/protection, Presentation }**
- indicate which parameters should be changed using the checkboxes
- give the new values
- leave the form by clicking **OK**

Changing U_{nom} for nodes collectively

It is possible to collectively change the nominal voltage of a group of nodes. If the nodes are connected by cables, connections, reactance coils or links, it is only allowed to change all the connected nodes together. If the nodes are connected with transformers, it is only allowed to change the voltage to a value within 20% of the voltage levels indicated by the transformerwindings.

3.6.3 Update types

The objects in a network may have components with type data that are different from the types in the type file (which can be view using: **Tools | Definitions | Type viewer**).

The type data of selected objects can be synchronised with the type file using: **Start | Edit | Special | Update types**.
Choose **Details** to see the changes before applying them.
Tick the checkboxes of the object types or object items to be changed.
Leave the form with **OK**.
After the update, only the modified components are selected.

Normally, this function works on the visible sheet only. If the checkbox **All sheets** has been checked, this function will work on all selected objects in the whole network.

3.6.4 Special, Simultaneity

Semi-automatic simultaneity calculation

The nodal simultaneity235 (or diversity/coincidence) factors can be adjusted, so they correspond to a specified current through a certain branch. Using this function the simultaneity factors can be calculated so that the computed branch current from the load flow matches a measured value.
First select all the nodes for which the simultaneity factors have to be calculated. For instance: select all the nodes belonging to a certain feeder. Also at least one branch (link, cable, connection or reactance coil) for which the calculated current should match a specified value, has to be selected.

Choose: **Start | Edit | Special | Simultaneity | Interactive**

Using the form the selected nodes become visible in a table. In this table, the nodes without load or transformer load are deselected. The user can change the selection (and thus the nodes which are taken into account in the calculation) in this table.

In the same form a choice can be made for a single branch, for which the calculated current should match the user specified current. For the selected branch the load flow current for the actual load is calculated and is presented in the form. In the input field the desired current value for this branch can be specified.
The user can choose whether the simultaneity factors for the selected nodes should be determined in a relative way or in an absolute way. Relative means that the actual simultaneity factors will be corrected equally. Absolute means that the simultaneity factors will be updated to one and the same value.

Using the **Calculate** button the simultaneity factors will be adapted in such a way that the current through the selected branch matches the desired value. If the desired value is feasible, the value is shown in black. If the calculated value is infeasible, the calculated value is shown in red.

On leaving the form with **OK** the simultaneity factors of the selected nodes are saved.

Automatic simultaneity calculation

The simultaneity235 factors between nodes can be calculated automatically so that they correspond to a specified current or power through a measuring field.

Select **Start | Edit | Special | Simultaneity | From measurement units**

Select a date range.
All measurement fields with the biggest current measurement or power measurement are shown in the selection form. The value of the measurements will therefore be shown in 'A', 'kW' or 'MW'.
The measurement fields that were selected before opening the form, have already been pre-selected in the table.
Select the desired measurement fields and leave the form with **OK**.
Generators and capacitors are turned off during the calculation of the simultaneity factors.
After the calculation, an overview of the adjustments is shown.

Automatic concurrency calculation via a file
The simultaneity 235 factors between nodes can also be calculated automatically so that they correspond to a specified current through a branch.

Select **Start | Edit | Special | Simultaneity | From file**

Select the Excel file with the measurements.
A specific worksheet must have the name 'cable', 'connection', 'link', 'reactance coil' or 'transformer'.
There are three possibilities for the columns:

- two columns: branch name and current
- three columns: from node name, to node name, and current
- four columns: branch name, from node name, to node name, and current

Generators and capacitors are turned off during the simultaneity calculation.
After the calculation, an overview of the adjustments is shown

3.6.5 Special, Subnet border

The automatic determination of suspected grid dividing limits.
Subnet borders separate parts of the network that are fed by different sources or transformers.
To automatically determine possible subnet borders, a route is determined from each mains supply and from each transformer.
To be identified as a subnet border:

- all branches of which one switch is open and the node on the other side is fed:
  - by another mains supply or
  - by another transformer.

The form shows three lists with branches:
Potential subnet border: branches that are now not classified as a subnet border, but probably are
Not plausible subnet border: branches that are now classified as a subnet border, but probably are not
Plausible subnet border: branches that are now regarded as a subnet border and that probably are

In the three lists, it is also indicated which are the two feeding nodes on both sides of the branch.

When leaving the form with **OK**, the **subnet border** of branches shown is set according to the check marks.
The names of the feeding nodes are also included in the relevant two parameters of the branch.

Select **Start | Edit | Special | Subnet border**.

3.6.6 Special, Profile situation

The powers of all elements will be multiplied by a factor that corresponds with the profile factor 230 on a specific time. In this way the power of elements can be changed over time.

Care should be taken when saving the network after this operation, since the new power values will be saved.

This operation brings the network in a specific state for time-independent calculations. All of the calculations are time independent except for the loadflow with profiles calculation.

Choose **Start | Edit | Special | Set profile situation**.

3.6.7 Special, Change voltage

The nominal voltage of some (probably connected) nodes can be changed collectively.

Select the relevant nodes.
Choose **Start | Edit | Special | Change voltage**.
Enter the new nominal voltage.

In addition to the nominal voltage of the selected nodes, adjacent objects are also changed slightly.
They are:
- rated voltage and type name (becomes blank) of machines
- rated voltage and tap size and type name (becomes empty) and voltage control of transformers.

Cables, lines, links and reactance coils that become between nodes with different nominal voltage are opened. The idea is to manually transfer them to a node with the new nominal voltage, via **Start, Edit, Topological, Transfer** and then close the switch.

And list of the changed objects will be displayed afterwards.

3.6.8 Transfer

The Transfer function offers the possibility to transfer the connecting point of a branch or element from one node to another. Using this function the branch or element does not need to be removed and subsequently inserted at the new node.
Also a switch/protection device can be transferred from one object to another.

The procedure for branches is as follows:
- select the branch to be transferred
- select the old node where the branch is connected to
- select the new node to which the branch needs to be transferred to
- choose **Start | Edit | Topological | Transfer**

The procedure for elements is as follows:
- select the element to be transferred
- select the old node to which the element is currently connected
- select the new node to which the element should be connected
- choose **Start | Edit | Topological | Transfer**

The procedure for switches/protections is as follows:
- select the switch/protection to be transferred
- select the branch or element where the switch/protection is to be transferred to
- select the node at the side of the branch/element where he switch/protection should be placed
- choose **Start | Edit | Topological | Transfer**

3.6.9 Split

The Split function enables the division of a node or a branch into two parts.

Splitting a node
A horizontally or vertically oriented line shaped node can be split as follows:
- select the node to be split
- choose **Start | Edit | Topological | Split**

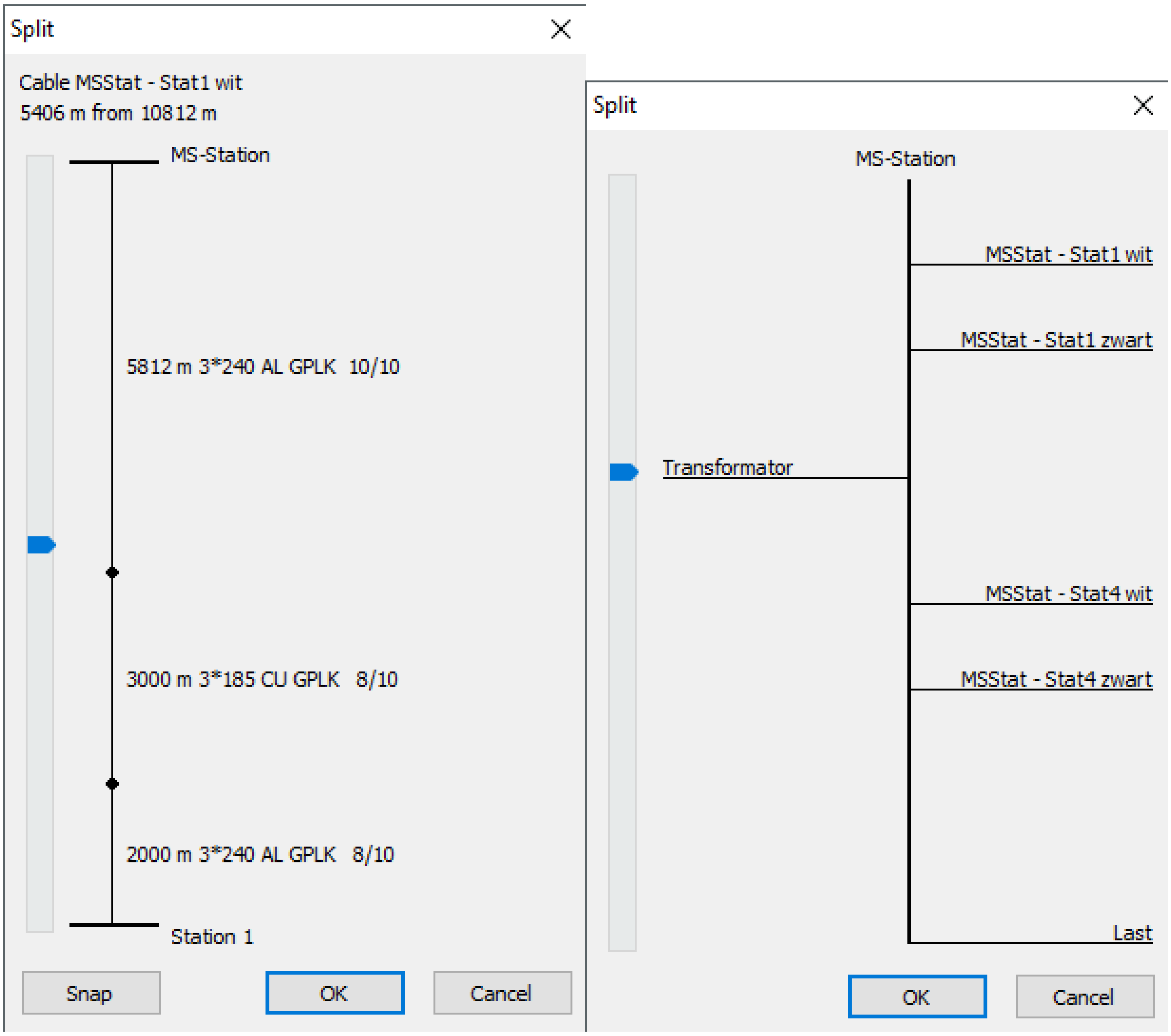
- choose the splitting location using the track bar.

The distribution of the connected branches and elements over the two nodes is graphically determined.

Splitting a cable
A cable or a connection can be divided into two parts or disconnected from a node at one side. This function involves automatic insertion of a new node at a distance to be specified by the user. All cable parameters are recalculated for the new situation. The procedure is as follows:
- select the cable to be split
- choose **Start | Edit | Topological | Split**
- adjust the distance at which the cable will be split using the track bar.

Using the button **Snap** the splitting point will be moved to the closest cable part junction. The junctions between the cable parts can be seen as small dots (see diagram below).

A splitting distance of 0% or 100% disconnects the branch at the from or the to node respectively. The disconnected end will be connected to a new, automatically generated, node.



Splitting a cable and splitting a line shaped node

Reconfiguration of a transformer load
A transformer load can be decomposed into a transformer, a secondary node and a load. All properties are transformed into the new configuration. Select the transformer load and choose: **Start | Edit | Topological | Split**.

3.6.10 Shift

It is possible to move a node which is situated between two cables and change the distance to its neighbouring nodes. The cable length and the number of cable parts will be adjusted automatically.

In order to do this, only select the node and choose **Start | Edit | Topological | Shift**.

3.6.11 Take out

A selected node between two cables, between two links or between a cable and a link can be removed with **Start | Edit | Topological Take out**.

Two cables or two links are combined into one cable or one link.
If a a cable and a link are combined, the link is removed.

3.6.12 Join

Two selected nodes, without a connecting branch, can be joined into one node, using **Start | Edit | Topological | Join**.

The node with the most branches and elements will remain. Only a few characteristics are transferred from the node which will be removed to the new node, among which the specifics.

3.6.13 Undo

Modifications to a network can be reversed using **Start | Edit | Undo**. Through the sub-menu one or multiple modifications that one wants to undo can be selected.

The undo function can also be applied by pressing **Ctrl-Z**.

3.6.14 Redo

Modifications to a network that were undone can be redone using **Start | Edit | Redo**. Through the drop-down menu the undo actions that need to be redone are shown and can be selected.

The redo function can also be applied by pressing **Ctrl-Y**.

3.7 Moving components

Components can be moved using the mouse. In case a network diagram is final, it can be protected against moving of components in the **Options** menu, using: **Editor | General | Edit | Do not move**.

3.7.1 Move

Object can be moved individually and collectively in the network.

Drag
Components can be moved individually:
- select the component or text to be moved
- place the mouse on the selected component and move the mouse while holding down the left mouse button

Object text can be moved in the same way. The location of the object texts are saved in the network file.

Move
When moving, all selected objects are moved simultaneously when the mouse cursor is placed on a node, text, frame or legend. If the mouse cursor is on a branch or element, it is moved individually.

Crosshairs while dragging nodes
When dragging a node crosshairs are optional. These crosshairs can be helpful for the horizontal and vertical alignment of components.
The crosshairs can be enabled trhough the **Options** menu at **Editor | Drawing | Drawing | Cross on node dragging**.

Lengthen or shorten
Nodes (depicted by a line symbol) can be lengthened or shortened as follows:
- place the mouse on the end of the node to be modified
- move the mouse while holding down the left mouse button

3.7.2 Bend

Sometimes it is desirable when dragging a branch to move only part of it. To do this, a bend has to be made in the branch.

A bend in a branch can be made in two ways.

From the menu:
- click on the branch at the point at which the branch should be bend
- choose **Start | Edit | Graphical | Bend**
- now part of the branch can be moved, while performing a moving action.

From the network form:
- click on the branch at the point at which the branch should be bend
- click using the right mouse button in the work area
- choose **Bend** from the menu
- now only part of the branch will be moved, while performing a moving action.

3.7.3 Align

Nodes can be horizontally or vertically aligned, using **Start | Edit | Graphical | Align**. The centres of the selected nodes will coincide on either a horizontal or vertical line.

It may be necessary to subsequently automatically place the branches and elements to their default poistion, using: **Start | Edit | Graphical | Replace | Object complete**.

3.7.4 Replace

All selected branches and elements, along with their accompanying texts, can be set to their default position with **Start | Edit | Graphical | Replace | Object complete**.

Choose **Start | Edit | Graphical | Replace | Object text** to only set the text to its default position for all selected objects.

3.7.5 Scale

A selected part of the network can be scaled by a given factor, relative to a chosen point.
This feature enables you to increase or decrease the size of part of the network.
It is also possible to mirror the network by entering a negative scaling factor.

The size of a selected part of the network can be scaled in two ways.

From the network form:
- select the network section to be scaled.
- click with the right mouse button at the point to which the part of the network should be scaled.
- select **Scale** from the pop-up menu.
- enter scaling factors for the X and Y axes.
- enter the object scaling coefficients and the text scaling coefficient

From the menu:
- click with the right mouse button at the point to which the part of the network should be scaled.
- select the part of the network which is to be scaled, without clicking the left mouse button.
- select **Start | Edit | Graphical | Scale**.

3.8 Deleting objects

Selected components can be deleted as follows:
- via the keyboard: press the **Delete** key
- via the menu: choose **Start | Edit | Delete | Selected**

Before the object will be deleted a warning will be given if not all the selected objects are currently visible.
Before the object will be deleted a warning will be given if any of the selected objects have multiple representations.

When deleting an object with multiple representations only the presentation of the object will be deleted. If the object only has one representation the entire object will be deleted.

A busbar system can be removed if all the nodes of the busbar system are selected, by using: **Start | Edit | Delete | Busbar system**. The nodes of the busbar system will not be deleted, only converted to ordinary nodes.
If both lines are selected, a mutual coupling between two lines can be deleted by: **Start | Edit | Delete | Mutual Coupling**. Only the coupling between the lines will be deleted, the lines will remain.
A load behaviour that is not in use, can be deleted using **Start | Edit | Delete | Load behaviour**. A menu will pop-up in which the load behaviour that should be deleted can be selected.
A load growth that is not in use, can be deleted using **Start | Edit | Delete | Load growth**. A menu will pop-up in which the load growth that should be deleted can be selected.
A profile (load or generation) that is not in use, can be deleted using **Start | Edit | Delete | Profile**. A menu will pop-up in which the profile that should be deleted can be selected.
A selection can be deleted using **Start | Edit | Delete | Selection**. A menu will pop-up in which the selection that should be deleted can be selected.The components in the deleted selection will not be deleted.
Specifics of a selected object can be deleted using **Start | Edit | Delete | Specifics**. See: Specifics 246

Take out a node

A node between two branches can be taken out, joining the two cables connecting the node. The node may not have any connection to other branches, elements, switches and protection devices.

Select the node that has to be taken out and choose **Start | Edit | Topological | Take out**.

3.9 Printing and reporting

The network and the components data can be printed in several ways. Also exports to Excel can be created. The contents of these exports can be defined by the user.

Print the network diagram
Using **Bestand | Print | Print** the graphical representation of the selected part of the network, the current sheet, or all the sheets can be printed.
With **Bestand | Print | Print preview** the graphical representation will be displayed on screen first.
If no objects are selected, the whole sheet or a selection of sheets will be printed
Print options can be defined in the **Options** at **Print**. See: Options, Print 134.

Print screen
The print screen function prints the part of the network which is currently visible on the screen. Partly visible objects will be printed accordingly. A print of the screen can be created by: **Bestand | Print | Print screen**.

Report
Network input and calculation results can be viewed and exported through the use of reports.
Using **Bestand | Print | Report** the selected components are reported on screen or in Excel. This report can be saved or printed afterwards.
The contents of a report can be defined 116 using **Tools | Definitions | Reports**.

When generating a report the user can choose between the defined reports. The Vision report comes predefined.

When generating a report the report-form will pop-up. In this form you can specify:
- Target: text, Word or Excel.
- Sorting: by name, ID, trace or result.
- Contents: only the selected components or all components.
- Sheet: only the active sheet or all sheets.
- Otherwise: add properties, comment, hyperlinks, other calculations, a graphical overview of the network diagram and exploded cable parts.

Pressing the **F3** key the will repeat the report using the most recently used settings.

3.10 Tools

The Tools menu hosts some general functions. These functions are:

Ribbon group **Compare**:
- Compare network 100
- Take over from network 100
- Add a network 100
- Protections 101

Ribbon group **Data**:
- Import 103
- Export 113

Ribbon group **Geography**:
- Grid Navigator (this is an additional component of Vision)
- Google Earth 113
- Map 113
- Excel 115

Ribbon group **Definitions**:
- Type viewer 115
- Views 115
- Reports 116
- Options file 116

Ribbon group **Tools**:

- Phase color and order 117
- Cable ampacity 118
- Arc flash 119
- Power lines 122
- Solar panel 125

Ribbon group **Macro**:

- Editor 125

3.10.1 Compare networks

Tools | Compare | Compare with network.
Two networks which are opened in Vision can be compared for the presence of the objects (nodes, branches, etc.) and the differences in attributes. The active network (which can be seen on the screen) is compared with another opened network (the passive network). This function lists the differences in attributes and presence of objects.

3.10.2 Take over from network

Elements, branches, switches, protection devices, load behaviours and profiles can be transferred from a previous version of the network into the current network. This function is useful, for example, if a network file is generated from a GIS and where additional objects have to be added compared to a previous version of the network file. For example, it is possible that only the nodes, the branches and the loads are generated from the GIS and that the switches and protection devices have to be added.

The function has effect on the active network.

- The function can be activated using **Tools | Compare | Take over from network** if also the other network, from which the information has to be imported, has been opened in Vision. A drop-down menu will be shown, in which the network with the data to be transferred should be selected.
- Once the function has been activated, the objects groups (elements, branches, switches, protections and other) to be imported can be specified. The function only imports the data of the selected objects groups.
- Both the previous and actual network files must represent the same network, since the function has to select similar object based on their object name and ID.
- Branches and elements can be imported only if the corresponding nodes are recognised (from their ID and/or name). Switches and protection devices will be imported if the corresponding node and branch or element names are recognised.
- Load behaviours, Load growths and Profiles are imported without restrictions.

After taking over data from another network, the affected objects are selected.

3.10.3 Add a network

Another network can be added to the active network with **Tools | Compare | Add network**.
The other network must already be open as a separate network.
The other network is added to the active network on separate sheets.

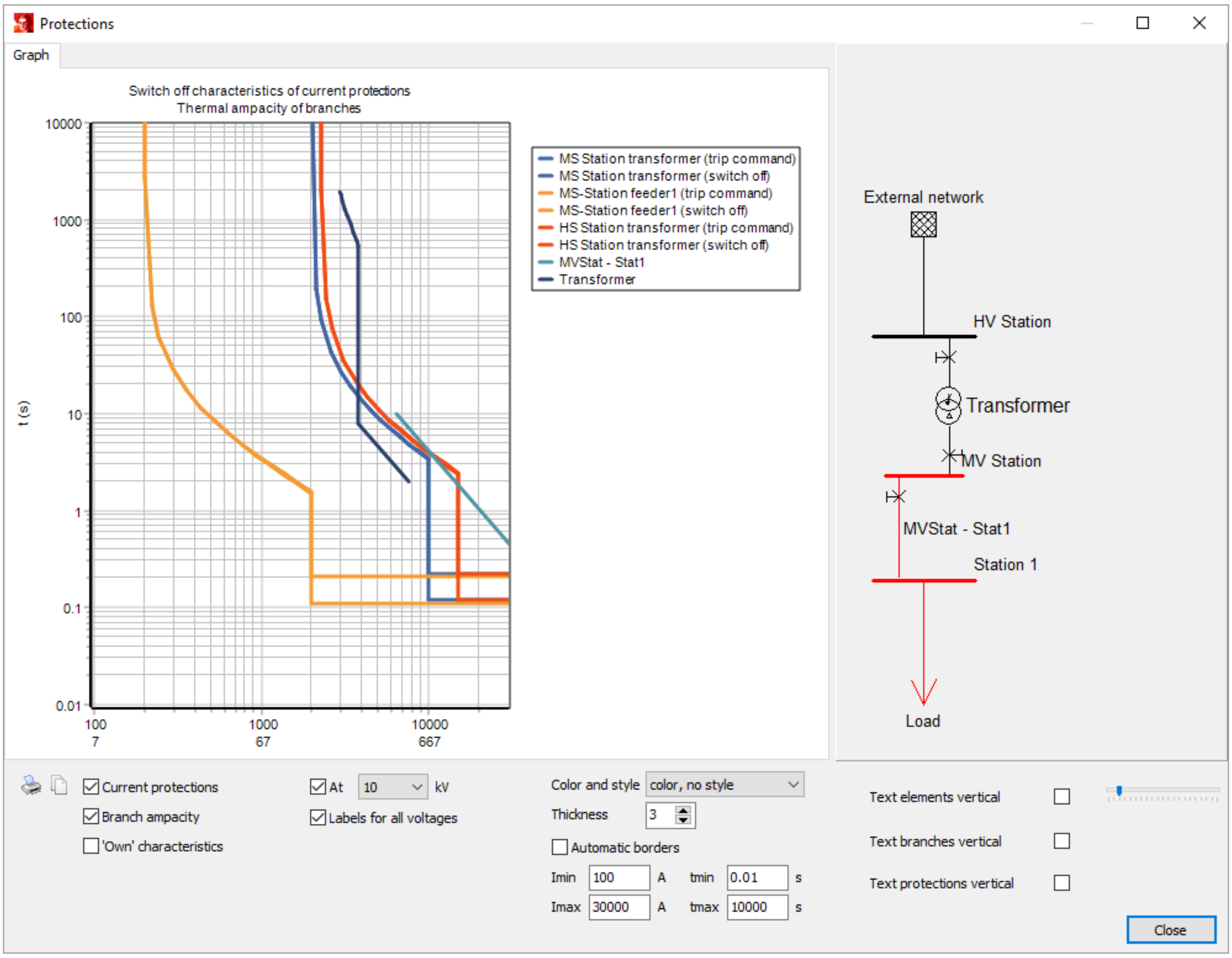
Possibly identical objects are optionally merged. You will be prompted for this.
Detecting identical objects works for visual objects primarily on the basis of name and ID. Name (possibly empty) and ID (not empty) must be the same. For nodes, the ID can be entered explicitly. For other objects, the ID can be specified via the specifics, via a specific with characteristic "ID".
Load behaviours, load growths and profiles must be exactly the same to be merged.

3.10.4 Protections

The characteristics of selected overcurrent protections can be shown together in one plot through the use of **Tools | Compare | Protections**. Defined tripping times are shown as function of the current. The switching characteristics can be combined with the branch ampacities, to spot possible thermal overloading of the cables.

The shortest route (the smallest number of branches) between two selected nodes/elements can be selected using **Start | Select | Route** or pressing **Ctrl+R**. In case protection devices are selected in this way, the route is automatically plotted next to the time-current curves.

- First, select the node at the beginning and at the end of the route.
- Then use **Start | Select | Route** (or **Ctrl+R**), to select the route.
- Hereafter the protections tool can be started:**Tools | Compare | Protections**.
- The route will be shown next to the plot. Its size can be changed with the slider in the lower right corner of the window. The direction of text for elements, branches and protection devices can be set using respective checkboxes.



Vission finds the optimal orientation of the part of the network (the selected route) to be drawn. The node located at the left or at the top in the network diagram is placed on top of the automatically generated diagram.

The checkbox **Current protections** determines whether time-current curves of overcurrent relays will be shown on the plot.

Branch ampacity plots I^2t characteristics of selected cables and lines. For transformers the damage curve according to the IEEE Std C57.109 (IEEE Guide for Liquid-Immersed Transformer Through-Fault-Current Duration) is drawn.

Motor start sets the point with coordinates: starting current on x-axis and starting time on y-axis (these numbers are specified on tab **Induction motor | Connection**).

The time-current curves can be displayed for their own specified voltages or transformed to a chosen voltage. To alter the voltage level check the box before **At** and select the voltage level from the drop-down menu. This option is handy for evaluating the protection devices on different sides of a transformer.

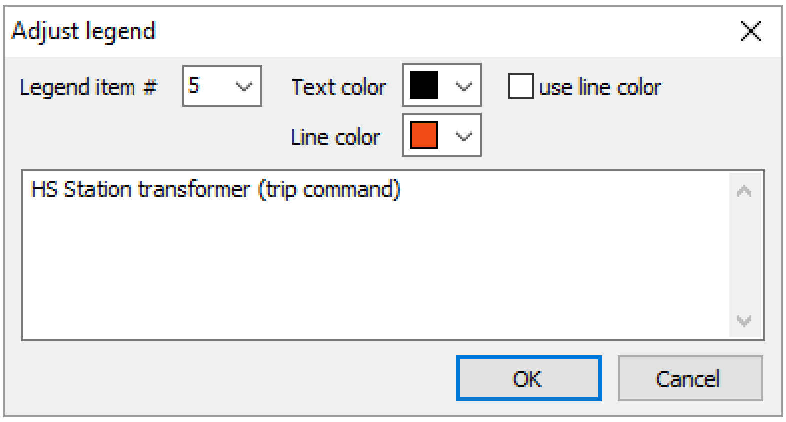
Labels for all voltages shows currents (x-axis labels) for all voltage levels of selected objects.

Time-current curves can be also displayed in black and white and/or using dashed lines. The colour and style can be used to adjust the following:

- with/without colour
- with/without different line styles
- thickness of lines

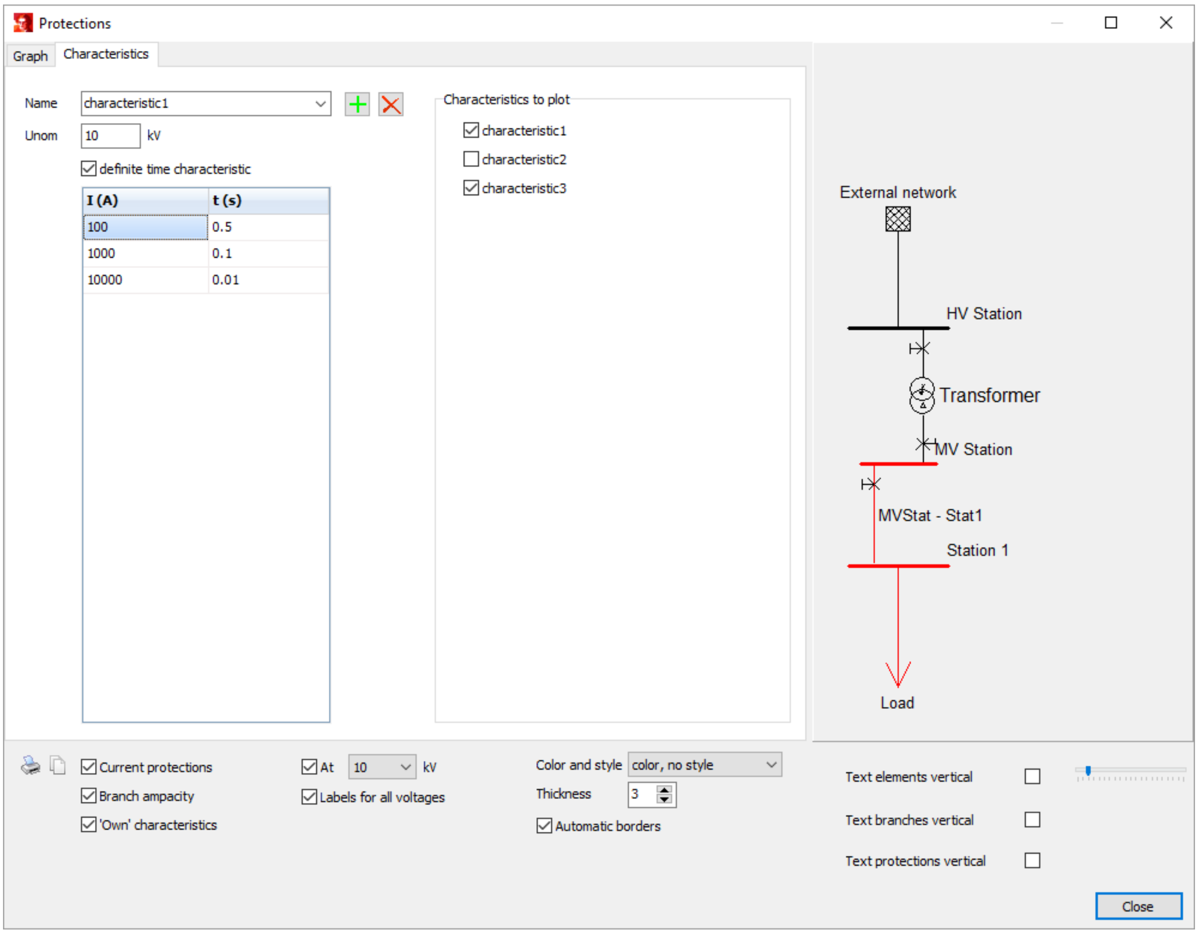
Plot limits can be set automatically or adjusted manual.

The plot can be copied or printed by pressing the copy or printer icon in lower left part of the window or by using the shortcuts (**Ctrl+C** or **Ctrl+P**). The colour of a line in the plot, its order in the legend and the corresponding text can be adjusted via a right mouse click on the legend item or the line on the plot. respectively



Using the left mouse button on a line will show the coordinates of a point on the line.

After checking the **'Own' characteristics** checkbox the tab **Characteristics** will appear. Here, the user can define there own characteristics to be shown in the plot.



This can be done as follows. First, the nominal voltage can be set (for deviating voltage and checked **At** option the currents of the own characteristic will be recalculated during plotting). **Definite time characteristic** checkbox determines whether the characteristic will be plotted in the form of stages (checked state) or in form of points on a curve (unchecked state). Further points in the time-current plot can be entered. It is possible to enter as many points as are needed, pressing **Enter** or **Tab** will add an extra row if necessary. After that the name of characteristic can be specified, and it can be added to the list of characteristics by clicking the plus icon to the right side of the input field. Removing a characteristic is possible with the icon next to it (in case of multiple characteristics are defined the desired characteristic first has to be selected from the list). In this way the characteristics can be created, selected and removed. Using the checkbox **characteristics to plot**, it can be determined whether the added characteristic shows in the figure.

3.10.5 Import

With this function object data can be adjusted to values from an Excel file, by importing the Excel file in Vision.

Importing takes place from an Excel file, whose worksheets have a fixed name. Below the types of objects which can be imported. The name of the worksheet is the same or the single variant:

- ***nodes***
- ***cables***
- ***connections***
- ***reactance coils***
- ***transformers***
- ***plural name of an element sort (all element sorts are available)***
- ***circuit breakers***
- ***load switches***
- ***measurement units***
- ***fuses***

- ***profiles***
- ***frames***
- ***variants***
- ***scenarios***

Each worksheet consists of a header row and data rows. The first row is always the header row, which defines the search parameters and the parameters to be changed. The data rows follow from the second row. Empty rows are allowed but the import function stops after five empty rows.

Search items have been defined for all objects, so the objects can be identified. These search items are preceded by a $-sign. One, two, three or four identifying values must match in order to identify the object to be changed. If an object is not found or if an object is found more than once, a warning message is generated.

In addition to the search items, change items are defined for all changeable parameters.

Specifics for existing objects can be imported.
A specific attribute can be removed by including: <characteristic>=.

Nodes

Header	**Parameter**	**Description**
earch-items		
$Name	Name	Name of the node
$Short name	Short name	Short name of the node
$ID	ID	Identification
$Number	Number	Internal number of the node
hange-items		
Name	Name	Name
Short Name	Short name	Short name
ID	ID	Identification
Simultaneousness	Simultaneousness	Simultaneousness factor
Railtype	Rail type	Name of the rail type
GX	X	Geographical X-coordinate
GY	Y	Geographical Y-coordinate
Failure frequency	Failure frequency	Failure frequency
Specific	Specific	Characteristic and value of the specific formatted as: ***characteristic>=<value>***
Specific+	Specific	Add a specification
^<characteristic>	Specific	Value of the specific to be modified
^<characteristic>+	Specific	Value of the specific to be added
Revisiondate	Revisiondate	Revision date
Note	Note	Note
Function	Function	Function
Icon.Text	Icon.Text	Text of the icon
Icon.Textcolor	Icon.Textcolor	Color of icon text (BGR)
Icon.Color	Icon.Color	Icon background color (BGR)
Icon.Shape	Icon.Shape	Icon shape (0=circle, 1=ellipse, 2=square, 3=rectangle)
Icon.Size	Icon.Size	Size of the icon

Cables

(where is the table?)

Lines

Header	Parameter	Description
earch-items		
$Name	Name	Name of the connection
$Node1.Name	Node1.Name	Name of the 'from'-node
$Node1.ID	Node1.ID	ID of the 'to'-node
$Node2.Name	Node2.Name	Name of the 'to'-node
$Node2.ID	Node2.ID	ID of the 'to'-node
$NodeX.Name	NodeX.Name	Name of one of the connected nodes
$NodeX.ID	NodeX.ID	ID of one of the connected nodes
$NodeY.Name	NodeY.Name	Name of one of the connected nodes
$NodeY.ID	NodeY.ID	ID of one of the connected nodes
hange-items		
Name	Name	Name
Revision	Revision	Revision date
Joint.GX		
Joint.GY		
Joint.Type		
GX	GX	Geographical X-coordinate of a point of the connection
GY	GY	Geographical Y-coordinate of a point of the connection
Specific	Specific	Characteristic and value of the specific formatted as: ***characteristic>=<value>***
Specific+	Specific	Add a specification
hange-items, in case the connection consist of a single part		
Description	Description	Description
R	R	Total resistance
X	X	Total reactance
C	C	Total capacity
R0	R0	Total zero-sequence resistance
X0	X0	Total zero-sequence reactance
C0	C0	Total zero-sequence capacity
Inom1	Inom1	Nominal current
Inom2	Inom2	Nominal current
Inom3	Inom3	Nominal current
Ik (1s)	Ik,1s	Maximum short circuit current during 1sec
Length	Length	Length

Reactance coils and transformers

Header	Parameter	Description
earch-items		
$Name	Name	Name
$Node1.Name	Node1.Name	Name of the 'from'-node
$Node1.ID	Node1.ID	ID of the 'from'-node
$Node2.Name	Node2.Name	Name of the 'to'-node
$Node2.ID	Node2.ID	ID of the 'to'-node
$NodeX.Name	NodeX.Name	Name of one of the connected nodes
$NodeX.ID	NodeX.ID	ID of one of the connected nodes
$NodeY.Name	NodeY.Name	Name of one of the connected nodes
$NodeY.ID	NodeY.ID	ID of one of the connected nodes
hange-items		
Name	Name	Name
Type	Type	Type name
Snom	Snom	Snom (only transformers)
Usoort	Sort	Sort voltage control (0=compounding; 1=load dependent)
Uset	Uset	Uset
Uband	Uband	Uband
Rc	Rc	Rc
Xc	Xc	Xc
P<<	P<<	
U<<	U<<	
P<	P<	
U<	U<	
P>	P>	
U>	U>	
P>>	P>>	
U>>	U>>	
Revisiondate	Revision date	Revision date
Specific	Specific	Characteristic and value of the specific formatted as: ***characteristic>=<value>***
Specific+	Specific	Add a specification

Elements (general)

Header	Parameter	Description
earch-items		
$Name	Name	Name
$ID	ID	ID
$Subnumber	Subnumber	Subnumber
$Node.Name	Nodename	Name of the node
$Node.ID	NodeID	Identification of the node
$Node.Number	Nodenumber	Internal node number
Search-for-new-items		
$Name+	Name	Name of the element; the element is added if it does not exist
hange-items		
Name	Name	Name
Name+	Name	Name; the element will be added
Switchstate	Switchstate	1 (on) or 0 (off)
Profile	Profile	Name of the profile
Specific	Specific	Characteristic and value of the specific formatted as: ***:haracteristic>=<value>***
Specific+	Specific	Add a specification
^<Characteristic>	Specific	Value of the specific to be modified
^<Characteristic>+	Specific	Value of the specific to be added
Revisiondate	Revision date	Revision date

Sources (complementary to elements)

Header	Parameter	Description
earch-items		
$Name	Name	Name
$Node.Name	Nodename	Name of the node
$Node.ID	NodeID	Identification of the node
hange-items		
Name	Name	Name
Uref	Uref	Reference voltage
Ik"nom	Ik"nom	nominal short circuit current
Ik"min	Ik"min	minimal short circuit current
Ik"max	Ik"max	maximum short circuit current

Loads en transformer loads (complementary to elements)

Header	Parameter	Description
earch-items		
$Name	Name	Name
$ID	ID	ID
$Subnumber	Subnumber	Subnumber
$Node.Name	Nodename	Name of the node
$Node.ID	NodeID	Identification of the node
$Node.Number	Nodenumber	Internal node number
hange-items		
Name	Name	Name
Name+	Name	Name; the load will be added
P	P	Active power (of the load)
Q	Q	Reactive power (of the load)
S	S	Apparent power (of the load)
I	I	Current (of the load)
Cos	Cos phi	Cos phi (of the load); must be combined with S or I
Profile	Profile	Name of the profile (of the load)
Pgen	Generation.P	Real power of the generation; Q becomes 0
Generationprofile	Generation.Profile	Name of the profile of the generation
Ppv	PV.Pnom	Power of the PV
PVprofile	PV.Profile	Name of the PV profile
Type	Type	Type name of the transformer
Tapsetting	Tapsetting	Tap setting of the transformer
#Bigcustomers	Number of big customers	Number of big customers
#Generouscustomers	Number of generous customers	Number of generous customers
#Smallverbruikers	Number of small customers	Number of small customers

The ratings are in MW, Mvar and MVA. The current is in A. The values for the transformer loads are related to the primary side of the transformers.

In some cases, more than one load object is changed per row. When specifying only the node name, all loads connected to that node are changed. When specifying only the Name, all loads in the network with that name are changed. If not exactly one load object is changed per row, a warning message is shown.

When setting a name or a note, the value can be cleared by means of a dash in the cell.

Synchronous generators (complementary to elements)

Header	Parameter	Description
hange-items		
Type	Type	Type name
Ppu	Nominal power	Nominal active power (power factor * Snom)
Pref	Reference power	Actual active power
Snom	Nominal power	Nominal power of the generator

Synchronous motors (complementary to elements)

Header	Parameter	Description
hange-items		
Type	Type	Type name
Ppu	Nominal power	Nominal active power (power factor * Snom)
Pref	Reference power	Actual Active power
Snom	Nominal power	Nominal power of the motor

Induction generators (complementary to elements)

Header	Parameter	Description
hange-items		
Type	Type	Type name
Ppu	Nominal power	Nominal active power (power factor * Snom)
Pref	Reference power	Actual Active power
Pnom	Nominal power	Nominal active power of the generator

Induction motors (complementary to elements)

Header	Parameter	Description
hange-items		
Type	Type	Type name
Ppu	Nominal power	Nominal active power (power factor * Snom)
Pref	Reference power	Actual active power
Pnom	Nominal power	Nominal active power of the motor

Induction motor groups (complementary to elements)

Header	Parameter	Description
hange-items		
Loadrate	Loadrate	Load rate of the active motors

PV's (complementary to elements)

Header	Parameter	Description
hange-items		
Pnom+	Pnom	Power of the next panel
Pnom1	Pnom	Power of the first panel
Pnom2	Pnom	Power of the second panel
Pnom3	Pnom	Power of the third panel

Circuit breaker with protection

Header	Parameter	Description
earch-items		

Header	**Parameter**	**Description**
$Name	Name	Name of the circuit breaker
$In	In	Name of the branch or element to which the circuit breaker is connected
$Node.Name	Nodename	Name of the connected node
$Node.ID	NodeID	ID of the connected node
hange-items		
Name	Name	Name
Specific	Specific	Characteristic and value of the specific formatted as: ***:haracteristic>=<value>***
Specific+	Specific	Add a specification
Remote control	Remote control	
Remote indication	Remote indication	
Note	Note	
Type	Type	Type of the circuit breaker
Shorttype	Short	Short type name
Inom	Inom	Nominal current circuit breaker type
Unom	Unom	Nominal voltage circuit breaker type
Ik_break		Tripping current circuit breaker type
Ik_thermal		Maximum thermal short circuit current
t_thermal		Maximum thermal short circuit current duration
Switchtime		Breaker opening time
Ip1.Direction	Current 1	Direction sensitivity (-1, 0, 1)
Ip1.RCA		RCA
Ip1.Type		Type
Ip1.Short		Short type name
Ip1.Inom		Nominal current
Ip1.Characteristic	Characteristic	1: fixed time 11-15: inverse (normal/very/extremely/long time/RI-inverse) 31-32: specific
Ip1.I>		I >
Ip1.t>		t >
Ip1.I>>		I >>
Ip1.t>>		t >>
Ip1.I>>>		I >>>
Ip1.t>>>		t >>>
Ip1.k		k-factor
Ip2.Direction	Current 2	Direction sensitivity (-1, 0, 1)
Ip2.RCA		RCA
Ip2.Type		Type
Ip2.Short		Short type name
Ip2.Inom		Nominal current
Ip2.Characteristic	Characteristic	1: fixed time 11-15: inverse (normal/very/extremely/long time/RI-inverse) 31-32: specific
Ip2.I>		I >
Ip2.t>		t >
Ip2.I>>		I >>
Ip2.t>>		t >>
Ip2.I>>>		I >>>
Ip2.t>>>		t >>>
Ep.Direction	Earth fault 1	Direction sensitivity (-1, 0, 1)
Ep.RCA		RCA
Ep.Type		Type
Ep.I>		I >
Ep.t>		t >
Ep.I>>		I >>
Ep.t>>		t >>
Ep.I>>>		I >>>
Ep.t>>>		t >>
Up.Type	Voltage	Type
Up.U<		U <
Up.t<		t <
Up.U<<		U <<
Up.t<<		t <<
Up.U>		U >
Up.t>		t >
Up.U>>		U >>
Up.t>>		t >>
Dp.Type	Distance	Type
Dp.I>		I >
Dp.U<		U <

Header	Parameter	Description
Dp.Z<		Z <
Dp.Kn		Kn-factor
Dp.Knangle		Kn-factor-angle
Dp.T0		Undirected end time
Dp.T4		Directed end time
Dp.T1		t zone 1
Dp.R1		R zone 1, in a polygon characteristic
Dp.X1		X zone 1, in a polygon characteristic
Dp.Z1		Z zone 1, in a circle characteristic
Dp.R1E		R during a earth fault zone 1, in a polygon characteristic
Dp.X1E		X during a earth fault zone 1, in a polygon characteristic
Dp.Z1E		Z during a earth fault zone 1, in a circle characteristic
Dp.T2		t zone 2
Dp.R2		R zone 2, in a polygon characteristic
Dp.X2		X zone 2, in a polygon characteristic
Dp.Z2		Z zone 2, in a circle characteristic
Dp.R2E		R during a earth fault zone 2, in a polygon characteristic
Dp.X2E		X during a earth fault zone 2, in a polygon characteristic
Dp.Z2E		Z during a earth fault zone 2, in a circle characteristic
Dp.T3		t zone 3
Dp.R3		R zone 3, in a polygon characteristic
Dp.X3		X zone 3, in a polygon characteristic
Dp.Z3		Z zone 3, in a circle characteristic
Dp.R3E		R during a earth fault zone 3, in a polygon characteristic
Dp.X3E		X during a earth fault zone 3, in a polygon characteristic
Dp.Z3E		Z during a earth fault zone 3, in a circle characteristic
Dp.T-1		t zone backwards
Dp.R-1		R zone backwards, in a polygon characteristic
Dp.X-1		X zone backwards, in a polygon characteristic
Dp.Z-1		Z zone backwards, in a circle characteristic
Dp.R-1E		R during a earth fault zone backwards, in a polygon characteristic
Dp.X-1E		X during a earth fault zone backwards, in a polygon characteristic
Dp.Z-1E		Z during a earth fault zone backwards, in a circle characteristic

Importing the distance protection zones via R and X yields a polygon in the form of a right triangle, where R and X form the right angle and the slanted side with an angle of -45 degree passes through the origin of the graph. Importing the distance protection zones via Z produces a circle with the specified radius.

Lastschakelaars

Header	Parameter	Description
earch-items		
$Name	Name	Name van lastschakelaar
$IN	IN	Name van tak of element waar lastschakelaar in zit
$Node.Name	Nodename	Name van aangesloten node
$Node.ID	NodeID	ID van aangesloten node
hange-items		
Name	Name	Name
Afstandbediening	Afstandbediening	
Notitie	Notitie	
Type	Type	Type lastschakelaar
Korttype	Kort	Korte typename
Inom	Inom	Nominale current
Unom	Unom	Nominale spanning
Ik_maak	Ik,maak	Maakcurrent
Ik_dynamisch	Ik,dynamisch	Maximale dynamische short circuitcurrent
Ik_thermisch	Ik,thermisch	Maximale thermische short circuitcurrent
t_thermisch	t,thernisch	Bijbehorende tijd

Measurement units

Header	Parameter	Description
earch-items		
$Name	Name	Name of the measurement unit
$IN	IN	Name of the branch or element to which the measurement unit is connected
$Node.Name	Nodename	Name of the connected node
$Node.ID	NodeID	ID of the connected node
$VS.Name	Circuit breaker name	Name van de circuit breaker in the same field

Header	Parameter	Description
hange-items		
Name	Name	Name
It1.Function		
It1.Type		
It1.Class		
It1.Transformerratio		
It1.Power		
It1.Inom		
It1.Ik_dynamic		
It1.Ik_thermal		
It1.t_thermal		
It2.Function		
It2.Type		
It2.Class		
It2.Transformerratio		
It2.Power		
It2.Inom		
It2.Ik_dynamic		
It2.Ik_thermal		
It2.t_thermal		
Ut.Function		
Ut.Type		
Ut.Class		
Ut.Transformerratio		
Ut.Power		
...2010...	Measurement from 2010	Measurement value
...2011...	Measurement from 2011	Measurement value
...2012...	Measurement from 2012	Measurement value
...2013...	Measurement from 2013	Measurement value
...2014...	Measurement from 2014	Measurement value
...2015...	Measurement from 2015	Measurement value
...2016...	Measurement from 2016	Measurement value
...2017...	Measurement from 2017	Measurement value
...2018...	Measurement from 2018	Measurement value
...2019...	Measurement from 2019	Measurement value

Fuses

Header	Parameter	Omschrijving
oek-items		
$Name	Name	Name of fuse
$ID	ID	ID of the fuse (particularity with characteristic "ID")
$In	In	Name of branch or element that contains the fuse
$Node.Name	Node name	Name of connected node
$Node.ID	Node ID	ID of connected node
$Field	Field	Fuse field
rander-items		
Name	Name	Name
Note	Note	
Type	Type	Type fuse
Shorttype	Short type	Short type name

Profiles

Profiles can be added trough the use of the types files.
The whole types file can be used for the importing of the profiles. The other worksheets in the types file will not be imported as the names of these worksheets will not match.

Frames

Header	Parameter	Description
earch-items		
$Name	Name	Name
hange-items		
Name	Name	Name
GX	X	Geographical X-coordinate
GY	Y	Geographical Y-coordinate

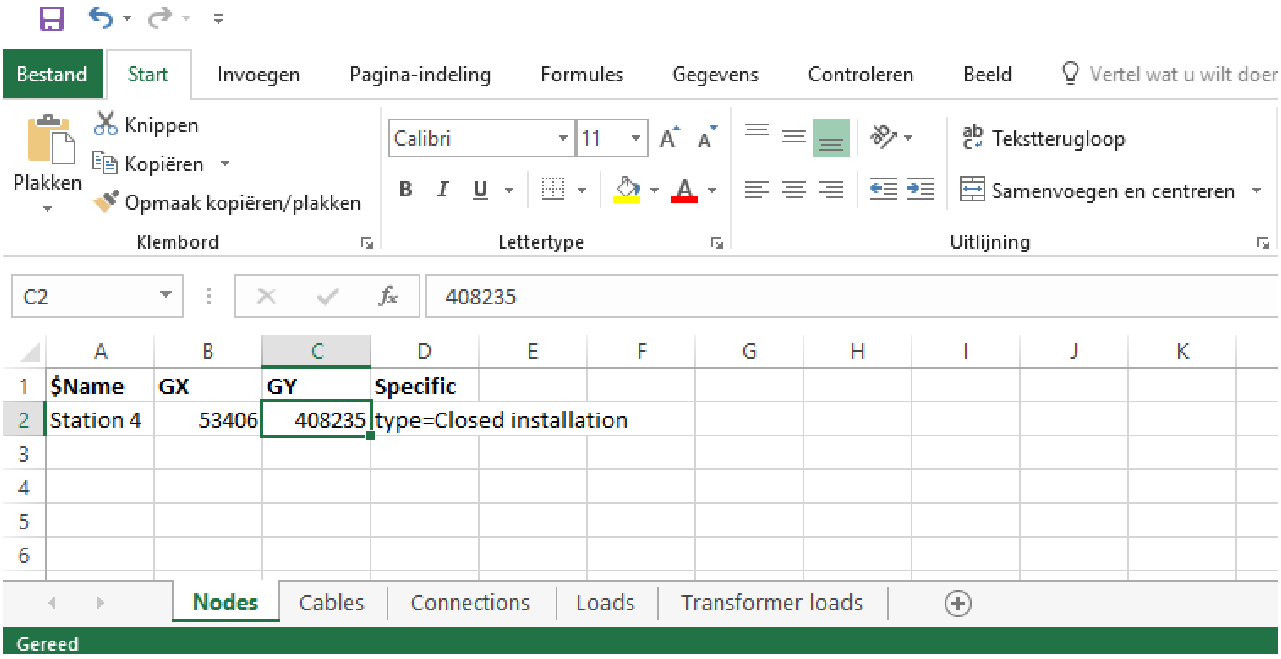
Scenario's

Header	Parameter	Description
earch-items		
$Name	Scenarioname	Name of scenario
earch-or-new-items		
$Name+	Scenarioname	Name of scenario; the scenario is added if it does not exist
hange-items or scenario-ems to be added		
Objecttype	Objecttypename	Name of the objectype (node, branch, etc.)
Objectname	Objectname	Name of the object
Date	Datetime	Datetime of entry
Parameter	Parameter	Node: 11: Simultaneity factor Branch: 1: from-switch state Branch: 2: to-switch state Transformer: 11: tapsetting Transformator: 12: fasedraaiing Element: 1: switch state Element: 11: absolute active power Element: 12: absolute reactive power Asynchrone motorgroep: 13: number in Windturbine: 13: absolute wind speed PV: 13: absolute scaling Element: 14: factor of the nominal power Windturbine: 14: factor of nominal wind speed Transformerload: 15: tap Element: 16: factor of the current power, wind speed or scaling Load and transformer load: 17: absolute apparent power Transformer load: 18: factor of current apparent power of the generation Transformer load: 19: absolute apparent power of the generation Wind turbine: 20: cosine phi Synchronous generator: 21: control type Synchronous generator: 22: isochronous control
Value	Value	Switch state: 1 (on) or 0 (off) Otherwise: the real value
Remark	Remark	

Or

Header	Parameter	Description
hange-items or scenario-ems to be added		
Objecttype	Objecttypename	Name of the objectype (node, branch, etc.)
Objectname	Objectname	Name of the object
Date	Datetime	Datetime of entry
Parameter	Parameter	See above
^<scenarioname>	Value	Switch state: 1 (on) or 0 (off) Otherwise: the real value

EXAMPLE



Example of records

Importing the examples below changes some parameters of the components in the demo.vnf file.

Modification of geographical coordinates and addition of a specific for node "Station 4":

```
$Name        GX       GY          Specific
Station 4    53406    408235      type=Closed installation
```

Modification of cable type and length of cable "Stat4 - Stat3" and addition of a specific:

```
$Name           Type                    Length   Specific
Stat4 - Stat3   3*150 CU GPLK   8/10    7000     Revision=Cable rerouted
```

Change of load on nodes "Station 1" and "Station3, rail A":

```
$Name   $Node.Name           P      cos
Last    Station 1            2.5    0.85
Last    Station 3, rail A    3.5    0.9
```

Change all transformer loads on "Station 4":

```
$Node.Name        I    cos
Station 4         18   0.88
```

Variants

Header	Parameter	Description
earch-items		
$Name	Variantname	Name of variant
earch-or-new-items		
$Name+	Variantname	Name of variant; the variant is added if it does not exist
hange-items or scenario-ems to be added		
Objecttype	Objecttypename	Name of the objectype (node, branch, etc.)

Header	Parameter	Description
Objectname	Objectname	Name of the object
Date	Datetime	Datetime of entry
Present	Presence	Presence: 'true' or 'false'
Remark	Remark	
Variant object	Variant object of the object	Whether the object is a variant object: "true" or "false

3.10.6 Export

The network data can be exported to Excel in a fixed format with **Tools | Data | Export**.
The following settings can be adjusted for an export:

- Content: export only selected objects or all objects
- Sheet: export only the active sheet or all the sheets
- Sorting: none, name, ID or trace
- Data: select whether type data, specifics (maximum 200 lines) and reliability data should be exported.
- Excel: indicate whether the generated Excel file be saved (with the same name and in the same folder as the network file) and subsequently be closed

3.10.7 Maps

The network diagram can be projected on a geographical layer using:**Tools | Geography | Map**. There are three different viewers available:

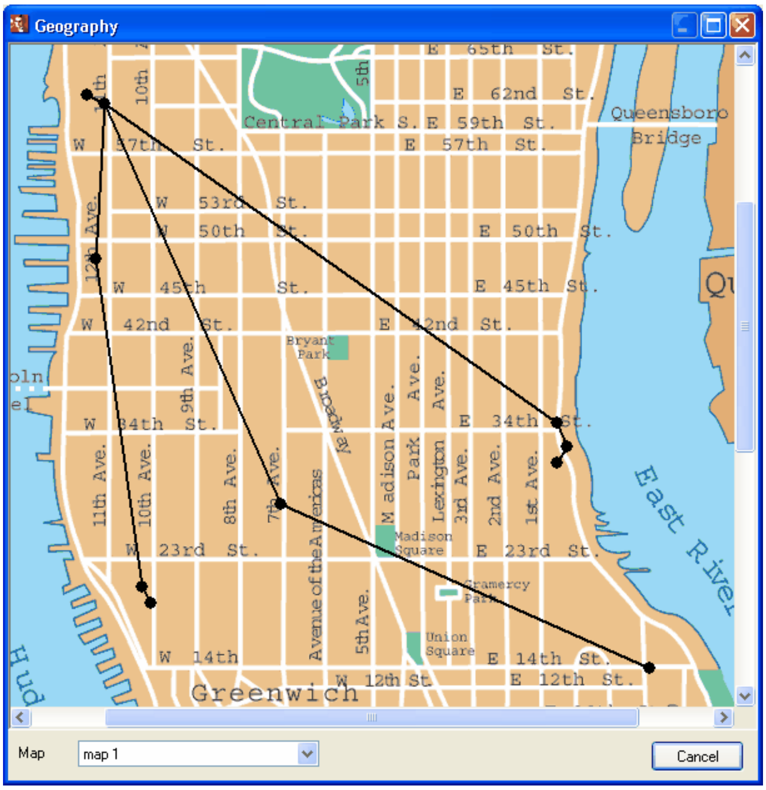
- Grid navigator (an add-on of Vision)
- Google Earth
- Map: a bitmap image, in which the coordinates of the vertices are recorded. The size of the area on the screen is defined in the graphic properties of the bitmap image.

The coordinates of the nodes can be entered on the "Geography" tab of the node form or be imported. The coordinates of intermediate points of branches can only be Imported 103. All nodes whose X and Y coordinates are specified, are shown on the geographic background. The branches between the nodes are automatically displayed.

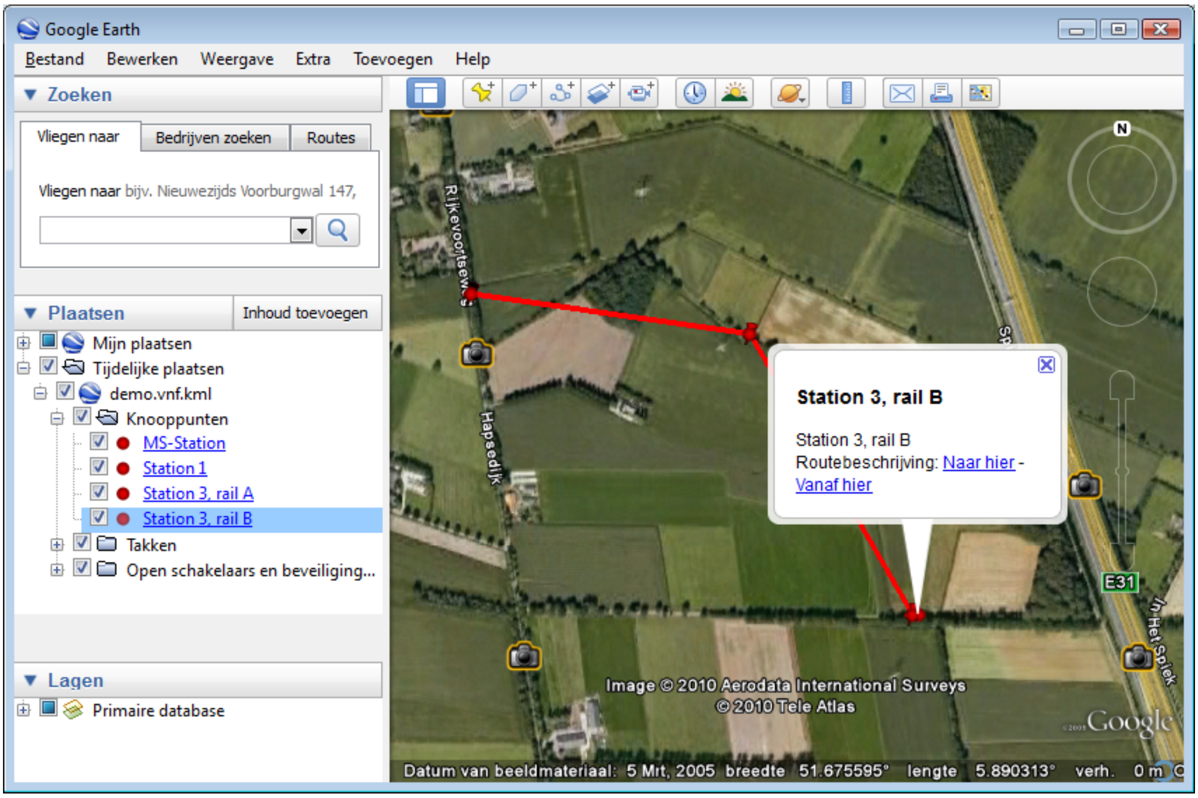
The coordinates can either be given in the RD new coordinate projection (EPSG 28992) or in the decimal geographical degrees format.

The geographical map should first be defined in **Options | Geography | Maps**.

Example of the map view:



Example of the Google Earth view:



See: [Options, Geography](135).

3.10.8 Geographical export

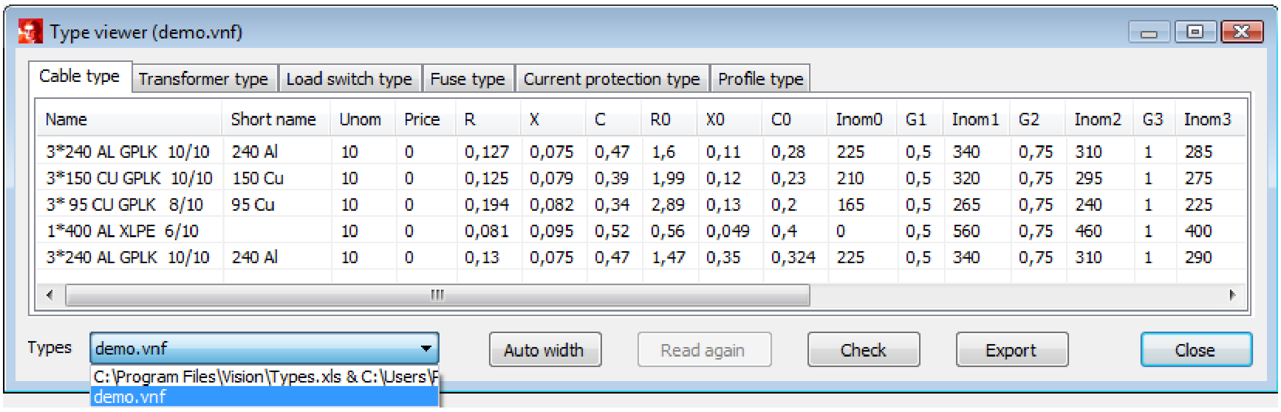
The geographical data of nodes, cables, joints and frames can be exported to an Excel spreadsheet file with **Tools | Geography | Excel**.
This function uses the options as defined in the **Options,** at: **Geography | General**.

3.10.9 Type viewer

With **Tools | Definitions | Type viewer** the parameters of all the defined components in the component type database can be viewed. These parameters cannot be changed using the Type viewer. In order to make changes to the component type file, the Excel file should be opened use Microsoft Excel.

Read again
If changes have been made to the type file, while Vision was opened, the component type file has to be read again in order to update the component file with the recent changes. This can be done by pressing the button **Read again**.

Types present in the network
It is also possible to view the type data of all components in the current network or in all open networks. To do this, choose the name of the network file or "All networks" in the drop-down menu in the lower left corner at **Types**.



Check
The available object types can be checked for basic errors, by using the function **Check**.

Export of type data
The object types shown can be exported to Excel with the **Export** button. The format is the same as the usual format of a type file.
This file can be specified as additional type file in the options, or additional records from this file can be added to the main type file.
See: Object types 75

3.10.10 Define views

By defining Views you can determine which information (such as name, type or voltage) is displayed in the diagram. This view also appears on the graphic printout. By default, a built-in view has been set. You can define a view yourself with **Tools | Definitions | Views**. A view can be chosen with **View | View <View name>**.

View definitions are saved in the *VisionViews.ini* configuration file.

For each main component type it can be indicated which data is displayed in the view. If **New** is chosen, a name for this view must be specified. The data can subsequently be defined on the tabs with the names of the main component types. The views can be specified for both the Edit mode and the Result mode.

View of input data
Input data can be selected for each main component type. This can be done for junction, branch, element and switch / protection. Not all input data is available.

View of calculated results
The calculated results can be selected per main component type. This can be done for the categories node, branch, element and switch / protection. Not all the result data are available. The calculation results are grouped on the tabs for based on the type of calculation.

Decimal reduction of results
By omitting decimals for larger values, the view of the network becomes clearer. The decimal reduction level can be specified on the **Other** tab. Possible values for decimal reduction are 0, 1, 2 and 3. This value roughly corresponds to the number of decimal places to be omitted. In order not to compromise on accuracy, the amount of decimals which are omitted is limited.

Copy view
A view can be copied to a new view by right-clicking in the list of views and then selecting **Copy** from the pop-up menu.

3.10.11 Reports

Reports may be defined with **Tools | Data | Reports**. Reports are stored in the configuration file *Vision.INI*. The Vision report is the default report. The user may define his own reports. Selected components can be reported 98 using **Application menu | Print | Report**.

For each component type the input and calculated data can be selected. Using **Tools | Data | Reports** an existing report can be altered or a new one can be created. The report definition allows the user to specify for each component the data that is to be included in the report. Under **Available** the user may choose input data and calculated data. The order in which the data items are to appear can also be specified.
If **New** is chosen, a report name must be given. Next the component data can be chosen.

Reports definitions file
The reports definitions are stored in the file *VisionReports.ini*.

Input data
For each component type the input data can be chosen. These are listed first. In some cases the input data are listed behind a group name, visible by a **+** mark. Selection of a group name means selection of all grouped input data.

Calculated data
For each component type the calculated data can be chosen. These can be combined with input data in a report. The calculated data are listed behind a group name for the calculation type, visible by a mark. Selection of a group name means selection of all grouped calculated data.

Copy reports
A report can be copied by right-mouse clicking in the reports-list (from: **Tools | Reports**) and choosing ***Copy*** from the pop-up menu.

3.10.12 Options file

It is possible to choose from several options files. Options files are specified by a name. Selecting, adding and deleting can be done with **Tools | Definitions | Options file**.
The file name of the options file is *Vision_<name>.ini*.

It is possible to initialize options on a corporate-level. Every time Vision starts up, the options will be set according to the company policy. These initialized options are presented as underlined text in the option menu. These options are kept in the file *Vision.set*.

It is possible to change these option when running Vision, but every time Vision starts, these options will be initialized to their fixed values again.

The easiest way to fix the initial values of the options is to copy the *Vision.ini* file into the file *Vision.set* in the directory of Vision. The options which should not be set can be removed from the *Vision.set* file using an text editor.

Location

The options file *Vision*.ini* , the desktop file *Vision.dsk* and the views- and reports definition files will normally be read from and written from %Appdata%\Vision.
There is an exception for the options file. If an options file is located in the executable folder, then this options file is used.

Set file directory

The options file *Vision.set* will normally be read from the Vision executable folder. This default location can be changed by creating or editing the configuration file *Vision.cfg* . To change the default directory of the options file add the following lines to the *Vision.cfg* file:

[Directories]
Set=<setdir>

3.10.13 Options

The network editor, calculations and other functions can be configured by the user using **Application menu | Options**. See: Options 127.
The **Options** menu can also be called using the **F11** key.

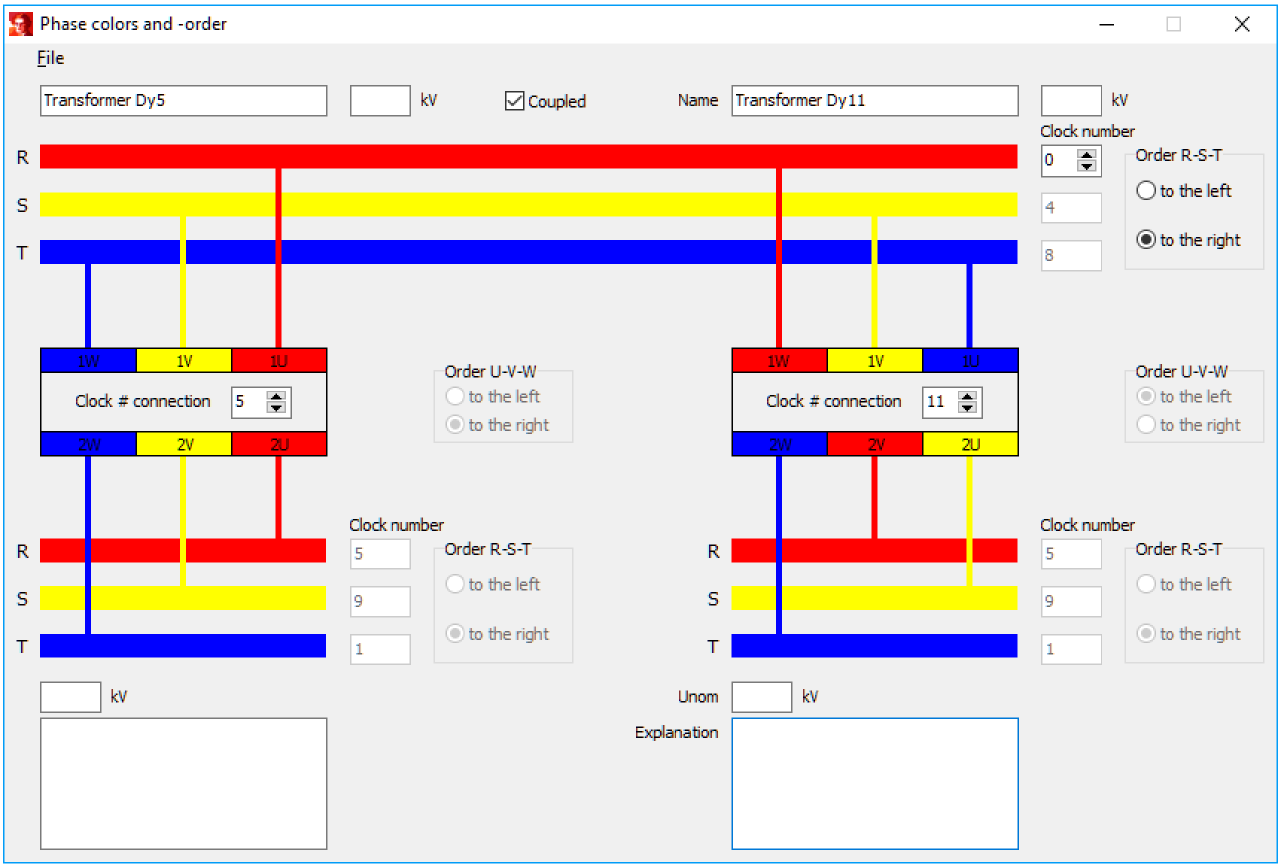
3.10.14 Transformer phase tool

With the help of this function it can be determined whether two transformers with different clock numbers can, in principle, be connected in parallel.

Start the phase sequence form with **Tools | Tools | Phase colors and order**.

By clicking with the left mouse button on the R-, S- and T-rails, a connection is made with the primary U, V and W terminals or the secondary u, v and w terminals. If the clock numbers and the direction of rotation (the sequence of R-S-T) corresponds to the secondary R, S and T tracks, the transformers could be connected in parallel.

By clicking with the left mouse button on the labels R, S or T, the color of the rail can be changed.
By double clicking the left mouse button in the name, Unom and explanation field will make these items disappear.



3.10.15 Cable rating tool

The cable ampacity can only be specified for specific environmental conditions. If a cable rating is known for one set of environmental conditions, the tool determines the cable rating for different conditions. The cable rating tool calculates the cable ampacity factor from the standardized cable rating tables (based on the NEN1010 norm).

For a buried cable the environmental conditions are:
- soil temperature
- soil thermal resistivity
- depth
- whether the cable is placed in a duct
- number of parallel circuits

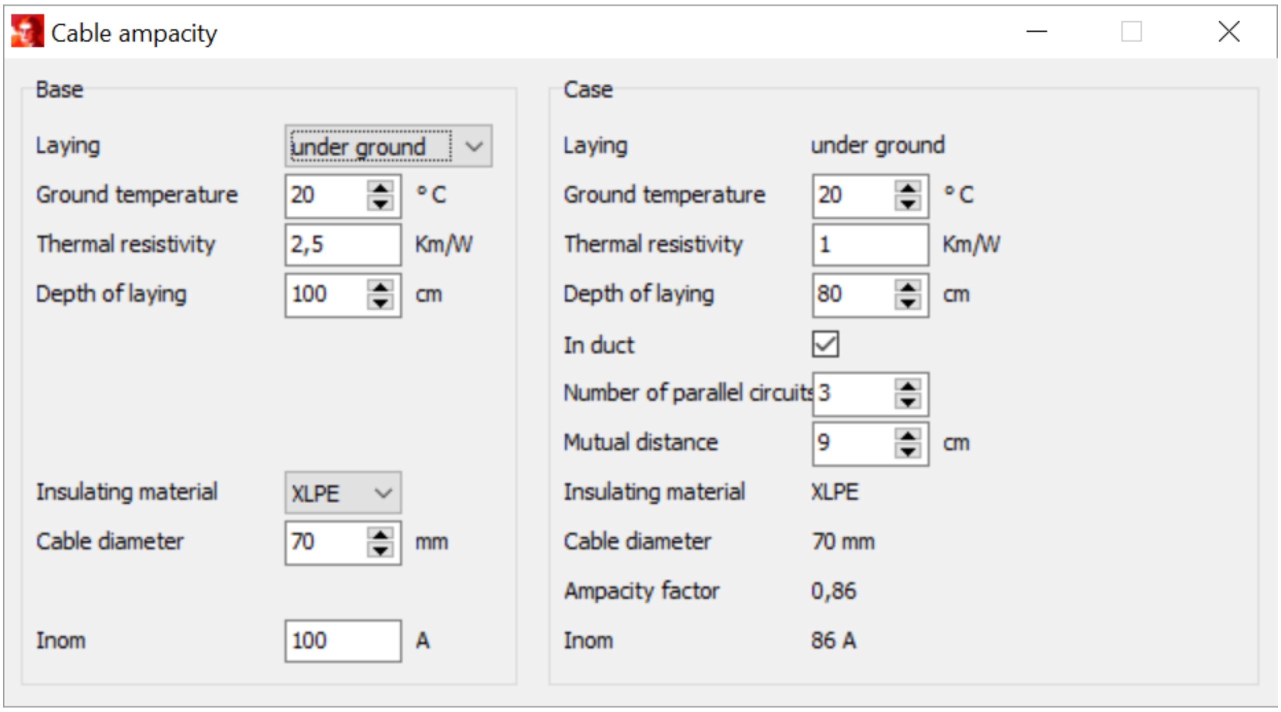
For a cable in free air the environmental conditions are:
- ambient air temperature,
- construction,
- presence of solar radiation,
- number of parallel circuits.

In case of other deviations, a calculation according to the IEC 60287 procedures should be performed.

The cable ampacity tool can be started by: **Tools | Tools | Cable ampacity**

The cable ampacity tool screen consists of two parts. The left part contains the base conditions for the cable ampacity, as denoted in the manufacturers data sheet. The right part contains the specific conditions for the cable. The result is reflected in the ampacity factor and the calculated I_{nom}.

The result should be used as input for the specific cables, in the cable input form, the **Ampacity factor** can be filled in.



3.10.16 Arc Flash

An arc flash will normally be accompanied with a large amount of energy. Personell, working on an installation, must therefore be protected. The arc flash tool calculates the amount of energy that someone may be exposed to. The maximum amount of energy determines the protection grade of protective clothing.

The arc flash tool can be started by: **Tools | Tools | Arc flash**

An arc flash exists in a conducting medium (plasma). It originates when a current is interrupted by opening a breaker or load switch. In the case of an alternating current the arc flash will be extinguished at every zero crossing and can be reignited every half period.

The arc flash energy, which occurs during a short-circuit may be a safety risk. Therefore personnel must be adequately protected. Remedial actions involve:

- proper procedures and work instructions
- determination of the arc flash energy for each installation
- determination of personal protective clothing.

The arc flash calculation in Vision is based on the American standard IEEE 1584. This standard prescribes to first calculate the short-circuit current and hereafter calculate the arc flash energy. The arc flash energy depends on the power system, the installation and the arcing current through the plasma.

METHOD IEEE 1584

The arc flash energy is calculated in two stages. In the first stage the arcing current through the plasma will be calculated. With this result the arc flash energy can be calculated. Using this, the flash boundary for the available protective clothing can be established. The calculations are based on:

- three-phase short-circuit current
- nominal system voltage
- gap between the conductors
- distance between the flash and a worker
- arcing time

The model is applicable for systems with:
- Voltages in the range of 208 V–15 kV, three-phase; for higher voltages the Lee method will be used
- Frequencies of 50 or 60 Hz
- Bolted fault current in the range of 700 A – 106 kA
- Grounding of all types and ungrounded
- Equipment enclosures of commonly available sizes
- Gaps between conductors of 13 mm – 152 mm
- Faults involving three phases.

Determination of the arcing current

LV-installations (U_{nom} < 1000 V)

$$I_a = 10^{K+0,662\cdot\log(I_k)+0,0966\cdot U_{nom}+0,000526\cdot G+0,5588\cdot U_{nom}\cdot\log(I_k)-0,00304\cdot G\cdot\log(I_k)}$$

Other installations ($U_{nom} \geq$ 1000 V)

$$I_a = 10^{0,00402+0,983\cdot\log(I_k)}$$

where:

I_a : arcing current (kA)
I_k : three-phase short-circuit current (kA), obtained from a short-circuit calculation
U_{nom} : nominal phase-to-phase voltage (kV)
K : factor: -0,153 for open configurations or -0,097 for closed configurations
G : gap between the conductors (mm)

Calculation of the arc flash energy

Installations with $U_{nom} \leq$ 15 kV

$$E_n = 10^{K_1+K_2+1,081\cdot\log(I_a)+0,0011\cdot G} \quad (cal/cm^2)$$

$$E = C_f \cdot E_n \cdot \left(\frac{t}{0,2}\right)\cdot\left(\frac{610^x}{D^x}\right) \quad (cal/cm^2)$$

where:

E : arc flash energy, for specified arc duration and working distance
E_n : arc flash energy, normalised for arc duration and working distance
K_1 : factor: -0,792 for open configurations or -0,555 for closed configurations
K_2 : factor: 0 for ungrounded systems (or high resistance grounded) or -0,113 for grounded systems
C_f : correction factor for the voltage level: 1.0 for U_{nom} > 1 kV; 1.5 for $U_{nom} \leq$ 1 kV
t : arc duration (s)
D : distance between the arc flash and a person (mm)
x : distance factor: exponent for type of installation

Installations with U_{nom} > 15 kV (Lee's method)

$$E = 5{,}12 \cdot 10^5 \cdot U_{nom} \cdot I_k \cdot \left(\frac{t}{D^2}\right) \quad (cal/cm^2)$$

where:

I_k : three-phase short-circuit current (kA)
U_{nom} : nominal phase-to-phase voltage (kV)

Protection characteristics impact

The arc duration depends on the protection characteristics and the magnitude of the short-circuit current. It may happen that a small short-circuit current takes more time to be switched off. The combination of small arcing current and long arc duration may lead to a large amount of arc flash energy. Therefore, the arc flash calculation also has to be made for a lower short circuit current and the corresponding longer arc duration.

Flash boundary

The arc flash energy may lead to:

- burns
- injury due to mechanical forces.

In 1982 Lee introduced a maximum energy level for third degree burns (The other electrical hazard: electrical arc blast burns). This level is called the "Curable Burn Level" and has a value of 1,2 cal/cm² (5 J/cm²).

Determination of the minimum working distance

The arc flash boundary determines the required protective clothing (minimum arc rating). For installations with $U_{nom} \leq 15$ kV the arc flash boundary is:

$$D_B = \left[C_f \cdot E_n \cdot \left(\frac{t}{0{,}2}\right) \cdot \left(\frac{610^x}{E_B}\right)\right]^{\frac{1}{x}} \quad (mm)$$

Installations with $U_{nom} > 15$ kV (Lee's method)

$$D_B = \sqrt{5{,}12 \cdot 10^5 \cdot U_{nom} \cdot I_k \cdot \left(\frac{t}{E_B}\right)} \quad (mm)$$

where:

E_B : arc flash energy on the arc flash boundary (cal/cm²)

Factors for equipment and voltage classes

Nominal voltage (kV)	Equipment	Typical gap between conductors G (mm)	Distance factor x
0,208 to 1	Open	10-40	2,000
	Switchgear	32	1,473
	Motor control and panel boards	25	1,641
	Cable	13	2,000
>1 to 5	Open	102	2,000

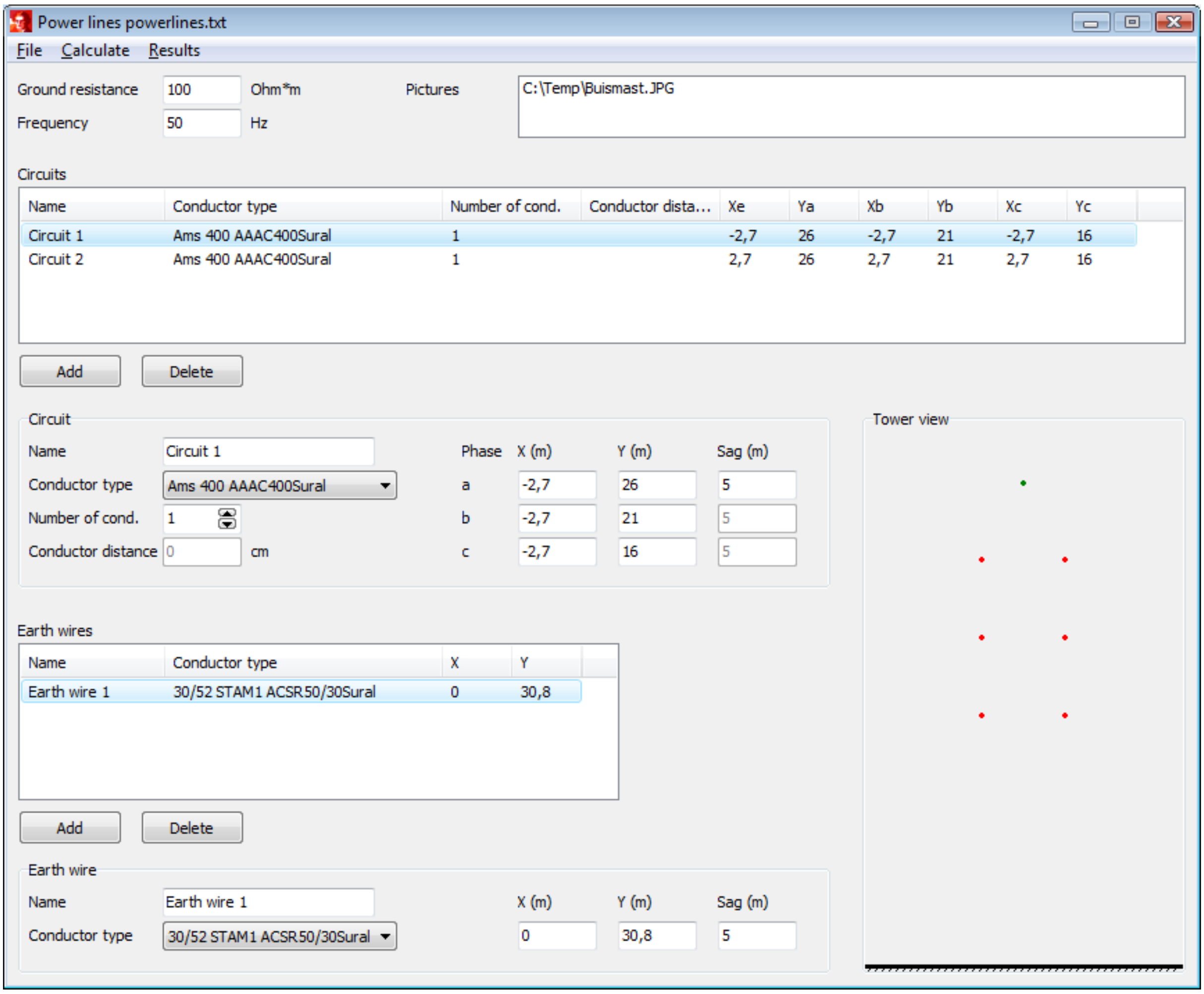
	Switchgear	13-102	0,973
	Cable	13	2,000
>5 to 15	Open	13-153	2,000
	Switchgear	153	0,973
	Cable	13	2,000

3.10.17 Overhead lines

An overhead line can be characterized by its line impedances. The mutual impedances of the overhead lines are influenced by the conductor sizing and positioning. The impedance calculation has been based on Carson's method for overhead lines with earth return.

This tool can be started by choosing: **Tools | Tools | Power lines**

Base for the calculation procedure is the tower configuration, containing the conductor positions and their types. Also bundle conductors can be defined here. Once a configuration has been defined, it can be saved as: <Name>.txt.



Conductor type
The calculation uses conductor type data from the types file. These data are on the work sheet **Lineconductor**. The parameters are:

Name	Unit	Description
Name		Conductor type name
Unom	kV	Rated voltage
Inom	A	Rated current
R	Ohm/km	Specific AC resistance
Lint	mH/km	Conductor internal inductance
d_ext	mm	Conductor outside diameter
d_int	mm	Conductor internal diameter, if hollow

Internal induction

The conductor self induction is the sum of the internal and the external induction. The external induction is a function of the conductor outside diameter. The internal induction can be calculated from the conductor material properties. A relationship exists between the internal induction, the relative permeability and the geometric mean radius.

The internal induction can be calculated from the relative permeability:

$$L_{int} = \frac{\mu_0}{2\pi} \cdot \mu_r \cdot h \cdot 1000$$

with:

$$r = \frac{d_{c,ext}}{2}$$

$$q = \frac{d_{c,int}}{2}$$

For hollow conductors (0<q<r):

$$h = \frac{q^4}{(r^2 - q^2)^2} \cdot \ln\left(\frac{r}{q}\right) - \frac{3q^2 - r^2}{4(r^2 - q^2)}$$

For solid conductors (q=0):

$$h = \frac{1}{4}$$

The relative permeability for a number of materials can be found in the table below.

Material	μ_r
Copper (Cu)	1
Iron (Fe)	100-1000
Aluminium (Al)	1
Bronze	1
All Aluminium Alloy Conductors (AAAC)	0.6 – 1.3
All Aluminium Standarc Conductors (AAC)	1.0 – 1.3
Aluminium Conductor Alloy Reinforced (ACAR)	0.8 – 1.1
Aluminium Conductor Steel Reinforced (ACSR)	0.5 – 6.5
ACSR EHS (extra high strength)	5.1 – 6.4
Allumoweld	6.8 – 8.2
EHS Cooperweld	22.3 – 35.4

When calculating the impedances of lines, the geometric mean radius (GMR) is used. In case the skin effect can be neglected, the GMR is equal to the geometric mean distance between all infinitesimal partial conductors in the conductor cross-section. For a solid conductor, consisting of magnetic material with a relative permeability of ${}_r$, this results in:

$$GMR = r \cdot e^{-\frac{\mu_r}{4}}$$

The internal induction can be calculated from the GMR:

$$L_{int} = \frac{\mu_0}{2\pi} \cdot \ln\left(\frac{r}{GMR}\right) \cdot 1000$$

Tower image

The conductors positions are presented in the tower image. Phase conductors and bundles are presented as red dots, while the earth conductor is presented as a green dot.

Calculate

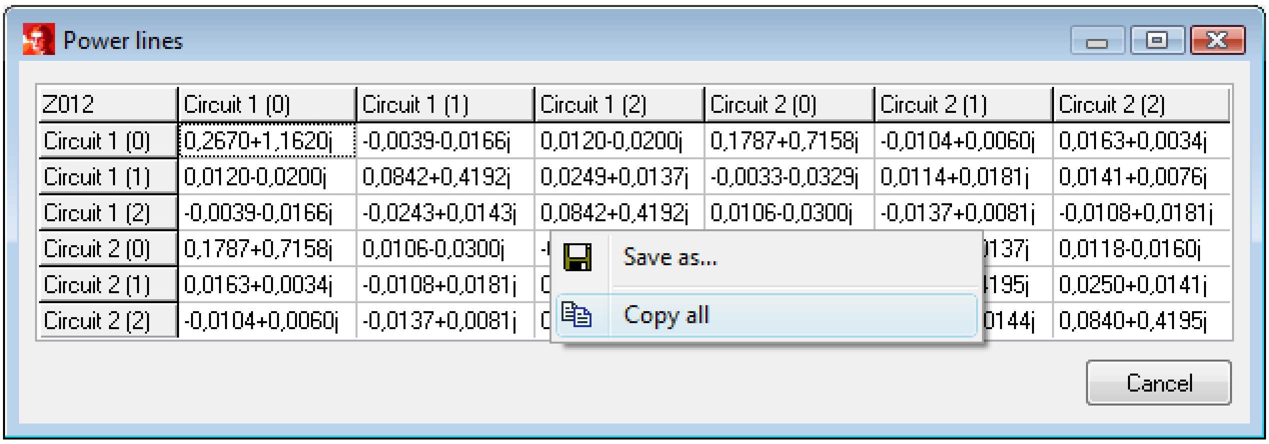
This function calculates the positive and zero sequence impedances (Z_1 and Z_0) and the mutual impedances (Z_{00}).

```
Circuits:
Name                                 Z1              Z0
                                 Ohm/km          Ohm/km
-------------------- --------------- ---------------
Circ1                  0,0842+0,4192j  0,2670+1,1620j
Circ2                  0,0840+0,4195j  0,2584+1,1861j

Mutual coupling:
Circuit 1            Circuit 2                       Z00
                                                  Ohm/km
-------------------- -------------------- ---------------
Circ1                Circ2                 0,1787+0,7158j
```

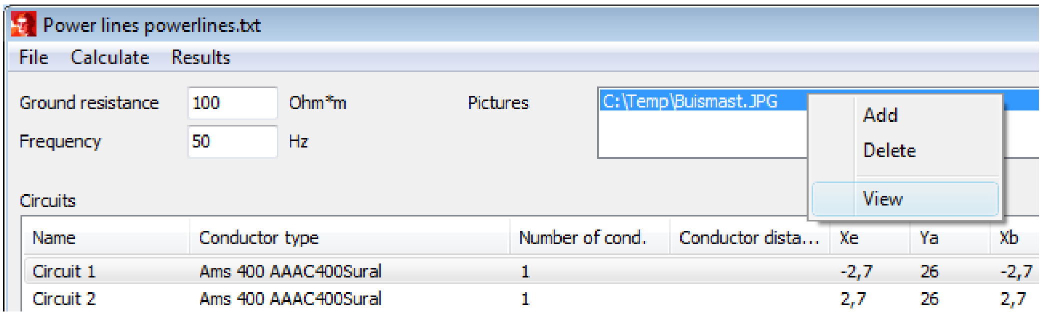
Results

This function presents the results in a matrix. The right mouse button allows saving the results or copying to Word or Excel.



Pictures

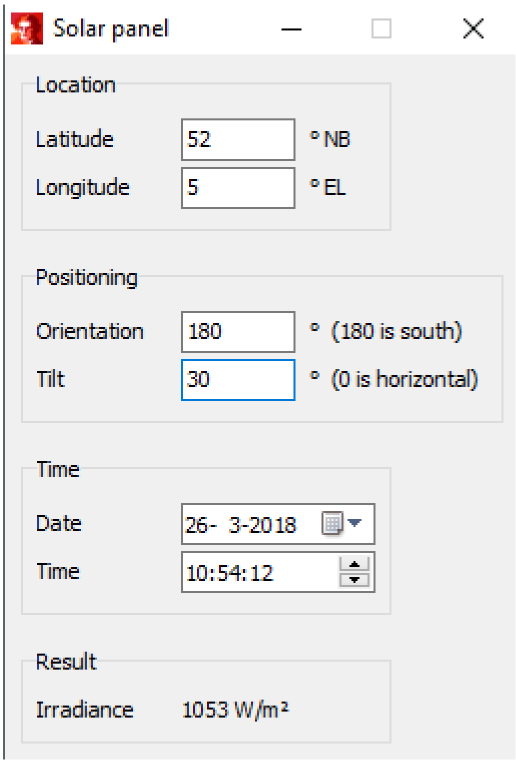
This function enables the depiction of the tower construction. By right-mouse clicking in the field at **Pictures**, a pop-up menu appears, in which pictures can be added, deleted and shown.



3.10.18 Solar panel

The irradiation of a solar panel can be calculated on the basis of its placement, the day in the year and the time of day.
The power of a solar panel (kWp) is specified at 1000 W / m².

Start the solar panel tool with **Tools | Tools | Solar panel**.



3.10.19 Macro

Vision supports a number of individual calculations. Sometimes, a particular calculation needs to be performed several times in succession, with only marginal changing to the input data. Vision is provided with a programming language (a macro language) to allow these kind of calculations. **Tools | Macro | Editor**.

See: Macro's 365

4 Options

The network editor, calculations and other functions can be configured by the user using **Application menu | Options**. These options allow the setting of one's own preferences for both the editor and the calculations.

The options form can also be invoked by pressing the **F11** key.

A large number of important settings for Vision can be defined using the options menu. The settings concern:

- Editor 127
- File locations 130
- Options Network 131
- Calculation 131
- Print 134
- Geography 135
- Key 136

Multiple Option Files
It is possible to have multiple option files, however only one of these files can be in use. The option files are identified by a file name. Selecting, adding and removing of these files can be done with **Extra | Definitions | Options file**. See: Options file 116.

4.1 Options Editor

The Editor options are categorised as follows:

- General 127 (language, units, colour scheme, selection mode, edit, network file, menu)
- Drawing 128 (tools, colours, symbols)
- Presentation defaults 128 (for all objects)
- Position defaults 129 (orthogonal or diagonal)
- View 129 (colours)
- Variables 130 (environment variables)

4.1.1 Options Editor General

Language
Used to choose the language. Possible languages are ***Dutch, English*** and *German*. Vision switches immediately to the selected language. If ***'national'*** is selected, the language is determined by a Windows setting.

Units of power
Used to define the input and output forms units. Common for transmission is: **MVA, MW** and **Mvar**. Common for distribution is: **kVA, kW** and **kvar**.

Miscellaneous

VNF protection :	Sets the network file as read only when already opened to prevent that two users modify the same data file.
Show comment :	After opening a network file the user comments will be displayed automatically.
Backup interval :	When working with Vision, a backup of the current network can be made periodically by selecting the interval in minutes greater than zero. The backup files are called *network.~vnf*, whereby 'network' is the name of the current network. The files are placed in the stated directory (see below). These files are deleted when Vision is closed normally.

Select mode

Active sheet : Object selection only on the active sheet
All sheets : Object selection on all sheets. Influences the function ***Select Trace*** and ***Select Route*** .

Edit

Some menu items can be activated or de-activated independently.

Don't edit in Result mode : An optional security measure that results are not erased by clicking an **OK** button in an edit form.
Don't drag and move : An optional security measure that objects are not moved when browsing through a network.
Replace object text at dragging : When dragging a node or a line, the accompanying text is replaced to the default position with respect to the object.

Items visibility in forms

The visibility of items in the objects forms can be enabled or disabled. The visibility can be enables for: Specifics, Note, Selection, Reliability and Variations. For each item a choice can be made from: never, if applied, always.

4.1.2 Options Editor Drawing

Drawing

Fine grid : Used to show a grid.
Major grid : Used to show a grid. To be defined per sheet 65.
Mapping grid : Used to show a mapping grid. To be defined per sheet 65.
Cross at node dragging : When dragging a node two aiming lines are shown to help line up the components.
Keep objects thicker at zooming out : Objects from which the thickness is specified to be larger than normal, keep this property on screen when zooming out.
Vertical texts : The possibility to automatically print text in a vertical direction, when close to a vertical oriented branch.

Colours

Used to define default colour for normal drawing, selected components, grid and islanded components.

Automatic colours

The colours that are used in special views, can be defined. Difficult visible colours can be changed by the user.

Open switch

Opened switches can be displayed with an opened square, a slanted line or a flag symbol. The size can be defined as large or small.

Circuit breaker

The circuit breaker symbol can be a cross or a two dots symbol (e.g. in combination with a slant line symbol for an opened switch).

Protection indicator

A small transverse line can be plotted, indicating the presence of a protection device.

4.1.3 Options Editor Presentation defaults

Used to define graphical default values for nodes, branches, elements, text, frame, legenda and sheet. The user can set defaults for colour, size, drawing thickness, style, shape and text font size.

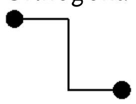
4.1.4 Options Editor Position defaults

Using these options, the default positions of new branches and elements can be defined. These positions can always be altered in the editor.

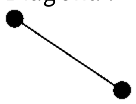
Branch

<u>Place between two point nodes:</u>
If the nodes at both sides of a new branch have a point symbol (circle, square, triangle, rhombus), the default presentation of a line can be: following the grid (orthogonal) or following the shortest distance between the two nodes (diagonal). In the case that one or both nodes have a line symbol, the presentation always will be orthogonal.

Orthogonal:



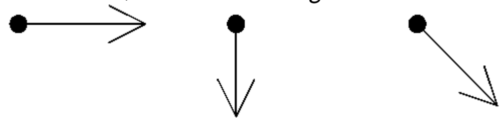
Diagonal:



Element

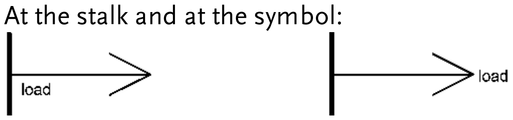
<u>Place at point node:</u>
If the node has a point symbol, the default presentation of an element can be: following the grid (horizontal or vertical) or diagonal. If the node has a line symbol, the presentation always will be orthogonal.

Horizontal, vertical and diagonal:



<u>Place text when at line node:</u>
If the node has a line symbol, the default element text position can be: at the stalk of the element symbol or at the symbol itself. If the node has a point symbol, the default position will always be at the symbol itself.

At the stalk and at the symbol:



4.1.5 Options Editor Appearance

Used to define the **View | Appearance in Edit mode** and **View | Appearance in Result mode** for input and result dependent symbols. All ***colours*** can be changed by mouse clicking a colour. In **View | Appearance in Edit/Result mode**, one can also define to overrule another colour scheme in case of an Open switch, Island, Mesh or Multiple presentation.

Power and current
If chosen ***Power*** or ***Current*** in **View | Appearance in Edit/Result mode**, on tab ***Symbol***, the element symbol will be a coloured circle. The circle size depends on the actual or set power or current. The ***symbol size*** defines the relative size for all the circles.

Voltage
If chosen *Voltage* in **View | Appearance in Edit/Result mode**, on tab *Colour*, the objects will be coloured according to the voltage scheme for voltage levels below and above 1, 30 and 100 kV.

Open switch
If chosen *Open switch* in **View | Appearance in Edit/Result mode**, on tab *Style*, the line style for branches and elements with opened switches will be as defined. The style can be chosen from a number or predefined styles.
If chosen *Open switch* in **View | Appearance in Edit/Result mode**, on tab *Colour*, the colour of branches and elements with opened switches will be as defined.

Other
The *Other* colour is used for several purposes. One of them is the presentation colour of objects with multiple presentation. Another is the presentation colour of objects which are part of a mesh.
If chosen *Mesh* in **View | Appearance in Edit/Result mode**, on tab *Colour*, the objects which are part of a mesh will be coloured in the *Other* colour.
If chosen *Multiple presentation* in **View | Appearance in Edit/Result mode**, on tab *Colour*, the objects which are present on more sheets will be coloured in the *Other* colour.

4.1.6 Options Editor Variables

Used to define the default loadability of cables, choosen from I_{nom0} to I_{nom3}.

4.2 Options File locations

Component type files
Used to specify the directory for the component type file *Types.xls*. Changes to this directory take effect when Vision is restarted.
See also: Type 76

Network files
Used to specify the default directory for the network files.
See also: Network file 78

Store files
Location of the store 90 files for the stored network fragments library.

Macro files
Default Location of the macro 365 files.

Temporary files
Used to specify a directory in which temporary files can be placed.

Backup files
Used to specify the directory for the backup files created periodically by Vision .

Company info file
File in RTF-format used for company messages to all users.

Station picture files
Directory for pictures of substations. See also: Node 138.

Type picture files
Directory for busbar type pictures. See also: Node 138.

Measurement fields image files

Folder for images of measurement charts of measurement fields or just measurement fields.

0.1 Hz measurements
Folder for 0.1 Hz measurement files, which can be displayed via the cable form, **Localisation** tab.

Note file
Name of a note import file, which is automatically imported after opening a network. It is a text file with three tab-delimited columns: node name and node ID to look up which node the note should be attached to and the actual note.

Info
For information, the locations of the program, the options file and the help file.

4.3 Options Network

Object defaults

The **ampacity** setting ensures that the maximum current loading capacity of a newly introduced cable is in default equal to **Inomo** (air) or **Inom1/2/3** (for G1/G2/G3).

Default trends

One or more profiles and growth rates, which are added automatically to a newly created network, can be defined.

4.4 Options Calculations

The calculation options are:
- General (base power, frequency, conductor temperature, connection ampacity, colour indication)
- Limits (voltage, load for normal/faulted situation, connection ampacity)
- Loadflow (advanced)
- Costs (losses, interest)
- Reliability (restoration durations)
- Protection (calculation steps, short circuit resistances)
- IEC 61363
- Arc flash (IEEE 1584 or Box test)
- Network analysis
- Macro (limits for the number of iterations and run time)
- Pseudomonitor
- Fault finder
- Transmission analysis

General

Base power
All power data is converted into normalised per unit values to ensure a stable numerical process inside the calculation procedures. It is not necessary to have an exact value for S_{base}. A general formula does not exist. The default value of 10 MVA will generally suffice.
The value assigned to Sbase is usually the estimated average of power required by and the power supplied to the nodes. This will typically be something like 1, 10, 100 or 1000 MVA.
Attention! A wrong value may in some cases lead to unpredictable results.

Frequency
The system frequency can be specified. It influences the reactances of components like cables, reactance coils and capacitors.

Link impedance

1 µ to 10 m

Conductor temperature

The conductor resistance has been specified at a specific conductor temperature. For the cables this has been specified in the type file. For connections this can be specified in the import form. For the Loadflow and Fault Analysis calculations the conductor resistance will be calculated for the temperatures which has been set in the options if the checkbox at **Apply** is checked. By removing the check at **Apply** the resistance as specified in the type database will be used without a correction.
In the IEC 60909 calculation a temperature of 20 degrees C is always assumed for calculation of $I_k"_{max}$.

Colour indication

For various calculations network components are coloured if they exceed certain limits. The colouring scheme can be specified here.
See also: View 69.

Limits

A distinction is made between limits for the "normal situation" and limits for the "fault situation". The limits for the normal situation are closer to the nominal values than limits for the fault situation. These limits are used for various purposes, depending on the calculation.
The boundaries for nodes can be defined separately for the four fixed voltage levels: LV (less than 1 kV), MV (between 1 and 30 kV), IV (between 30 and 100 kV) and HV (greater than 100 kV).
The load limits for connections, transformers and elements can be defined separately. These limits are used for various calculations.
If **Thinnest cable part** is selected in a custom view, the type name of the thinnest cable section is displayed, together with the nominal current (I_{nom}') and this current is multiplied by the value of Bmax for the fault situation.

Connection ampacity

It is possible to choose from three values for the indication of the connection ampacity, for example for a high-voltage line. In this way the influence of the season (summer/winter) on the maximum connection ampacity can be set. However, this does not apply to the cables, where the choice of connection ampacity per cable part must be specified.

Loadflow

There are a number of advanced loadflow options which can be applied if the loadflow diverges. These options will not be saved in the options file.

Costs

Here the cost-related parameters regarding losses (service time and energy price), interest and load factor can be specified.
See also: Cost 287.

Reliability

Here the reliability parameters, e.g. the restoration time durations, can be specified.
See also: Reliability 289.

Protection

Form to input parameters for the Protection calculation.

Cable calculation steps : The number of equidistant places within the cable/line where a short circuit should be simulated, can be specified with the number of cable calculation steps. An option has been added to simulate short-circuits close to the from and to nodes (at a 1% and 99% distance).

Fault resistances : Range from which the short-circuits resistances are chosen in order to obtain the selectivity curves.

Influence element protection : Dependent on this setting, disconnecting an element by switching a fuse or a circuit breaker may influence the selectivity or not.

See also: Protection 294.

IEC 61363

Here the parameters for the IEC 61363 calculation can be specified.

Arc flash

Here the parameters for the arc flash calculation can be specified.

Network analysis

Voltage dip analysis and protection analysis

Cable/line steps The number of cable calculation steps determines how many short-circuits have to be simulated in all cables and connections. The number of calculation steps is set to zero by default. The maximum is 9. An option has been added to simulate short-circuits close to the from and to node (at a 1% and 99% distance).

Fault type share The fault type share is a range of numbers, defining the weight of all possible fault types in the failure frequency parameter.

Protection analysis

Fault resistances Values for the fault resistance at the fault location: 0 Ohm and two additional values. The last additional value is not used for faults in cables and in case of single phase to ground fault the last additional value will be doubled.

Refusal level The number of sequentially protections/switches which refuse to operate (analysis of 0, 1 or 2 refusing switches).

Signalling limit Functionality to determine the latest large switch-off times.

Report Choose the reported items

Disturbance analysis

Maximum number of switchings The maximum number of switching actions that can be performed to restore power.

Limits Determines whether the normal or failure situation limits are used when rerouting the network.

At cost of overload If checked a temporary overload is allowed when rerouting the network to restore power after a fault, i.e. the restoration process has priority over overloading prevention.

At cost of under voltage If checked a temporary under voltage is allowed when rerouting the network to restore power after a fault, i.e. the restoration process has priority over the provision of an adequate voltage level.

At cost of subnet border switching If checked subnet borders can be deactivated during the restoration process.

Macro

This allows a limitation to be built in, in case a macro calculation inadvertently ends up in an infinite loop. The limitation can also be included in case a macro calculation would take too long. The options are:

Maximum number of iterations (while and repeat) :	The maximum number of iterations for a single loop
Maximum execution time :	The maximum execution time of a macro. When 0 is specified the maximum execution time is set to infinity.

Pseudomonitor

Number of iterations

The number of iterations that should be performed in order to obtain a matching with the measurements

Store monthly value in measurements of measurement units

The monthly maximum values are automatically added to the field in the measurement unit

Save extreme networks

The five time instances for which the network loading is maximal are saved as network files.

See also: Pseudomonitor 324

4.5 Options Print

The settings which are used when plotting 98 the network.

Item	Description
Outer margins	Print margins in cm
Inner margin	Distance of the objects to the frame, in % of the frame
Colour	Printing the network in colour or greyscale
Automatic orientation	Automatically determines whether to print in portrait or landscape orientation
Thicker lines (2) for width 1	Prevents lines in large networks from becoming too thin
Footer	Printing a footer with network properties and comments
Width	Width of the footer as percentage of the page width
Width/height	Height of the footer with respect to the width of the footer
Item 1 ... 5	5 items, which can be chosen from a list

Printing to a file

If automatic orientation is activated, all network sheets will be printed to separate files. Otherwise, all sheets will be printed in one file.

Item

Up to 5 items can be chosen from the list. The items will be printed in 5 compartments in the footer of each page from left to right. The width of each compartment can be defined in percent. The available footer items are:

Item	Contents
Phase to Phase logo	Adds the Phase to Phase logo to the footer
picture 1)	Adds a bitmap file (*.bmp)
text file 1)	The name of a text file (.txt)
network file name	The network file name
filename+date	The network file name + date + time
name+date+version	The network file name + date + time + Vision version number
name+date+comm.	The network file name + date + time + network comment
network comment	Comments for the network (from **Start | Edit | Comment**)
extra comment	Additional comment which can be made when printing
sheet name and comment	sheet name and sheet comments
calculation info	information after performing a calculation
name+date+setting	network file name + date + year/variant/scenario/variation date
network properties	Properties of the network: Number of connections, project, date, etc.

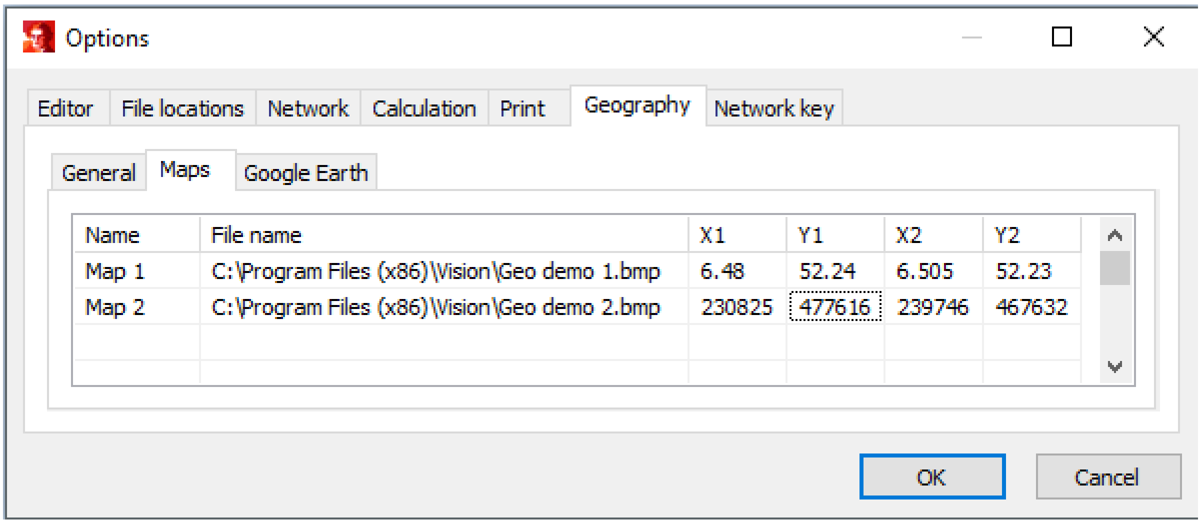
1) When selecting an image or text file, a pop-up in which the file can be selected will appears after clicking in the File field.

4.6 Options Geography

The network can be displayed on a geographical background. Under General, you can specify which objects should be shown. Here it can also be indicated whether intermediate points and joints of cables should be shown. The geographical background can be:

- Maps: a bitmap image, with recorded coordinates of the vertices. The coordinates can either be given in the EPSG:28992 or in the decimal-degree coordinate system. The size of the geographical background is defined in the graphical properties of the bitmap image.
- Google Earth: nodes, cables and joints are shown in Google Earth through the use of a kml-file.

Map (bitmap)
First, the geographical background must be defined. In the options, the map files (only bitmap images) can be specified with the X and Y coordinates of their corner points. The parameters X1 and Y1 represent the vertex of the top left corner and the parameters X2 and Y2 represent the vertex of the bottom right corner. The example below shows a map definition in decimal geographic coordinates (Map 1) and a map definition in EPSSG:28992 coordinates (Map 2). See: Tools Maps 113



Parameter	Description
Name	Name van de graphical layer during usage
File name	Full path and name of the graphical layer bitmap file
X1, Y1	X- and Y- coordinate of the upper left corner
X2, Y2	X- and Y- coordinate of the lower right corner

The coordinates can be entered in the EPSG:28992 coordinate system or in the decimal-degree coordinate system.

4.7 Options Key

This option determines whether Vision uses the network key or the licensing service. However, Vision always checks first whether a PC-key is present, and if valid uses it. See Hardware key 443.

5 Components and parameters

A network is defined as a collection of components with their parameters. There are a number of object types available in Vision:

- Node 138
- Branch 144
- Element 171
- Switch and protection device 201
- Others 223

Definition of characteristics (attributes)

All objects are specified through forms with multiple tabs. All electrical properties, among others, are specified on these tabs.

Most objects have predefined types 76 available. The electrical properties of these object types are predefined, so the user does not have to specify them each time.

Five tabs are present for all objects. These tabs are **Specifics**, **Note**, **Presentation** (graphic), **Selection** and **Variations**.

Specifics

For all components the user may input on or multiple specific 246 characteristics. A specific characteristic consists of a Characteristic and a Value.

Note

A note 248 can be added to almost all objects. This note is shown in a yellow frame near the object. The size of the note is independent of the zoom level.

Presentation

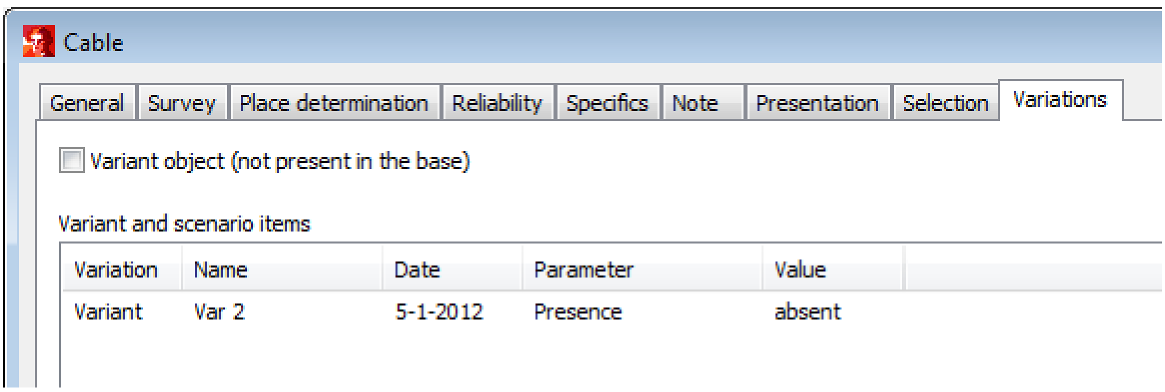
The graphical presentation of an object can be defined in this tab. See also: Presentation Components 248.

Selection

A component can be present in a number of selections 235.

Variations

An object that does not exist in the base situation, but only in a variant from a specific date, is a **Variant object**. This is indicated on the **Variations** tab by means of a checkmark at **Variant object**. The object has then become a **variant object**. If the object is not yet included in a variant, it will no longer be visible in the standard view after the **Variant object** box has been checked.



The form also indicates the variant in which the object appears and the date on which the object is taken into or out of service. Active variant items are displayed selected.

The form also specifies the scenario in which the object appears and possibly the date on which the change takes place. Active scenario items are displayed selected.

5.1 Nodes

A node represents a busbar or a substation. Branches (lines, cables, transformers, etc..) and elements (loads, motors, generator, etc.) can be connected to a node.
The nodes determine the nominal voltages in the network. Nodes with an equal nominal voltage can be connected using cables, lines or reactance coils. To connect nodes with unequal voltage levels, a transformer will be needed.

A node can be added in two ways:
1. Left-click in the workspace and choose **Insert | Node | Node** in the ribbon menu.
2. Right-click in the workspace and choose **Node** from the pop-up menu.

See:

- Node 138
- Simultaneousness 235
- Busbar system 143

5.1.1 Node

A node represents a rail.

PARAMETERS

General

Parameter	Default	Unit	Description
Name			Name of the node
Unom	Unom 1)	kV	Rated voltage
Simultaneousness	1		Simultaneousness factor of the connected loads
ID	2)		Identification
Short Name			Short name
Function			Function

1) On exiting a node form via OK, Unom is saved as the default value
2) On exiting a node form via OK, a warning will appear if the ID is not unique

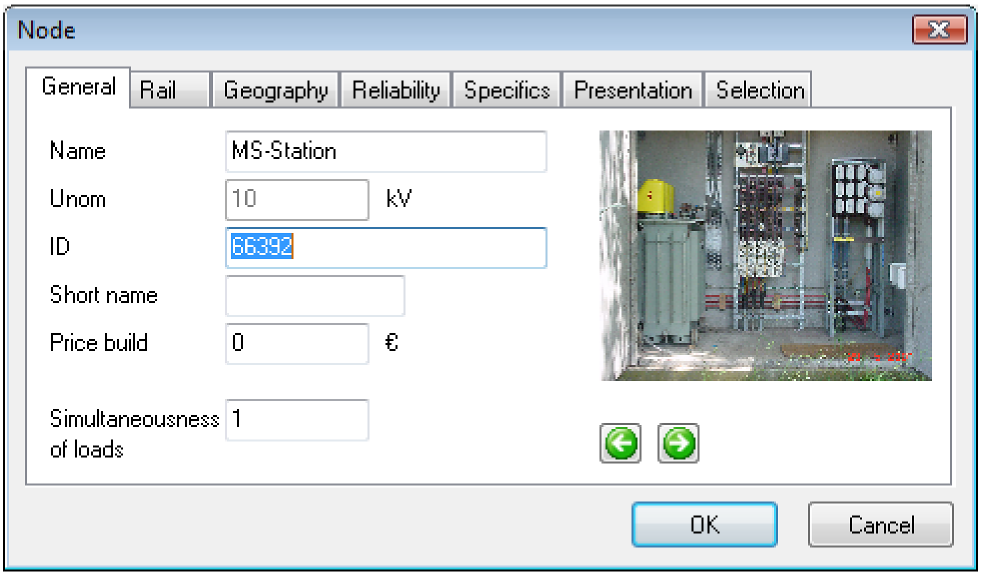
Name
Preferably a different name should be chosen for each node.

ID

In addition to the name, the ID (consisting of a maximum of 25 characters) can be used to identify a node. This ID is also used when importing or exporting network data.

In the node form, the **Geography** tab shows a picture of the station if *ID* .jpg or *ID|ID* .jpg or *Regio|ID* .jpg or *Regio|ID|ID* .jpg matches the name of a jpg image file in the folder with station images specified in the **Options** under **File locations | Pictures**. Clicking on the image opens it with the default program in Windows.

In the node form, the **General** tab displays a series of images if *ID_** . Jpg or *ID|** . Jpg or *Regio|ID_** . Jpg or *Regio|ID|** . Jpg matches the name of a jpg image file in the folder with station images specified in the **Options** under **File locations | Pictures**. The asterisk (*) in the reference to the jpg is a wildcard symbol. You can use the arrow buttons to browse through the images. Clicking on the image opens it with the default program in Windows.



U_{nom}

U_{nom} indicates the nominal operating voltage (for example 380 kV, 110 kV or 10 kV). This U_{nom} can be changed as long as the node is not connected to another node.
When leaving a node with **OK**, U_{nom} is saved as default value.
There is a possibility to collectively change the nominal voltage of multiple nodes. If the nodes are connected to each other by means of cables, connections, reactance coils or links, it is only possible to change the U_{nom} of all connected nodes simultaneously via **Start | Edit | Collective | Node**. If the nodes are connected by transformers, the rule applies that the nominal voltage of transformer winding and node may not deviate more than 20% with respect to each other.

Simultaneity

For each node a simultaneity factor can be specified with which all the (transformer)loads (P and Q) connected to the node are multiplied.
See also: Simultaneousness 235

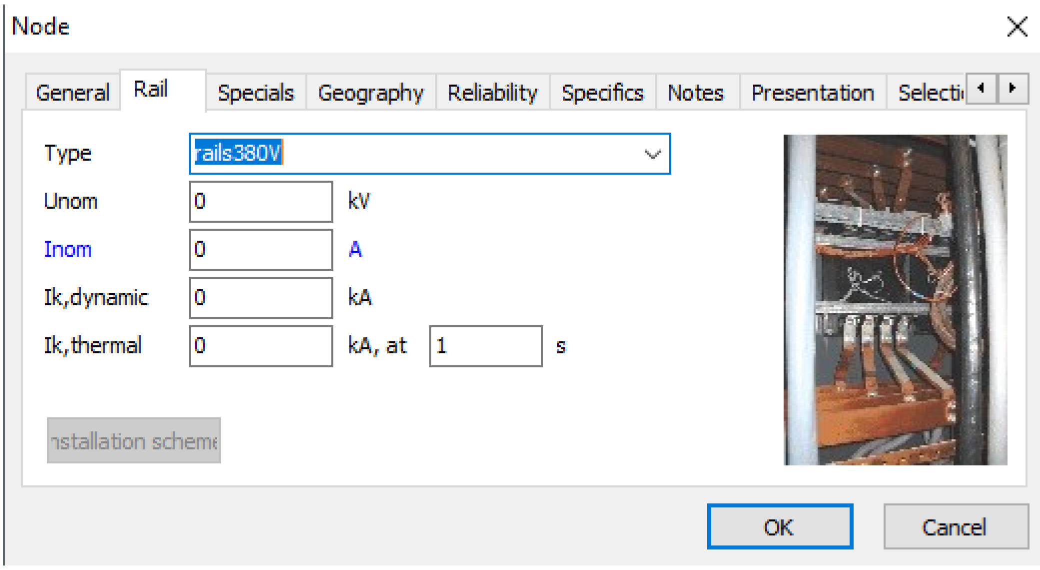
Rail

Parameter	Default	Unit	Description
Type			Busbar type
Unom	0	kV	Rated voltage (not for calculation)
Inom	0	A	Rated current
Ik dynamic	0	kA	Admissible dynamic short-circuit current
Ik thermal	0	kA	Admissible thermal short-circuit current
at	1	s	Duration of defined admissible thermal short-circuit current

Type

In the node form on the tab **Rail**, a picture of the rail type will be shown if *railtype* .jpg or railtype_* .jpg or railtype|* .jpg matches the name of of a jpg file in the Types directory, defined in the **Options**, at **File locations | Pictures**. By clicking on the picture, it will be opened with the default Windows viewing program.

In the node form on the tab **Rail**, the button Installation scheme will open one or multiple pdf files if ID|* .pdf of Regio|ID|* .pdf matches the name of a pdf file in the Stations directory, defined in the **Options**, at **File locations | Pictures**.



Dynamic short-circuit current

The mechanical (dynamic) forces on the installation at the node are determined by the peak short-circuit current (Ip). This current is calculated by the IEC 60909 calculation. The result is compared with the admissible dynamical short-circuit current. This is reflected in the colour indication.

Thermal short-circuit current

The thermal stress on the installation at the node is determined by the sub-transient short-circuit current (I_k").

This current can be calculated by both the IEC 60909 calculation and by the Fault Analysis calculation. The result is compared with the admissible thermal short-circuit current. From this, the maximum short circuit duration (t_{max}) is calculated.

Diverse

Installation

The data of the installation is only required when performing the arc flash calculation.

Parameter	Default	Eenheid	Omschrijving
Type			
Solidly earthed	not		
Conductor gap		mm	
Working distance		mm	
Enclosed position	not		
Arc flash protection	not		
Electrode configuration			
H		mm	Height
B		mm	Width
D		mm	Depth
Kb			
Kp			
Kt			

Feeders

The feeders of a node can be defined on this sheet. The order must correspond to the real order of the feeders on the rail structure.

Parameter	Default	Unit	Description
Name			Name of the feeder
Sort			Type of the feeder
To			Indication of the direction of the branch in the feeder
Type			Type for the arc flash calculation
Conductor gap [mm]		mm	The conductor gap, in case this differs from the rail conductor gap
Electrode			Horizontal/Vertical; Closed/Open
H [mm]		mm	Height of the compartment
B [mm]		mm	Width of the compartment
D [mm]		mm	Depth of the compartment
Information			Additional information

Ripple control source

The ripple control calculation allows for the calculation of the propagation of ripple control signals in the network. See: Harmonics 277. One or more ripple control sources of different frequencies can be inserted into the network.

Parameter	Default	Unit	Description
Frequency	0	Hz	Frequency of the ripple control signal
Voltage	0	%	Relative voltage of the ripple control signal with respect to the nominal voltage
Angle	no	degree	Angle of the ripple control voltage with respect to the loadflow voltage

External neutral point grounding

A node may have an external grounding connection. This can serve as a common grounding point for the star-points of several components. For example, the star-points of synchronous generators, synchronous motors, capacitor, shunt coil or transformer can be commonly grounded. This has consequences for the short-circuit calculation with ground connection. In this tab the grounding impedance can be specified.
If one of the connected elements uses the external grounding connection, it should be defined at the **Connection** tab of the concerning element.

Customer

These are informative data about a possibly customer.

Rail differential protection

This is a rail differential protection. All involved circuit breakers has to be mentioned and all involved circuit breakers will also switch off in case the protection is tripped.
There is no correction for direction and ratio: the sum of the currents has to be zero during normal operation. For the detail working see Differential protection 213.

Limits

The voltage control can be turned off or there can be alternative limits.

Icon

A short text can be displayed in a point symmetrical form near the node in the diagram. Text, text color, background color, shape and size are adjustable.

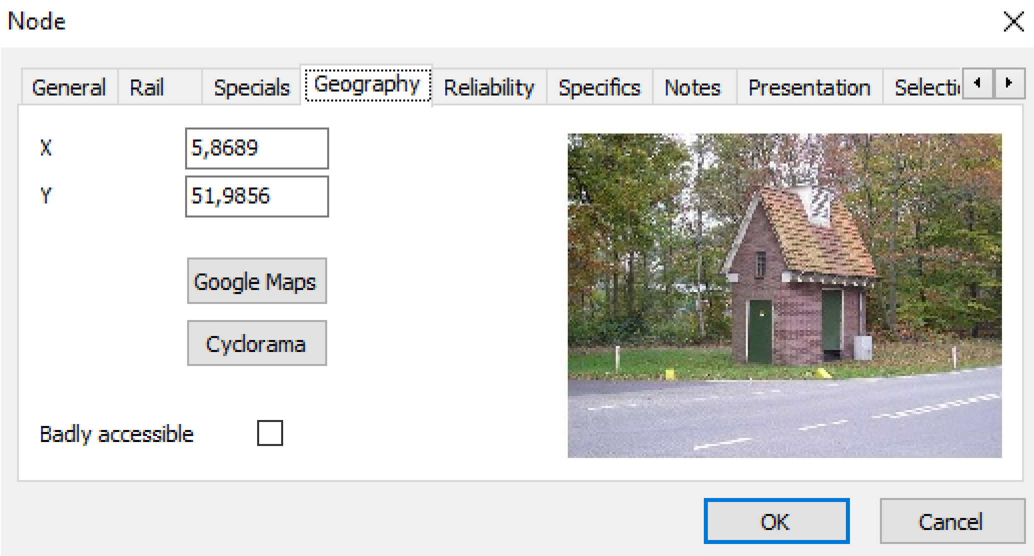
Gaia

A Gaia network of the node can be opened in Gaia. The name of the gnf must match the ID of the node. The root of the Gaia network files must be entered in the options at File Locations, Specific. In this directory, sub-directories are allowed.
If an IEC 60909 calculation has been performed, the calculated symmetric short-circuit currents are written or updated in the short-circuit currents.txt file.
If there is a node in the Gaia network with a name and / or ID from the short-circuit currents and there is a power supply, then the Ik "nom is set to the value from the file.

Geography

Parameter	Default	Unit	Description
X	0	degrees	Geographical X-coordinate
Y	0	degrees	Geographical Y-coordinate
Badly accessible	no		Rather don't visit station (normal open point optimization)

By specifying the geographical coordinates, the object can be presented on a geographical layer or in a geographical application. See: Geography 113.



Using the button **Google maps**, the station geographical location will be presented using the default web browsers through the web-application Google maps.

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the node fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the node is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency
Remote status indication	no	yes / no	Presence of remote node status indication

The remote status indication influences the time to signal a fault (short/long).

MODELLING

Load flow and fault analysis

For all loads present at a node, the load is corrected by the simultaneousness factor for load flow calculations and sequential fault analysis.

$$P_{load,calculation} = Simultaneousness * P_{load}$$
$$Q_{load,calculation} = Simultaneousness * Q_{load}$$

The values of P_{load} and Q_{load} are determined from the scaling and growth factors from the Load growth 229:

$$P_{load} = P_{specified} * Scale\ factor(year) * f(growth,\ year)$$
$$Q_{load} = Q_{specified} * Scale\ factor(year) * f(growth,\ year)$$

IEC 60909
As loads are not taken into consideration in an IEC 60909 calculation, the simultaneousness factor is not applicable when performing this calculation.
The ratio $I_k''/I_{k,max}$ is used for the colour indication.

5.1.2 Busbar system

Nodes can be combined into a busbar system. All nodes that belong to the same busbar system have to be created separately and grouped into one busbar system later on. The separate nodes will continue to exist. The advantages of a busbar system are:
- all components belonging to the same busbar system are graphically treated as one component
- branches and elements can be switched easily from one node of the busbar system to another
- the busbar selection is represented in a compact way.

The busbar system can be defined by selecting the nodes and choosing: **Insert | Node | Busbar system** from the ribbon menu. The following points and limitations apply to the nodes of the rail system in the network editor:
- the nodes must be represented as a horizontal or vertical line
- the nodes must have the same orientation (horizontal or vertical)
- the nodes may not be separated more than 8 grid points from each other.

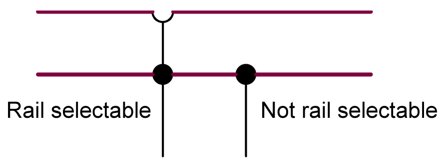
The next figure illustrates the maximum separation. Nodes A, B and C can be combined into one busbar system. Node D can not be combined with the other three because is is separated more than 8 grid points from node A..

A busbar system can be deleted by using: **Start | Edit | Delete | Busbar system**. In order to perform this action all the nodes of the busbar system must be selected.
Only non-busbar nodes can be combined into a busbar system. It is not possible to extend a busbar system with a node to a larger busbar system. In that case, the original busbar system must first be removed.
A busbar system can only be extended with another node by first deleting it and then redefining it.

Adding a new branch
A new branch can be connected to a busbar system by selecting only one of the nodes of the busbar system. If the branch has to be connected to another busbar system, also from that busbar system only one node should be selected.

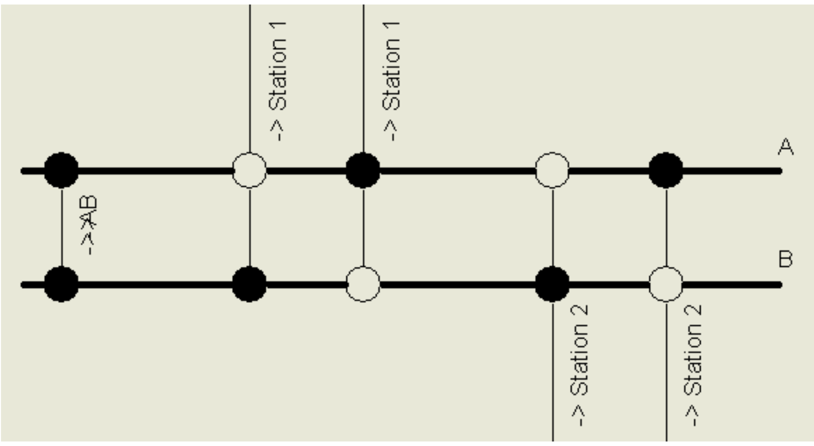
Busbar selection
The connection of a link 149 to a busbar system can be defined on the link tab **Connection** as:
- rail selectable,
- not rail selectable or
- fixed.

Each other new branch (e.g. cable, line, transformer) will always be rail selectable.



In the busbar system form a name can be defined and the busbar selection can be altered. The form can be accessed with **Start | Edit | Busbar system** or with the key combination **Ctrl-Alt-R**. Before this at least one of the nodes of the busbar system must be selected. For changing the busbar selection switches the following applies:

- an open circle represents an open switch
- a closed circle represents a closed switch
- for each feeder (branch or element) only one switch can be closed
- a mouse click on an open switch closes it, opening an the closed on another node of the busbar system
- a mouse click on a closed switch opens it, isolating the feeder from the busbar system.



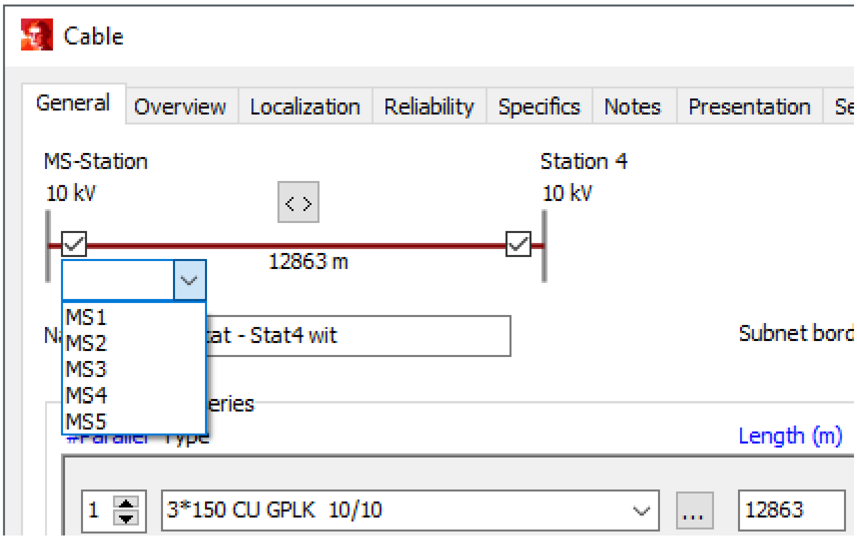
With **View | Appearance | Colour | Island** it can be easily seen whether the busbar selection leads to any isolated nodes.

5.2 Branches

A branch connects two or three nodes. Unless the branch is a transformer, the nodes must have the same voltage. Only a three winding transformer can connect three nodes.

A branch can be added by selecting two (or three) nodes and choosing the appropriate branch type from the ribbon menu **Insert | Branches**.

Each branch can be assigned to a field at a node. The fields have to be defined in the node form before they can be assigned to a branch.



See:

- Line 145
- Cable 150
- Link 149
- Reactance coil 154
- Transformer 155
- Special transformer 161
- Three winding transformer 166
- Mutual coupling 147

5.2.1 Line

A line is the model for a three-phase (high-voltage) line or another connection between two nodes, of which the type data is not known but the electrical properties.
A connection consists of one or more serial connection parts, where a description can be specified. A connection part has three values for **Inom**. The choice can be made in the general calculation options.

With a connection, the nominal voltages of both nodes must be the same.

PARAMETERS

General

In this screen, the positions of the switches on both sides of the connection can be changed.

Parameter	**Description**
Name	Name of the connection
Resistance symbol	Resistance symbol in the scheme
Subnet border	Division of parts of the network which are fed through different transformers or sources
From-node	Name of the node from which the cable is connected
To-node	Name of the node to which the cable is connected

A line runs from a **From-node** towards a **To-node**. The **From-node** and **To-node** can be exchanged using the button: **<>**.

A line is composed of one or several line parts. For each line part a name can be given. Several line parts can be added with the buttons **Add** (add to the bottom of the list) or **Insert** (insert before the current connection part in the list). With the button **Remove** the line part can be removed from the list.

Line parts

Parameter	Default	Unit	Description
Rac	0	Ohm	Operational A.C. resistance, at specified temperature
TR	30	degrees C	Temperature corresponding to the value of R
X	0	Ohm	Operational reactance
C	0	µF	Operational capacity
R0	0	Ohm	Zero sequence resistance
X0	0	Ohm	Zero sequence reactance
C0	0	µF	Zero sequence capacity
Length	0	m	Length (for harmonics calculation)
Inom1	0	A	Nominal current
Inom2	0	A	Alternative nominal current
Inom3	0	A	Alternative nominal current
Ik 1s	0	kA	Admissible short-circuit current for 1 second
TIk(1s)	0	degrees C	Temperature corresponding to Ik(1s)

TR

Specification of the temperature, for which the specified conductor resistance applies. It enables the calculation of the resistance at another temperature (T_{act}), using the correction factor:

$$(1+0.004(T_{act}-20)) / (1+0.004(TR-20)).$$

Calculation of the maximum short-circuit current according to IEC 60909 is performed using a conductor temperature of 20 degrees C.

X

The line operational reactance must be larger than zero. A small impedance sometimes is required for a short coupling connection, but a value smaller than 1 mOhm is usually not realistic.

R0 and X0

For the calculation of short circuits with earth, the following two tests are conducted: R0> R1 and X0> 0. If either of these tests fail, a warning will be generated.

Inom

The nominal current must be specified and must be larger than zero.

TIk(1s)

The conductor temperature at I_k(1s) is used for calculating the minimum short-circuit current according to IEC 60909.

Reliability

The reliability parameters apply for the whole line. It is not possible to specify these parameters for each line part.

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the line fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the line is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

Pi-model

F the description of the pi-model see: Cable 150.
The tangent of delta is not applied for lines.

Inom'

For branches the terms **Inom'** and **Snom'** have been introduced for signalling an overload in the loadflow. These values have been introduced to obtain clarity about the maximum load capacity of a branch. For a connection, the value of **Inom'** is chosen from the input data according to the connection ampacity settings in th***Options*** , at **Calculation | Limits**.

IEC 60909
For symmetrical short-circuit calculations, only the normal "longitudinal impedance" (R+jX) is used. The "transverse impedance" Xc is not taken into account.
In asymmetrical short-circuit calculations, the inverse impedance is equal to the normal impedance ($Z_1 = Z_2$). The pi-model with the zero sequence "transverse impedance" X_{oc} applies to the zero sequence impedance (Z_0).
The zero sequence data are not relevant to the calculation of a symmetrical fault (PPP) or a two-phase fault without earth contact (PP).
For the calculation of short circuits with earth, the following two tests are conducted: R0> R1 and X0> 0. If either of these tests fail, a warning will be generated.
The maximum admissible short-circuit time t_{max} is calculated using $I_{k,1s}$.
Calculation of the maximum short-circuit current according to IEC 60909 assumes a conductor temperature of 20 degrees C. The conductor temperature at $I_{k,1s}$ is used for calculating the minimum short-circuit current according to IEC 60909.
The conductor resistance is specified for a reference temperature TR. The resistance for the actual temperature T_{act} will be calculated using the correction factor:
$(1+0.004(T_{act}-20)) / (1+0.004(TR-20))$.

Parallel lines
The electromagnetic influence in case of parallel lines can be modelled using the mutual coupling 147.

Harmonics
For the calculation of harmonics the distributed parameter model is used. See: Harmonics: Model 278

5.2.2 Mutual coupling

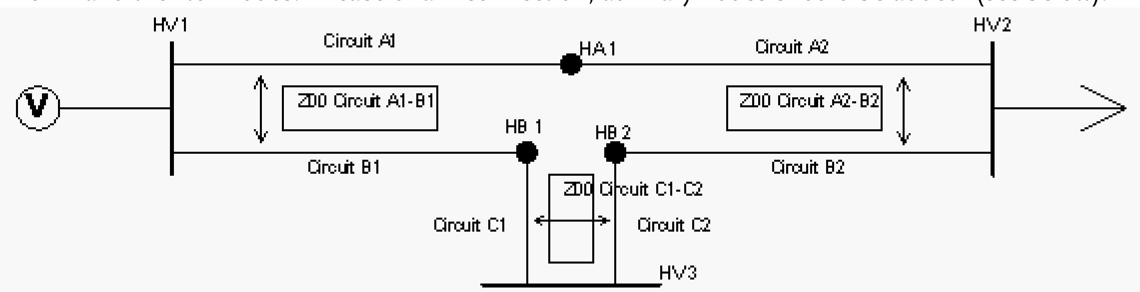
The mutual coupling is a value, representing the electro-magnetic coupling between parallel lines. Through this mutual coupling the line currents in both lines are influenced by one another, especially in the case of unbalance. The effect is particularly visible in case of a phase to ground fault in one of the parallel lines. For this reason the mutual coupling has been modelled as an impedance in the zero sequence system.

The mutual coupling can only be applied to lines.

The mutual coupling has an effect on the zero sequence impedance and is modelled for the asymmetrical short-circuit calculations: fault analysis and IEC (60) 909.

Multiple connections, that are mutually coupled together, form a mutual group. Such a mutual group has been limited to a maximum of 10 mutual couplings. The number of mutual groups has not been limited.

A mutual coupling has been modelled for the whole length of the mutually coupled connections between the "from" and the "to" nodes. In case of a T-connection, auxiliary nodes should be added (see below).



New
A new mutual coupling can be defined by firstly selecting the two parallel connections and secondly choosing from the main menu: **Insert | Branches | Mutual coupling**.

Always mind the proper directions of both mutually coupled connections. If both connections do not have the same direction, the effect matches that of a negative mutual impedance.

Select

Normally, mutual couplings are not visible in the network diagram. Using a special select function the branches with a mutual coupling will be selected: **Start | Select | Special | Mutual connection**.

Edit

An existing mutual coupling can be edited by first selecting the two parallel connections and subsequently choosing from the main menu: **Start | Edit | Mutual coupling** or using the keys: **Ctrl-Alt-M**.

Delete

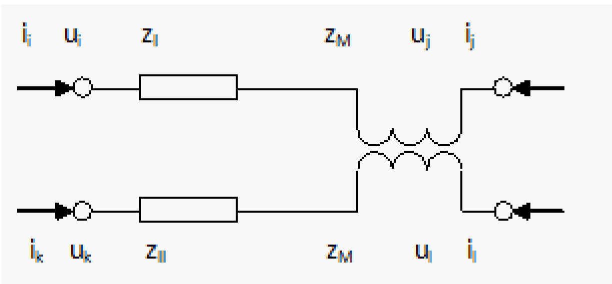
An existing mutual coupling can be deleted by first selecting the two parallel connections and subsequently choosing from the main menu: **Start | Edit | Delete | Mutual coupling**.

PARAMETERS

Parameter	Default	Unit	Description
Roo	0	Ohm	Mutual coupling zero sequence resistance
Xoo	0	Ohm	Mutual coupling zero sequence reactance

MODELLING

The schematic of a basic model of two parallel connections, which are interconnected via an impedance Z_M, is shown below:



In the case of two connections with a mutually coupling, an impedance occurs in the branch impedance matrix. The following equations in the zero sequence system relate to two connections between nodes i and j and k and l with impedances Z_I and Z_{II} and mutual coupling Z_M:

$$u_{ij} = Z_I \cdot i_{ij} + Z_M \cdot i_{kl}$$
$$u_{kl} = Z_{II} \cdot i_{kl} + Z_M \cdot i_{ij}$$

In practice, mutual couplings are modelled only in the zero sequence circuit, so that the equations for two circuits according to the symmetrical component method changes to:

$$\begin{bmatrix} U_{0,i} - U_{0,j} \\ U_{1,i} - U_{1,j} \\ U_{2,i} - U_{2,j} \\ U_{0,k} - U_{0,l} \\ U_{1,k} - U_{1,l} \\ U_{2,k} - U_{2,l} \end{bmatrix} = \begin{bmatrix} Z_{0,I} & & & Z_{0,M} & & \\ & Z_{1,I} & & & & \\ & & Z_{2,I} & & & \\ Z_{0,M} & & & Z_{0,II} & & \\ & & & & Z_{1,II} & \\ & & & & & Z_{2,II} \end{bmatrix} \cdot \begin{bmatrix} I_{0,I} \\ I_{1,I} \\ I_{2,I} \\ I_{0,II} \\ I_{1,II} \\ I_{2,II} \end{bmatrix}$$

5.2.3 Link

A link is the model for a connection between two nodes, which has close to zero impedance.

A link can only be applied if the nominal voltages of both nodes are equal.

PARAMETERS

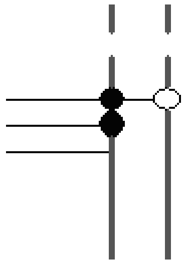
General
In this form the switches on both sides of the connection can be opened or closed.

Parameter	Description
Name	Name of the connection
Subnet border	Division of parts of the network which are fed through different transformers or sources
From-node	Name of the node from which the cable is connected
To-node	Name of the node to which the cable is connected

The link runs from a **From-node** towards a **To-node**. The **From-node** and **To-node** can be exchanged by using the button: **<>**.

Ampacity
A Link has a rated current I_{nom} and a maximum short-circuit current I_k(1s). If specified, the loading will be presented in the results. If not specified, the link is assumed to be infinitely strong and its loading will not be shown.

Connection
The connection of a link to a busbar system can be defined on the tab **Connection** as:
- rail selectable,
- not rail selectable or
- fixed.



This only affects the graphical representation.

Impedances
The impedances of the link are adjustable in the options, in **Calculation | General**. The possible values are:

R, X, R0 and X0 = 1 μΩ tot 10 mΩ

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the link fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the link is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

5.2.4 Cable

A cable is a three-phase cable connection between two nodes, whose type data are known. The electrical properties are usually copied from the type file.

In the type file, data for circuits with three and single conductor cables are included. The single conductor cables are always treated per circuit of three parallel cables and therefore do not need to be entered separately.

A cable can only be installed between two nodes with the same nominal voltage.

PARAMETERS

General

In this screen, the positions of the switches on both sides of the cable can be changed.

Parameter	Description
Name	Name of cable
Subnet border	Separation of parts of the network that are fed by different power supplies or transformers
Source left	Name of the feeding object on the side of the from-node, in the case of a subnet border
Source right	Name of the feeding object on the side of the to-node, in the case of a subnet border

The cable runs from the **From-node** to the **To-node**. The **From-node** and **To-node** can be interchanged using the **<>** button.

Subnet border

An open switch in such a cable is displayed as a double flag, provided that a flag for an open switch is selected for the symbols in the editor options 127.

Cable parts in series

A cable consists of one or more cable parts in series. The cable is configured or modified as follows:
With the green buttons **+** cable parts can be added to a cable. With this, a cable part can be placed in front of or behind another cable part. With the red button **X** a cable part is removed from the list.
In some calculations, such as fault analysis and protection, the specific sequence of the cable parts in a cable connection is taken into account. This is particularly important when alternating strong and weak cable pieces are present in one branch.
With the **<>** button the order of the cable parts can be reversed.

With the button **...** the parameters of the cable type of a cable section can be viewed and changed.

The length, load capacity and load factor can be specified for all cable parts.

Parameter	Default	Unit	Description
#Parallel	1		Number of parallel circuits for this cable part
Type			Cable type for this cable part
Length	0	m	Length of the cable part
Inom		A	Nominal current, to be chosen dependent on environmental conditions
Ampacity factor	1		Multiplication factor with which Inom can be reduced
Year			Year of construction

Parallel cable parts

For each cable part, the number of parallel cable circuits for that cable part exists. The advantage is that for a double circuit connection, of which both circuits are protected with a common protection relay, no auxiliary node needs to be made. Moreover, the network diagram becomes less cluttered.
The equivalent electrical data is calculated for all parallel circuits jointly in the relevant cable section.
For a cable part that consists of two parallel three-conductor cables, there are two parallel circuits. The #Parallel attribute is then 2.
In the case of a cable component consisting of two parallel circuits of single-core cables, in reality six single-core cables are next to each other. Since each circuit consists of 3 cables, the #Parallel attribute is also equal to 2.

A short circuit in one of the parallel cables can only be calculated correctly if the specific cable is modelled separately.

Ampacity factor

With this factor, I_{nom} can be reduced if several cables are next to each other. This can occur with cables that are routed at substations.

Cable type

The form that is called from the **General** tab with the button **...** gives the following information about the selected cable section: type, shortened type name, maximum ampacity and maximum short-circuit current.

Parameter	Default	Unit	Description
Type			Type of cable part
Short			Short cable designation
Unom	0	kV	Nominal voltage
Price	0	/m	Price of the cable per meter
Rac	0	Ohm/km	Operational A.C. resistance, at specified temperature
TR	30	degrees C	Temperature corresponding to the value of R
X	0	Ohm/km	Operational reactance, at specified frequency
C	0	µF/km	Operational capacity
tan delta	0		dielectric loss angle
R0	0	Ohm/km	Zero sequence resistance at 20 degrees C.
X0	0	Ohm/km	Zero sequence reactance
C0	0	µF/km	Zero sequence capacity
Inom0	0	A	Nominal current for cables in air
Inom1/2/3	0	A	Nominal current for buried cables for three soil thermal heat resistances
at	0	Km/W	Specific heat resistance of the soil, belonging to Inom1/2/3
Ik 1 s	0	kA	Admissible short circuit current for 1 second
TIk(1s)	0	degrees C	Temperature at Ik(1s)
Frequency	50	Hz	Frequency, corresponding with X
Pulse velocity	0	µs/m	Velocity of a partial discharge (PD) pulse for fault location

Type

In the list of applicable types are all the cables from the cable database of which U_{nom} equals 75 - 350% of the U_{nom} of the two nodes.
The type name consists of a maximum of 40 characters.
After selecting the desired cable type from the cable list, all parameters are copied.
The Types.xlsx type file supplied with Vision contains data from many commonly applied cable types.
See also: Type 76

TR

Specification of the temperature for which the specified resistance applies. This makes it possible to calculate the approximate behaviour of the grid at a different temperature (T_{act}) on the basis of the correction factor:

$$(1+0.004(T_{act}-20)) / (1+0.004(TR-20)).$$

This formula assumes that the skin effect and proximity effect are constant and therefore has a somewhat greater tolerance for very thick cables (cross-sections of 1000-3000 mm²). The calculation of the maximum short-circuit current according to IEC 60909 is based on a conductor temperature of 20° C.

R0 and X0

For the calculation of short circuits with earth contact, the following is tested: R0>R1 and X0>0. If not, a warning is generated.

Inom

The nominal current that a cable may carry depends on the permissible conductor and jacket temperature and is partly determined by the specific thermal resistance of the soil G. For each cable type, an I_{nom} can be specified for three different values of G. A nominal current can also be specified for overground cables (free in air).
The stated values for G are used in the calculations to select the appropriate maximum current loading. With several cable parts, the weakest part is driving.

TIk(1s)

The conductor temperature at I_k(1s) is used for calculating the minimum short-circuit current according to IEC 60909.

Frequency

The business reactance is based on the nominal frequency, which is taken from the type data: X = L. With a deviating operating frequency (specified in the **Options**, at **Calculation**) the operating reactance is corrected.

Copy and paste type data

The type data of a cable type can be copied to a special clipboard by clicking ***Copy type data*** in the Cable type form at the bottom left. The data can be pasted into another new or existing cable with ***Paste type data*** .

Reliability

The reliability data applies to the entire cable and does not have to be specified separately for each cable part

Parameter	Default	Unit	Description
Failure frequency	0	per km per year	Mean number of occurrences that the cable fails (short circuit) per km
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the cable is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
Maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency
Joint Failure frequency	0	per year	Mean number of occurrences that a joint fails (short circuit)

Localization

Distance determination via pulse reflection

Using the attribute **pulse velocity** for the cable type, the distance from a node to the fault location (short circuit) can be determined. The distance is calculated from the entered runtime and the pulse velocity of each cable type. This function is particularly useful if many different cable types are used in a cable connection.
Via ***cable trav. time*** of a possible non-disturbed conductor, the exact measured running time of the entire cable can optionally be specified, for better localization.
The two distances indicate the resulting range of the location, using pre-programmed error margins.

Location by distance(s)

The calculated distances, or own distance(s), can be entered here to determine the geographical location(s).

Connection

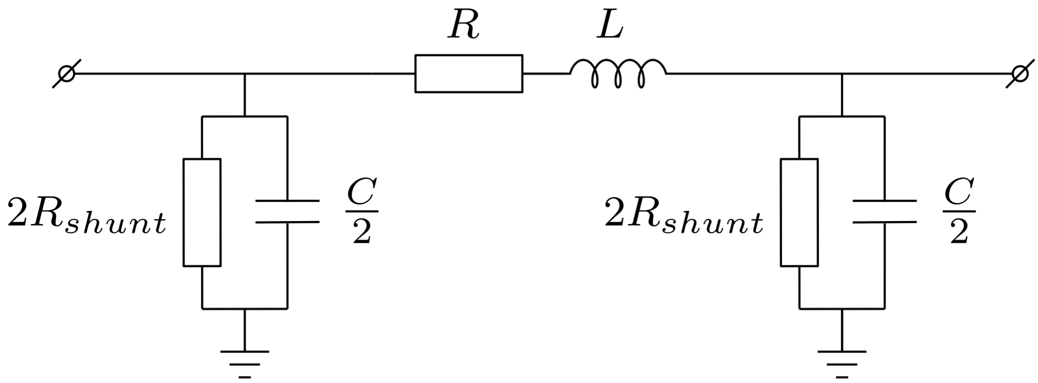
Parameter	Default	Unit	Description
Lmax (normal)	0	%	Alternative maximum load rating in normal situation; only if different from options
Lmax (failure)	0	%	Alternative maximum load rating in failure situation; only if different from options

MODELLING

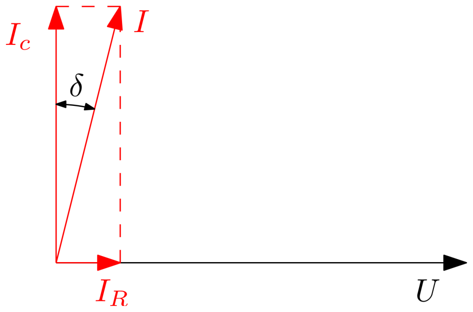
Pi model

The pi model is used for modelling lines and cables. For R, L, Rshunt and C holds:

R	resistance
L	depending of the inductive reactance
C	capacitive reactance
Rshunt	based on tangens delta



The shunt resistance is calculated from the *tan( )* , the dielectric loss angle is measured to determine the degree of ageing of a cable connection. The *tan( )* of a cable depends, among other things, on the type of insulation, the ageing and the temperature of the cable. A cable using XLPE as an insulator has a *tan( )* typically between the 0.35E-3 at 20 ° C and 0.61E-3 at 90° C, in Vision this temperature dependence is neglected. Below the derivation of *Rshunt* from the dielectric loss factor *tan( )* :



$$\tan(\delta) = \frac{I_R}{I_C} = \frac{\sqrt{I^2 - I_C{}^2}}{I_C}$$

$$\tan(\delta) = \frac{U / R_{shunt}}{U / \left(\frac{1}{\omega C}\right)} = \frac{1}{R_{shunt}\,\omega C}$$

$$R_{shunt} = \frac{1}{\tan(\delta)\omega C}$$

The pi-model is valid for cables up to approximately 50 km and for lines up to approximately 200 km. Longer lines can be modelled by applying fictitious nodes, as a result of which several part lines arise. For example, a three-section Pi model provides an accuracy to 1.2 % for a quarter wavelength line (a quarter wavelength corresponds with 1500 and 1250 km at 50 and 60 Hz respectively). Source: J. Arillaga, D.A. Bradley, P.S. Bodger: "Power System Harmonics".

Inom 'and Snom' for branches

For branches the terms **Inom'** and **Snom'** have been introduced for signalling an overload in the load flow. These values have been introduced to obtain clarity about the maximum load capacity of a branch. **Snom'** is used for a transformer. For a cable, the value of **Inom'** is determined from the input data of the weakest cable section. For the cable **Inom'** is specified as follows:

- **Inom'** is the weakest cable type.Inom (G) x ampacity factor over the cable parts.
- G refers to the chosen heat resistance of the ground.

IEC (60) 909

The zero sequence data are not relevant for the calculation of a symmetrical closure (FFF) or a two-phase closure without earth contact (FF).
For the calculation of short circuits with earth contact, the following is tested: R0> R1 and X0> 0. If not, a warning is generated.
Zero sequence impedances of cable connections are difficult to determine and depend, among other things, on:

- one three-phase or three one-phase cable
- distance, plane or triangle
- Grounding of the earth screen (one-sided, two-sided, cross bonding)
- other conductive objects such as other cables or pipelines

The maximum permissible short-circuit time tmax is calculated on the basis of $I_k(1s)$.

The calculation of the maximum short-circuit current according to IEC 60909 is based on a conductor temperature of 20° C. The conductor temperature at $I_k(1s)$ is used for calculating the minimum short-circuit current according to IEC 60909.
The conductor resistance (R) is specified for reference temperature (TR). The resistance for the actual temperature (T_{act}) is calculated on the basis of the correction factor:
$(1+0.004(T_{act}-20)) / (1+0.004(TR-20))$.
The zero sequence resistance (R_0) is not corrected for temperatures that deviate from 20 ° C.

Harmonics

The distributed parameter model is used for calculating harmonics. See: Harmonics: Model 278

5.2.5 Reactance coil

A reactance coil is a three-phase impedance between two nodes. The reactance coil is often used at the beginning of a medium-voltage feeder to the limit short-circuit current. The electrical properties are sometimes copied from the type file.

With a reactance coil, the nominal voltages of both nodes must be the same.

PARAMETERS

General

Parameter	Description
Name	Name of reactance coil

The reactance coil runs from the **From-node** towards the **To-node**. The **From-node** and the **To-node** of the reactance coil are determined automatically. To switch the **From-node** and the **To-node** use the **<>** button.

Reactance coil

Parameter	Default	Unit	Description
Type			Reactance coil type definition
Short			Short name
Unom	1)	kV	Nominal voltage
Ik (2 s)	0	kA	Admissible short-circuit current for 2 seconds
Inom	0	A	Nominal current
R	0	Ohm	Resistance
X	0	Ohm	Reactance
R0	0	Ohm	Zero sequence Resistance
X0	0	Ohm	Zero sequence Reactance
R2	0	Ohm	Inverse Resistance
X2	0	Ohm	Inverse Reactance

1) U_{nom} of the nodes between which the reactance coil is located

Z0 becomes Z1 (Z1 -> Z0)
Using this button the contents of the normal impedance will be copied to the zero sequence impedance.

Z2 becomes Z1 -> Z2
Using this button the contents of the zero sequence impedance will be copied to the inverse sequence impedance.

Reliability

Parameter	**Default**	**Unit**	**Description**
Failure frequency	0	per year	Mean number of occurrences that the reactance coil fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the reactance coil is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

For all calculations the reactance coil is modelled as a longitudinal impedance $R+jX$.

Inom'
For branches the terms **Inom'** and **Snom'** have been introduced for signalling an overload in the load flow. These values have been introduced to obtain clarity about the maximum load capacity of a branch. **Inom'** is specified as follows for the reactance coil:
- **Inom'** is taken from the input data Reactancecoiltype.Inom

5.2.6 Transformer

A transformer connects subsystems with different voltage levels. Examples are an 150/10 kV supply transformer and a 10/0.4 kV distribution transformer.

PARAMETERS

General
In this form the switches on both sides of the transformer can be opened or closed.

Parameter	**Description**
Name	Name of transformer
Tap	Actual transformer tap position

The transformer runs from the **From-node** towards the **To-node**. The **From-node** and the **To-node** of the transformer are determined automatically. To switch the **From-node** and the **To-node** use the **<>** button.

Transformer

Parameter	Default	Unit	Description
Type			Transformer type
Short name			Short name transformer type for plotting in one line diagram
Snom	0	MVA	Nominal apparent power
Unom	1)	kV	Nominal winding voltage
Connection	2)	D / Y / YN / Z / ZN	Winding connection type
Tapside	w1		Location of the tap changer: winding 1 or 2
uk	0	%	Relative short circuit voltage
Pk	0	kW	Short circuit loss
Pnull	0	kW	No-load loss
Inull	0	A	No-load current (at low voltage side)
Z0	0	Ohm	Zero sequence impedance
R0	0	Ohm	Zero sequence resistance
Side Z0	0		Side on which homopolar impedance is involved for YY, YZ, ZY and ZZ (0=automatic)
Ik 2 s	0	kA	Admissible short circuit current (secondary side) for 2 seconds
Clock #	0		Transformer windings configuration
Tap size	0	kV	Tap size of the tap changer
Tap min	0		Tap with smallest number of windings
Tap nom	0		Tap with nominal transfer ratio
Tap max	0		Tap with largest number of windings

1) The default value of the nominal voltage is chosen equal to the nominal voltage of the node to which the winding is connected
2) The default connection is selected on the basis of the nominal voltage of the respective winding

Type

The type list contains all transformers from the typefile which have an $U_{nom,w1}$ and $U_{nom,w2}$ between the $0.8*U_{nom}$ and $1.2*U_{nom}$ for both the nodes.
See also: Type 76

Unom

If a new transformer is defined, the values for $U_{nom,w1}$ and $U_{nom,w2}$ are set based on nominal voltage of the nodes .

Connection

In the case of two-winding transformers in which the star point would be earthed both at the primary and secondary side (for example YNyn), the transformer enclosure would behave as a third winding in the case of an asymmetrical load or short circuit. The modelling of these transformers as two-winding transformers is not supported by Vision. In these cases, the transformer must be modelled as a three-winding transformer (YNynd).

R0 and Z0

For the calculation of short circuits with earth contact, it is checked whether: Z0> 0. If not, a warning is generated.

Clock #

The clock number is important in order to be able to calculate the phase voltages and phase currents "beyond" the transformer in case of an asymmetrical fault.

Tap min, nom and max

The indication of the tap position can be defined by the user by indicating the minimum, nominal and maximum tap position. Note that, for example, the minimum tap position can be defined as the tap position at the smallest number of windings and thus (depending on the tap side) can give the largest voltage ratio!

Copy and paste type data

The type data of transformers can be copied to a special clipboard by right-clicking in the form. A pop-up menu will appear with the *Copy Type Data* and *Paste Type Data* items. The data can be pasted into another new or existing transformer(load). This is useful, for example, for converting a transformer into a transformer load and vice versa.

Connection

Parameter	Default	Unit	Description
Neutral point	isolated	isolated/own/external	Earthing of the neutral point in case of a YN/ZN-sinding
Own Re	0	Ohm	Earthing resistance with earthed neutral point
Own Xe	0	Ohm	Earthing reactance with earthed neutral point
External node			Node with neutral earth connection
Snom'	0	MVA	Maximum apparent power; only if different from Snom
Clock'	0		Connection clock number; only if different from type clock number
Phase shift	0	degrees	Phase shift of the transformer windings
Step-up trafo	no		Indicates whether the transformer is used as a step-up transformer (IEC 60909)
Lmax (normal)	0	%	Alternative maximum load rating in normal situation; only if different from options
Lmax (failure)	0	%	Alternative maximum load rating in failure situation; only if different from options

External neutral point

Allows for the use of a common earthing point for multiple transformers.

Snom'

The variable **Snom'** has been introduced for a uniform overload indication in the load flow. For a transformer the value is obtained as follows:

- **Snom'** is set from the typefile or the **Snom'** from the connection tab is applied.

Voltage control

Parameter	Default	Unit	Description
Own control present	off		Indicates whether the transformer is equipped with an individual voltage control
Meas. side	2		Measuring side of voltage control
Node			Node based on which the voltage is regulated
Uset	1)	kV	Setpoint of then voltage control
Uband		kV	Deadband of the voltage control
Rc	0	Ohm	Real part of the voltage control compounding impedance
Xc	0	Ohm	Reactive part of the voltage control compounding impedance
Also in backw. direction			Also compounding when the power goes back
Load dependent			Choice for load dependent control
P<<		%	Power below which is regulated at voltage U<<; above: linear between U<< and U<<
U<<		kV	Control voltage at a power less than P<<<
P<	-100	%	Power where on voltage U< is controlled; above: linear between U< and Uset
U<		kV	Control voltage at a power of P<
P>	100	%	Power where on voltage U> is controlled; below it: linear between Uset and U>
U>		kV	Control voltage at a power of P>
P>>		%	Power above which voltage U>> is controlled; below which: linear between U> and U>>
U>>		kV	Control voltage at a power greater than P>>
Master control usable	off		Transformer taps may follow a master voltage control
Master			Name of master voltage controlling transformer
Status	off		Voltage control activated / deactivated or use of master-slave voltage control: Control off: no voltage control actions Own control on: individual voltage control switched on Follow master control: voltage control is a slave of the master transformer Follow master control; own control standby: voltage control is a slave of the master transformer; if the master control is switched off the individual control will be switched on

1) The default value is chosen equal to the nominal voltage of the transformer winding, which is on the measurement side.

Master-slave regulation with parallel transformers

Master control has to do with the possibility to arrange two parallel transformers according to the "master-slave" principle, so that the tap switches of the transformers always have the same control position. The tap position of the controllers is determined by one transformer (the "Master"). With an independent regulation it can sometimes happen that this is not the case.

- With a single transformer: "Own control present" and "Own control on".
- With two parallel transformers, the choice consists of an independent regulation (both transformers then have "Own control on") or a dependent control. In the case of a dependent master slave control, the following must be specified:

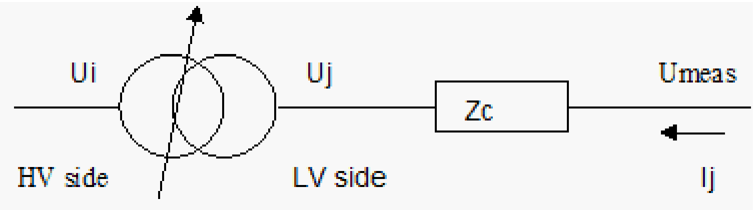
- for the "Master" transformer: "Own scheme present" and "Own scheme on"
- for the "Slave" transformer: "Master control usable"; the name of the "Master" transformer; "Follow master" (the step switch follows that of the master control).

There is another option:
"Follow master scheme, own control standby". This means that the tap switch follows the master control. In case the master control is switched off, the own control is active.

When using master-slave control with parallel transformers, the master's voltage ratio is chosen or approached by the slaves with unequal types.

Current compensation

In load flow calculations, Vision can use the voltage control to determine a correct tap position, taking into account the secondary current (Ij) and a compounding impedance Z_c. The tap position is determined in such a way that the voltage on the measured side (w_1 or w_2) will be within the specified voltage limits $U_{set} \pm ½ * U_{band}$, corrected with the product of Ij and Z_c. The figure below shows an example of transformer with voltage control with tap side w_1 (i), measurement side w_2 (j) and a fictitious measurement point on the w_2 side (note the direction of Ij).



The voltage U_{meas}, on the basis of which the voltage control chooses a different tap, is:

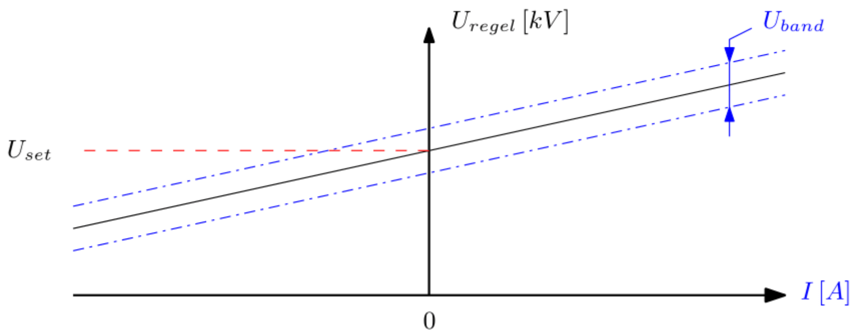
$$U_{meas} = U_j + I_j * Z_c$$

where:

$$Z_c = R_c + jX_c$$

The compounding in Vision takes into account the direction of the current due to the complex multiplication. Note: in practice it can occur that the absolute current value is assumed. In those cases, the model of the voltage regulation will respond differently when it is delivered back than in practice.

If $U_{meas} > U_{max}$ or $U_{meas} < U_{min}$ on the w_2 side, a different tap mode is selected on the w_1 side (until the minimum or maximum tap position is reached).
If the voltage regulation has to compensate the voltage loss over a certain connection, this can be done by indicating a compounding impedance Z_c. The way in which Z_c can be determined from a graph $U = f\,(I)$ is indicated by the following figure.



If Rc/Zc = cos($load$), the following applies:

$$U / I = Z_c$$

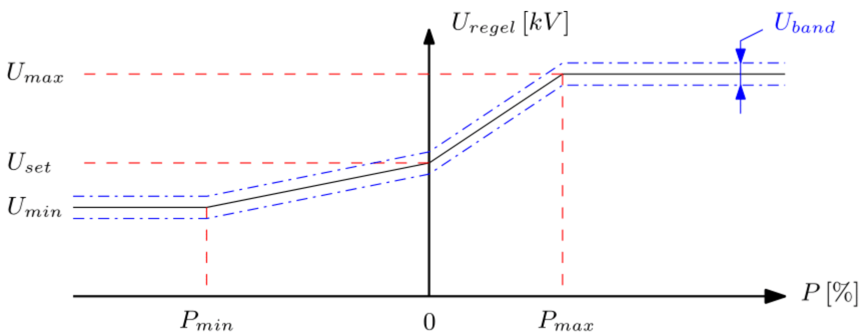
which can be used to determine R_c and X_c:

$$R_c = Z_c * \cos(\varphi)_{load}$$
$$X_c = Z_c * \sin(\varphi)_{load}$$

If the values found for R_c and X_c are given in the form, the transformer voltage will be dependent on the load current.

The dead band is located around the to be controlled voltage. The transformer will not change tap if the measured voltage is between U_{regel} - ½*U_{band} and U_{regel} + ½*U_{band}.

There is also a "load dependent" control.
This can be configured in a more comprehensive way than the compounding. The behaviour can be set separately for upward and downward regulation. The control limits are adjustable and follows the following figure:

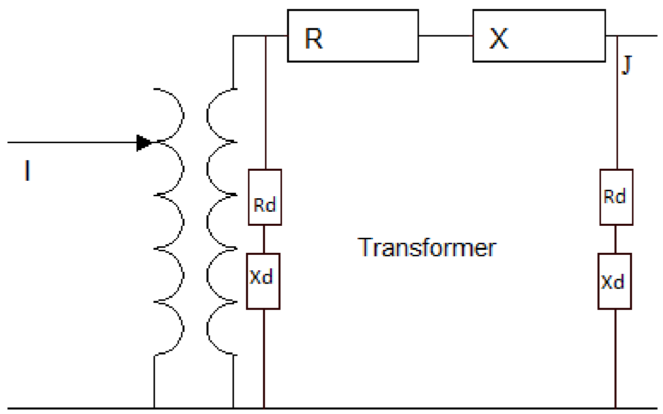


Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the transformer fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the transformer is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

For all the calculations, the transformer is modelled in accordance to the figure shown below, in which R is determined by P_k, and X determined by u_k. The tap changer is usually located on the HV-side (w_1).



The voltage ratio is determined depending on the tap side in accordance with the following:

Tapside w_1: $(U_{nom,w1} + tap_{standardised} * tapsize) / U_{nom,w2}$

Tapside w_2: $U_{nom,w1} / (U_{nom,w2} + tap_{standardised} * tapsize)$

The transformer impedance is determined as follows:

$$Z_{eq} = \frac{u_k}{100} \cdot \frac{U_{nom}^2}{S_{nom}}$$

$$R_T = \frac{{P_k}/{1000}}{S_{nom}} \cdot \frac{U_{nom}^2}{S_{nom}}$$

$$X_T = \sqrt{Z_{eq}^2 - R_T^2}$$

$Y_d = I_{nul} / (1000 * U_{nom,ls}/wortel3)$

$re(Y_d) = P_{nul} / (1000 * U_{nom,ls}^2)$

IEC 60909 and fault analysis

In asymmetrical short-circuit calculations and fault analyses, the inverse impedance is equal to the normal impedance (Z1 = Z2).

Connection

All connection type combinations are supported. However, two sided earthed circuits are not supported because these combinations are not practical. When earthing at two sides is desired, a three windings transformer is used, where the third winding is a Delta type winding to prevent unwanted zero sequence effects.

Connection type, zero sequence and star point impedances are not important when calculating a symmetrical short circuit or a two-phase short circuit without earth contact (FFF or FF).

IEC 60909

A short-circuit calculation in accordance with IEC 60909 262 can be determined using a nominal tap (voltage ratio: $U_{nom,w1} / U_{nom,w2}$) or using the voltage ratio which follows from the set tap.

The voltage control has no influence on IEC 60909 262 calculations. Transformers with voltage control are modelled in the same way as transformers without voltage control.

When a transformer functions as a step-up transformer, this can be stated in the form. In this case, the impedance of a step-up transformer is corrected as follows:

$$R_{step\text{-}up\ transformer} = R_{transformer} * c_{max,LV}$$
$$X_{step\text{-}up\ transformer} = X_{transformer} * c_{max,LV}$$

where:

$c_{max,LV}$ is the maximum voltage factor (including in a minimum short-circuit current calculation) associated with the U_{nom} of the node of the secondary side of the transformer

In the IEC 60909 calculation an impedance correction factor K_T has been introduced for the transformer impedance Z_T.

For the calculation of short circuits with earth contact, it is checked whether: Z0> 0. If not, a warning is generated.

Fault analysis

Transformers with voltage control are modelled for the sequential failure analysis in the same way as transformers without voltage control. However, a load flow calculation is performed to determine the "pre-fault" situation (sequence 0). With this load flow calculation, the step position can be determined by the voltage regulation.

Harmonics

The distributed parameter model is used for calculating harmonics. See: Harmonics: Model 278

5.2.7 Special transformer

Special transformers are objects that require a different modelling than normal transformers. There is a large variety of control transformers, both in terms of voltage levels and the structure.The following are examples of transformers that can be modelled as a special transformer:

- Auto transformer
- Auto booster transformer
- Auto transformer with built in zig-zag coil
- Low Voltage control transformers with continues regulation
- Low Voltage control transformers with rotating regulation

A number of these special transformers are already implemented in Vision. They have in common that the short circuit voltage and the short circuit losses both have a strong relation to the tap position.

PARAMETERS

General

In this form the switches on both sides of the transformer can be opened or closed.

Parameter	Description
Name	Name of transformer
Tap	Actual transformer tap position

The special transformer runs from the **From-node** towards the **To-node**. The **From-node** and the **To-node** of the special transformer are determined automatically. To switch the **From-node** and the **To-node** use the **<>** button.

Transformer

Parameter	Default	Unit	Description
Type			Transformer type
Short name			Short name transformer type for plotting in one line diagram
Sort			Construction type (auto transformer, booster, shunt)
Snom	0	MVA	Nominal apparent power
Unom	1)	kV	Nominal winding voltage
uk	0	%	Relative short circuit voltage
Pk	0	kW	Short circuit loss
Pnul	0	kW	No-load loss
Inul	0	A	No-load current (at low voltage side)
Z0	0	Ohm	Zero sequence impedance; related to the side on which the star point is earthed or, in case of autotransformer, on the primary side (winding 1)
R0	0	Ohm	Zero sequence resistance; related to the side on which the star point is earthed or, in case of autotransformer, on the primary side (winding 1)
Ik 2 s	0	kA	Admissible short circuit current secondary side for 2 seconds
Tapside	w1		Location of the tap changer: winding 1 or 2
Tap size	0	kV	Tap size of the tap changer
Tap min	0		Tap with smallest number of windings
Tap nom	0		Tap with nominal transfer ratio
Tap max	0		Tap with largest number of windings

1) The default value of the nominal voltage is chosen equal to the nominal voltage of the node to which the winding is connected

Type

The type list contains all transformers which have an $U_{nom,w1}$ and $U_{nom,w2}$ between $0.8*U_{nom}$ and $1.2*U_{nom}$ for both nodes.

See also: Type 76

Sort

A number of special transformers are modelled. The possible types which can be chosen are: Yd11 Auto transformer, Y0 Auto transformer, Yn0 Auto transformer, Yn0 Auto transformer asymmetric, Booster transformer, Shunt transformer, Quadrature boost R-S, Quadrature boost R-T, AXA Low Voltage regulator and RELO Low Voltage regulator.

Unom

With a new transformer, the nominal voltage of the nodes concerned is adopted for $U_{nom,w1}$ and $U_{nom,w2}$.

Z0 and R0

Due to the construction the zero sequence impedance resembles that of a normal connection, so it is not dependent on the transformers' tap position. In the model the values for Z_0 and R_0 are interpreted as the zero sequence longitudinal impedances.
An exception is made for the Low Voltage AXA control transformer, where Z_0 and R_0 are used for the zig-zag coil impedance. The AXA zero sequence longitudinal impedance equals the normal longitudinal impedance.

Tap min, nom and max

The indication of the tap position can be defined by the user by indicating the minimum, nominal and maximum tap position. Note that, for example, the minimum tap position can be defined as the tap position at the smallest number of windings and thus (depending on the tap side) can give the largest voltage ratio!

Control transformer

Based on an MS control transformer, with which the asymmetry can be reduced in some (especially above-ground) MS networks, a sort of "YN0, asymmetric auto transformer" has been added. With this transformer, the voltage control is designed such that the tap switches of the three phases can each be controlled independently, so that the voltages of the three individual phases will fall within the desired voltage band. Also, on the "General" tab of the special transformer, each tap can be set manually.

Connection

The earthing of the neutral point of the transformer is defined in the transformer model.

Parameter	Default	Unit	Description
Neutral point	no	no/own	Earthing of the neutral point
Own Re	0	Ohm	Earthing resistance with earthed neutral point
Own Xe	0	Ohm	Earthing reactance with earthed neutral point
Snom'	0	MVA	Maximum apparent power
Phase shift	0	degrees	Phase shift of the transformer windings
For motor start	no		The transformer is used for motor start (see IEC 60909 below)
Lmax (normal)	0	%	Alternative maximum load rating in normal situation; only if different from options
Lmax (failure)	0	%	Alternative maximum load rating in failure situation; only if different from options

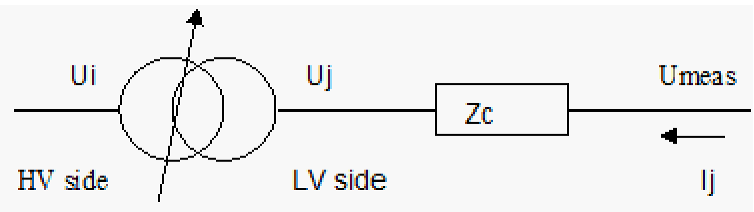
Voltage control

Parameter	Default	Unit	Description
Present	off		Presence
Status	off		Indicates whether the voltage control is active
Meas. side	2		Measuring side of voltage control
Uset	1)	kV	Setpoint of then voltage control
Uband		kV	Deadband of the voltage control
Rc	0	Ohm	Real part of the voltage control compounding impedance
Xc	0	Ohm	Reactive part of the voltage control compounding impedance
Also in backw. direction			Also compounding when the power goes back
Load dependent			Choice for load dependent control
P<<		%	Power below which is regulated at voltage U<<; above: linear between U<< and U<<
U<<		kV	Control voltage at a power less than P<<<
P<	-100	%	Power where on voltage U< is controlled; above: linear between U< and Uset
U<		kV	Control voltage at a power of P<
P>	100	%	Power where on voltage U> is controlled; below it: linear between Uset and U>
U>		kV	Control voltage at a power of P>
P>>		%	Power above which voltage U>> is controlled; below which: linear between U> and U>>
U>>		kV	Control voltage at a power greater than P>>

1) The default value is chosen equal to the nominal voltage of the transformer winding, which is on the measurement side.

Current compensation

In load flow calculations, Vision can use the voltage control to determine a correct tap position, taking into account the secondary current (I_j) and a compounding impedance Z_c. The tap position is determined in such a way that the voltage on the measured side (w_1 or w_2) will be within the specified voltage limits $U_{set} \pm ½ * U_{band}$, corrected with the product of Ij and Z_c. The figure below shows an example of transformer with voltage control with tap side w_1 *(i)*, measurement side w_2 *(j)* and a fictitious measurement point on the w_2 side (note the direction of Ij).



The voltage U_{meas}, on the basis of which the voltage control chooses a different tap, is:

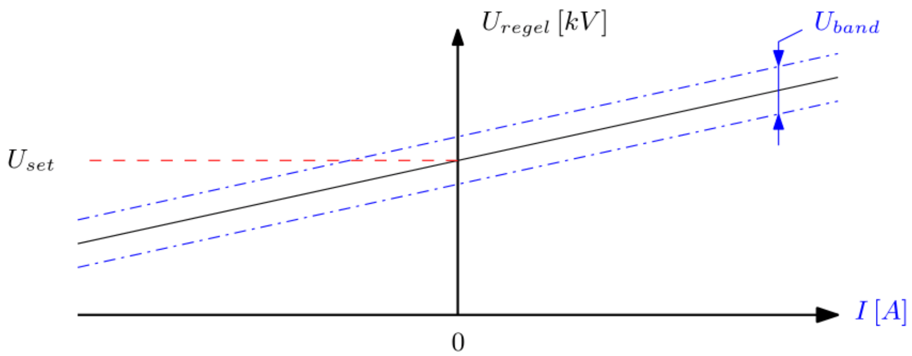
$$U_{meas} = U_j + I_j * Z_c$$

where:

$$Z_c = R_c + jX_c$$

The compounding in Vision takes into account the direction of the current due to the complex multiplication. Note: in practice it can occur that the absolute current value is assumed. In those cases, the model of the voltage regulation will respond differently when it is delivered back than in practice.

If $U_{meas} > U_{max}$ or $U_{meas} < U_{min}$ on the w_2 side, a different tap mode is selected on the w_1 side (until the minimum or maximum tap position is reached).
If the voltage regulation has to compensate the voltage loss over a certain connection, this can be done by indicating a compounding impedance Z_c. The way in which Z_c can be determined from a graph $U = f(I)$ is indicated by the following figure.



If $Rc/Zc = \cos(load)$, the following applies:

$$U / I = Z_c$$

which can be used to determine R_c and X_c:

$$R_c = Z_c * \cos(\varphi)_{load}$$
$$X_c = Z_c * \sin(\varphi)_{load}$$

If the values found for R_c and X_c are given in the form, the transformer voltage will be dependent on the load current.

The dead band is located around the to be controlled voltage. The transformer will not change tap if the measured voltage is between U_{regel} - $½*U_{band}$ and U_{regel} + $½*U_{band}$.

Power control

The types "quadrature boost" and "shunt" can be equipped with power control. The active power is controlled by the load flow within a band, by adjusting the tap position.

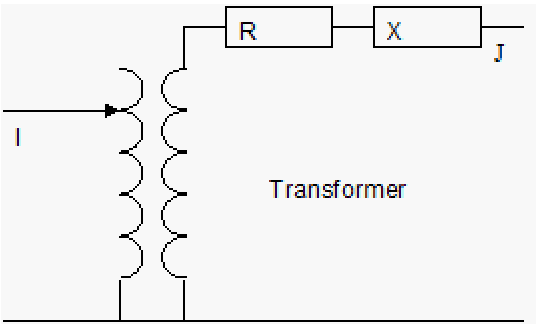
Parameter	Default	Unit	Description
Status	off		Indicates whether the power control is active
Pmin	0	MW	Lower bound of the active power control from the primary to the secondary side
Pmax	0	MW	Upper bound of the active power control from the primary to the secondary side

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the transformer fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the transformer is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

For all calculations, the transformer is modelled in accordance with the figure shown below, in which R is principally determined by P_k, and X principally by u_k. The tap changer is usually located on the primary side (w_1).



The voltage ratio is determined in accordance with the following, depending on the tap side:

$$Tapside\ w1:\ (U_{nom,w1} + tap_{standardised} * tapsize) / U_{nom,w2}$$

$$Tapside\ w2:\ U_{nom,w1} / (U_{nom,w2} + tap_{standardised} * tapsize)$$

Introduction of Inom' and Snom' for branches

For all branches the variables Inom' and Snom' have been introduced for a uniform overload indication in the load flow. For a special transformer the value is obtained as follows:

- Snom' is set to the Snom input or to the special input (formerly Smax)

IEC 60909 and fault analysis

In asymmetrical short-circuit calculations and fault analyses, the inverse impedance is equal to the normal impedance (Z1 = Z2).

IEC 60909

A short-circuit calculation in accordance with IEC 60909 [262] can be determined using a nominal tap (transfer ratio: Unom,w1 /Unom,w2) or using the transfer ratio which follows from the set tap.

The voltage control has no influence on IEC 60909 [262] calculations. Transformers with voltage control are modelled in the same way as transformers without voltage control.

For the calculation of short circuits with earth contact, it is checked whether: Z0> 0. If not, a warning is generated.

If *For motor start* is enabled, the secondary rated voltage of the transformer (eventually corrected with the tap position in case of set tap calculation setting) is used as the c*U_{nom} voltage of the voltage source in case of short circuits at nodes connected to the secondary side of the transformer. The adjustment takes place up to a maximum of three coupled nodes. If more nodes are coupled on the secondary side, an error message is generated. This additional functionality (not explicitly reported in the IEC60909 standard) is useful if the current voltage during motor start differs significantly from the rated voltage of the motor node. Then the short-circuit current also differs significantly from the short-circuit current in the rated situation.

Fault analysis

Special transformers with voltage control are modelled for sequential fault analysis in the same way as special transformers without voltage control. A load flow calculation is carried out to determine the "pre-fault" situation (sequence 0). In this load flow calculation, the tap can be determined via the voltage control.

Harmonics

The distributed parameter model is used for calculating harmonics. See: Harmonics: Model [278]

5.2.8 Three winding transformer

The three-winding transformer is an object that has many embodiments. Thus, due to the combinations of circuits of the windings, many conventional and less common types are conceivable. This chapter deals with the input fields of the three winding transformer.

PARAMETERS

General

The windings of a three-winding transformer are automatically assigned by Vision to the nodes in the grid. The primary winding is always assigned to the node with the highest nominal voltage. The tertiary winding is always assigned to the node with the lowest nominal voltage. In the event that nodes have equal nominal voltages, the windings are assigned in order of user input of the nodes. Thus when 380/50/380 kV is entered and the nodes have this sequence, the primary and secondary windings are 380 kV and the tertiary winding is 50 kV.

Parameter	**Description**
Name	Name of the transformer
Tap	Tap of the regulated and adjustable switch

Three winding transformer

Parameter	Default	Unit	Description
Type			Transformer type
eneral			
Snom	0	MVA	Nominal apparent power
Unom	1)	kV	Nominal winding voltage
Ik (2 s)	0	kA	Admissible short-circuit current for 2 seconds
Connection	2)	D / Y / YN / Z / ZN	Connection of the windings
Clock	2)		Winding to winding configuration
npedances			
uk	0	%	Relative short-circuit voltage
Pk	0	kW	Short-circuit loss
at S		MVA	Uk and Pk reference MVA
Zo	0	Ohm	Zero sequence impedance (see explanation for circuit below)
Ro	0	Ohm	Zero sequence resistance (see explanation for circuit below)
Pnul	0	kW	No-load loss
Inul	0	A	No-load current (at LV side)
ap			
Tap side	w1		Location of the tap changer
Tap size	0	kV	Tap size of the tap changer
Tap min	0		Tap with smallest number of windings
Tap nom	0		Tap with nominal transfer ratio
Tap max	0		Tap with greatest number of windings

1) The default value of the nominal voltage is chosen equal to the nominal voltage of the node to which the winding is connected
2) The default connection and clock number is selected on the basis of the nominal voltage of the respective winding

Unom

With a new three winding transformer, the nominal voltage of the windings $U_{nom,w1}$, $U_{nom,w2}$ and $U_{nom,w3}$ is determined based on the nominal voltage of the connected nodes.

Type

The type list contains all three winding transformers from the component type database for which $U_{nom,w1}$, $U_{nom,w2}$ and $U_{nom,w3}$ are between $0.8*U_{nom}$ and $1.2*U_{nom}$ for all three of the nodes.
See also: Type 76

Clock

The clock number denotes the windings configuration to enable the calculation of phase voltages and phase currents during fault conditions.

at S

The transformer parameters will be calculated from u_k and P_k, using the minimum value of the rated powers of the two related windings. However, if **at S** has been specified for the related parameters, this value will be used instead of the minimum rated power.

Tap min, nom and max

The indication of the tap position can be defined by the user by indicating the minimum, nominal and maximum tap position. Note that, for example, the minimum tap position can be defined as the tap position at the smallest number of windings and thus (depending on the tap side) can give the largest voltage ratio!

Zo and Ro

The starting point for the input of the zero sequence impedances is always a measurement. The measured values can be found in the measurement report of the installed three winding transformer. Depending on the type of connection, the zero sequence impedances are measurable and applicable. Sometimes a single measurement is sufficient (for example with a YNdd-transformer) but sometimes three measurements are required. Sometimes windings have to be shorted when performing the measurements (YN-windings). If a winding for the measurement is shorted, it may be that the value of two parallel-connected windings (for example a shorted YN and a D-winding) is measured.
With 98 of all 125 possible connections, the zero sequence impedance (Z_0) and resistance (R_0) must be entered according to the table below. This also applies to the values in the type file. A measurement can only be performed from a YN-winding or from a ZN-winding. Incidentally, a ZN-winding does not have a continuous zero sequence coupling with the other windings. For each transformer connection, it is indicated in the table below with the aid of a code whether windings are shorted for the measurements. If for a measurement a YN-winding needs to be shorted at the other side, it is indicated by an exclamation mark (for example: measuring winding 1 with winding 2 shorted: w1 -> w2!). A D-winding is by definition always shorted for zero sequence flows and this is not explicitly stated in the code. A measurement from a winding can also be carried out with the two other windings shorted (shorted YN or D). In the network model, these two windings are parallel for the zero sequence flows. This is indicated in the table by // (for example: measuring on winding 1 with winding 2 a shorted YN-winding and winding 3 a D winding: w1 -> w2! // w3).

If, for example, a YNYND-transformer is measured, there are four different ways to measure the zero sequence impedances:

1. measure winding 1, with winding 2 open; in that case, winding 1 and the transformation of winding 3 (triangular winding) are measured (indicated by: w1-> w3).
2. measuring winding 1, with winding 2 shorted; in that case, winding 1 and the transformation of winding 2 (shorted YN) are measured in parallel with winding 3 (triangle winding) (indicated by: w1-> w2! // w3).
3. measure winding 2, with winding 1 open; in that case, winding 2 and the transformation of winding 3 (triangular winding) are measured (indicated by: w 2 -> w 3).
4. measuring winding 2, with winding 1 shorted; in that case, winding 2 and the transformation of winding 1 (shorted YN) are measured in parallel with winding 3 (triangular winding) (indicated by: w2-> w1! // w3).

Only three of the four measurements are needed to derive the zero sequence network model parameters. In the example above, measurements 1, 2 and 3 have been implemented for the YNYND-transformer in the table below.

The table below lists all the measurements that are used to derive the model parameters. The indicated measurement results are entered in the transformer form for the zero sequence impedances.

Connection	Zo_12 and Ro_12	Zo_13 and Ro_13	Zo_23 and Ro_23
YN YN YN	w1->w2!	w1->w3!	w2->w3!
YN YN Y	w1->w2!		
YN YN ZN	w1->w2!		w3
YN YN Z	w1->w2!		
YN YN D	w1->w2!//w3	w1->w3	w2->w3
YN Y YN		w1->w3!	
YN Y Y	w1		
YN Y ZN			w3
YN Y Z	w1		
YN Y D		w1->w3	
YN ZN YN		w1->w3!	w2

Connection	Zo_12 and Ro_12	Zo_13 and Ro_13	Zo_23 and Ro_23
YN ZN Y		w2	
YN ZN ZN		w2	w3
YN ZN Z		w2	
YN ZN D		w1->w3	w2
YN Z YN		w1->w3!	
YN Z Y	w1		
YN Z ZN			w3
YN Z Z	w1		
YN Z D		w1->w3	
YN D YN	w1->w2	w1->w3!//w2	w3->w2
YN D Y	w1->w2		
YN D ZN	w1->w2		w3
YN D Z	w1->w2		
YN D D	w1->w2//w3		
Y YN YN			w2->w3!
Y YN Y		w2	
Y YN ZN			w3
Y YN Z		w2	
Y YN D			w2->w3
Y Y YN			w3
Y Y ZN			w3
Y ZN YN		w2	
Y ZN Y		w2	
Y ZN ZN		w2	w3
Y ZN Z		w2	
Y ZN D		w2	
Y Z YN			w3
Y Z ZN			w3
Y D YN			w3->w2
Y D ZN			w3
ZN YN YN	w1		w2->w3!
ZN YN Y	w1		
ZN YN ZN	w1		w3
ZN YN Z	w1		
ZN YN D	w1		w2->w3
ZN Y YN	w1		
ZN Y Y	w1		
ZN Y ZN	w1		w3
ZN Y Z	w1		
ZN Y D	w1		
ZN ZN YN	w1	w2	
ZN ZN Y	w1	w2	
ZN ZN ZN	w1	w2	w3
ZN ZN Z	w1	w2	
ZN ZN D	w1	w2	
ZN Z YN	w1		
ZN Z Y	w1		
ZN Z ZN	w1		w3
ZN Z Z	w1		
ZN Z D	w1		
ZN D YN	w1		w3->w2
ZN D Y	w1		
ZN D ZN	w1		w3
ZN D Z	w1		
ZN D D	w1		
Z YN YN			w2->w3!
Z YN Y		w2	
Z YN ZN			w3
Z YN Z		w2	
Z YN D			w2->w3
Z Y YN			w3
Z Y ZN			w3
Z ZN YN		w2	
Z ZN Y		w2	
Z ZN ZN		w2	w3
Z ZN Z		w2	
Z ZN D		w2	
Z Z YN			w3
Z Z ZN			w3
Z D YN			w3->w2
Z D ZN			w3

Connection	Zo_12 and Ro_12	Zo_13 and Ro_13	Zo_23 and Ro_23
D YN YN	w2->w1	w3->w1	w2->w3!//w1
D YN Y	w2->w1		
D YN ZN	w2->w1		w3
D YN Z	w2->w1		
D YN D	w2->w1//w3		
D Y YN		w3->w1	
D Y ZN			w3
D ZN YN		w3->w1	w2
D ZN Y		w2	
D ZN ZN		w2	w3
D ZN Z		w2	
D ZN D		w2	
D Z YN		w3-w1	
D Z ZN			w3
D D YN		w3->w1//w2	
D D ZN			w3

Zero sequence impedance for YNyy and YNyz three-windings transformer

In the case of a transformer consisting of one earthed star winding and two non-earthed windings in star or zigzag, the zero sequence impedance of the earthed winding is not neglected. As a result, in networks where these transformers are modelled, a value greater than zero must be entered for the zero sequence impedance of the earthed star winding. By default, the value is always zero, but the value for the zero sequence impedance of a transformer is a factor times the normal impedance. The factor depends on the construction of the core of the transformer. See the table below.

Core construction	factor
Three limps	3 ... 10
Five limps	10 ... 100
Three times one phase	10 ... 100

Connection

Parameter	Default	Unit	Description
Neutral point	own		Earthing of the neutral point with a YN-winding
Re	0	Ohm	Earthing resistance with earthed star point
Xe	0	Ohm	Earthing reactance with earthed star point
Snom'	0	MVA	Maximum apparent power; may differ from Snom
Phase shift w1-w2	0	degrees	Additional phase shift from winding 1 to 2 (between -15 .. +15 degrees)
Phase shift w1-w3	0	degrees	Additional phase shift from winding 1 to 3 (between -15 .. +15 degrees)
Lmax (normal)	0	%	Alternative maximum load rating in normal situation; only if different from options
Lmax (failure)	0	%	Alternative maximum load rating in failure situation; only if different from options

Snom'

The variable **Snom'** has been introduced for a uniform overload indication in the load flow. For a three winding transformer the value is obtained as follows: **Snom1'**, **Snom2'** and **Snom3'** are set to the input values or are taken from the type file.

Voltage control

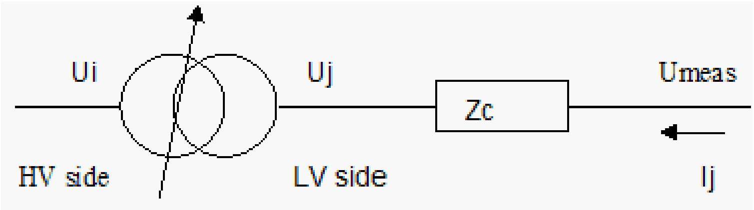
Parameter	Default	Unit	Description
Own control present	off		Indicates whether the transformer is equipped with an individual voltage control
Meas. side	w2		Measuring side of voltage control
Umin	1)	kV	Lower limit of voltage control
Umax	1)	kV	Upper limit of voltage control
Rc	0	Ohm	Real part of the compounding impedance of the voltage control
Xc	0	Ohm	Reactive part of the compounding impedance of the voltage control
Master control usable	off		Transformer taps may follow a master voltage control
Master			Name of master voltage controlling transformer
Status	off		Voltage control activated/deactivated or use of master-slave voltage control: Control off: no voltage control actions Own control on: individual voltage control switched on Follow master control: voltage control is a slave of the master transformer Follow master control; own control standby: voltage control is a slave of the master transformer; if the master control is switched off the individual control will be switched on

1) The default value equals the nominal voltage of the transformer winding, that is connected to the measuring side.

When using master-slave control with parallel transformers, the master voltage ratio is chosen or approximated by the slaves if these are of unequal types.

Current compensation

In load flow calculations, Vision can use the voltage control to determine a correct tap position, taking into account the secondary current (Ij) and a compounding impedance Z_c. The tap position is determined in such a way that the voltage on the measured side (w_1 or w_2) will be within the specified voltage limits $U_{set} \pm ½ * U_{band}$, corrected with the product of Ij and Z_c. The figure below shows an example of transformer with voltage control with tap side w_1 (i), measurement side w_2 (j) and a fictitious measurement point on the w_2 side (note the direction of Ij).



The voltage U_{meas}, on the basis of which the voltage control chooses a different tap, is:

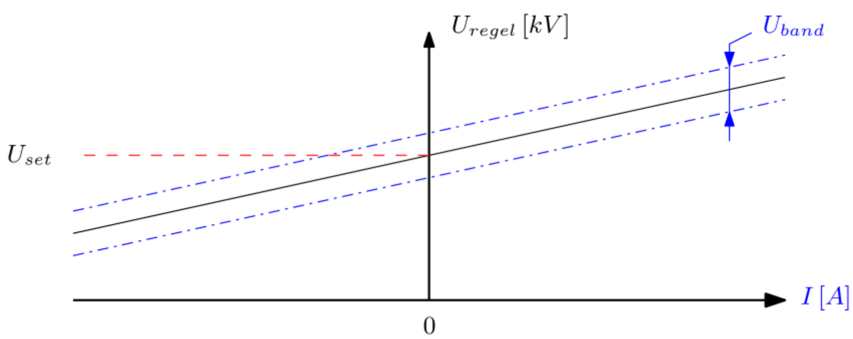
$$U_{meas} = U_j + I_j * Z_c$$

where:

$$Z_c = R_c + jX_c$$

The compounding in Vision takes into account the direction of the current due to the complex multiplication. Note: in practice it can occur that the absolute current value is assumed. In those cases, the model of the voltage regulation will respond differently when it is delivered back than in practice.

If $U_{meas} > U_{max}$ or $U_{meas} < U_{min}$ on the w_2 side, a different tap mode is selected on the w_1 side (until the minimum or maximum tap position is reached).
If the voltage regulation has to compensate the voltage loss over a certain connection, this can be done by indicating a compounding impedance Z_c. The way in which Z_c can be determined from a graph $U = f\,(I)$ is indicated by the following figure.



If $Rc/Zc = \cos(load)$, the following applies:

$$U / I = Z_c$$

which can be used to determine R_c and X_c:

$$R_c = Z_c * \cos(\varphi)_{load}$$
$$X_c = Z_c * \sin(\varphi)_{load}$$

If the values found for R_c and X_c are given in the form, the transformer voltage will be dependent on the load current.

The dead band is located around the to be controlled voltage. The transformer will not change tap if the measured voltage is between U_{regel} - $½*U_{band}$ and U_{regel} + $½*U_{band}$.

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the transformer fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the transformer is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

CALCULATION

IEC 60909 and Fault analysis

In asymmetrical short-circuit calculations and fault analyses, the inverse impedance is equal to the normal impedance ($Z_1 = Z_2$).

The values of R_e, X_e, Z_0 and R_0 are not relevant for the calculation of a symmetrical fault (FFF) or two-phase-fault without earthing (FF).

IEC 60909

A short-circuit calculation in accordance with IEC 60909 262 can be determined using a nominal tap (transfer ratio: Unom w1 /Unom w2) or using the transfer ratio which follows from the set tap.
The voltage control has no influence on IEC 60909 262 calculations. Transformers with voltage control are modelled in the same way as transformers without voltage control.

Fault analysis

Transformers with voltage control are modelled for the sequential failure analysis in the same way as transformers without voltage control. However, a load flow calculation is performed to determine the "pre-fault" situation (sequence 0). With this load flow calculation, the step position can be determined by the voltage regulation.

5.3 Elements

An element represents load or generation at a certain node.

A feeder name can be assigned to an element. The feeder names are defined at the node to which the element is connected.

The following elements are defined:

- Source 172
- Synchronous generator 174
- Synchronous motor 178
- Asynchronous generator 180
- Asynchronous motor 182
- Asynchronous motor group 186
- Wind turbine 196
- PV 199
- Load 188
- Transformer load 190
- Capacitor 192

- Coil 194
- Zigzag transformer 195
- Battery 198

5.3.1 Source

The source is a fictitious network element which is necessary to carry out load flow calculations. The source (swing bus) "supplies" the difference between generation and load, including the network losses, in load flow calculations. The source can thus also be considered for load flow calculations as a connection with an infinitely powerful network. For a calculation on a 10 kV network, for example, it is thus best to incorporate the 150 kV/10 kV supply transformer and place the source on the 150 kV side of the transformer.
In order to enable more realistic performance of short-circuit calculations on a network with a source, the short-circuit power must be given in kA, Ohm or MVA.
Use **Appearance** to switch between the possible short-circuit power indicators.

Only one source can be present at a node.

PARAMETERS

Source

Parameter	Default	Unit	Description
Name			Name
Uref	1	pu	Reference voltage as a factor of Unom
Profile	Default		Name of the voltage profile
Angle	0	degrees	Reference voltage phase angle
Sk"nom	100 * Unom	MVA	Sub-transient short-circuit power
Sk"min	90 * Unom	MVA	Minimum sub-transient short-circuit power
Sk"max	100 * Unom	MVA	Maximum sub-transient short-circuit power
Ik"nom		kA	Sub-transient short-circuit current
Ik"min		kA	Minimum sub-transient short-circuit current
Ik"max		kA	Maximum sub-transient short-circuit current
Znom		Ohm	Impedance
Zmax		Ohm	Maximal impedance
Zmin		Ohm	Minimal impedance
R/X	0 or 0,1		Ratio between source impedance R and X
Z0/Z1	1		Ratio between source impedance zero and normal sequence
Smin	0	MVA	Minimal to be tested power
Smax	0	MVA	Maximal to be tested power

Harmonics

Parameter	Default	Unit	Description
h	3 t/m 99		Harmonic number
Voltage	0	%	Harmonic voltage, relative to rated voltage
Angle	0	degrees	Harmonic voltage angle, relative to load flow voltage

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the source fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences thet the source is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

A network usually has only one source. In Vision it is possible to have several sources, but caution is required. A source has a fixed voltage in size and angle. When multiple sources are connected, different angles might be calculated for the network with respect to practice. In a network consisting of multiple sources, it is best to use only one source. If the grid is powered by an "external grid" at various locations, it is best to work with an equivalent for the external grid, in which only one source is included.

Load flow

U_{ref} can be used to give the voltage of the source in pu. This U_{ref} is a factor of the U_{nom} of the node concerned stated in the source form. The following applies for each node to which a source is added:

$$|U| = U_{ref} * U_{nom\ node}$$

$$angle = angle$$

so that the voltage at the node always remains constant, with the define angle.

During the motor start calculation the source is modelled as an equivalent voltage behind its sub-transient impedance:

$$U_{equivalent} = U_{ref} + I_{load\ flow,pre} * Z_{source}$$

IEC 60909

In IEC 60909 calculations, a source is represented as a passive impedance to earth (IEC 60909, clause 3.2) For the source, the short-circuit power is given in kA or MVA. The impedance of the source is determined in accordance with the formula below. The following applies for the impedance of the source:

$$Z_{source} = c * U_{nom} / (\sqrt{3} * I_k'')$$

where:

c	the voltage factor c_{max} or c_{min} (depending on minimum or maximum short-circuit current calculation) associated with the U_{nom} of the node of the source.
I_k''	the sub-transient short-circuit current of the source

With asymmetrical short-circuits, the normal impedance is equal to the inverse impedance ($Z_1 = Z_2$). The zero sequence impedance Z_0 is determined using the ratio $I_k''_3/I_k''_1$:

$$\frac{I''_{k3}}{I''_{k1}} = \frac{Z_0 + 2Z_1}{3Z_1}$$

This can be rewritten as:

$$\frac{Z_0}{Z_1} = 3\frac{I''_{k3}}{I''_{k1}} - 2$$

Fault analysis

In the sequential fault analysis, the source is represented as a Norton equivalent. The R/X ratio of the source impedance is determined in the same way as in an IEC 60909 calculation.
I_k'' is used to determine the short-circuit power of the source instead of $I_k''_{max}$ or $I_k''_{min}$.

5.3.2 Synchronous generator

PARAMETERS

General

Parameter	Default	Unit	Description
Name			Name of generator
Pref	0	MW	Set actual power
Profile	Default		Name of the generator power profile
f/P-droop	0	%	Governor droop (island mode)
cos phi	0.85		Power factor
Q	supply		Reactive power direction (supply / absorb)
Uref	1	pu	Reference voltage of voltage as a factor of Unom of the node
U/Q-static	0	%	Voltage-reactive power static
Q-limit			Q control limit application
Other control node			Voltage control based on other node

Generator

Parameter	Default	Unit	Description
Type			Generator type
Unom	1)	kV	Nominal voltage of the generator
Snom	0	MVA	Nominal apparent power
cos phi nom	0.85		Nominal cos phi
Qmin	0	Mvar	Lower limit for the reactive power to be supplied
Qmax	0	Mvar	Upper limit for the reactive power to be supplied
xd"	0.2	pu	Sub-transient reactance 2)
rg	0	pu	Fictitious resistance
Excitation	rotating		excitation system: rotating / static, not terminal fed / static, terminal fed
Rotor	turbo		rotor: turbo / salient pole
IkP	0	kA	maximum stationary short-circuit current
Uf,max	1.3	pu	maximum excitation voltage
Xd,sat	1.6	pu	Saturated synchronous reactance

1) The default value equals the nominal voltage of the node
2) For the calculation of short-circuit currents the saturated value of x_d" is taken

Type

The type list contains all generators from the component type database, where the U_{nom} of the generator varies between 80 and 120% of the U_{nom} of the node. See also: Type 76.

Excitation, Uf,max and xd,sat

The implementation of the excitation and the construction of the rotor is used for calculating the stationary short-circuit current according to IEC 60909. The data on the maximum stationary short-circuit current (I_{kP}), the maximum excitation voltage ($U_{f,\ max}$) and the saturated synchronous reactance ($x_{d,\ sat}$) are also required.

- For cylindrical rotor generators: $U_{f,max}$ is 1.3 or 1.6 pu. and $x_{d,sat}$ between 1.2 and 2.2 pu.
- For salient pole generators: is $U_{f,max}$ 1.6 or 2.0 pu. and $x_{d,sat}$ between 0.6 and 2.0 pu.

Connection

Parameter	Default	Unit	Description
Star point earthing	no		Indicates whether the star point is earthed
Re	0	Ohm	Earthing resistance with earthed star point
Xe	0	Ohm	Earthing reactance with earthed star point
External node			Node with neutral earth connection
Pnom'		MW	Maximal real power; supplementary to Snom

External node

Possibility to connect the neutral point of the generator to the earthing electrode at another node .

PQ-diagram

Parameter	Default	Unit	Description
P	0	MW	Active power points of the generator capability diagram
Qlimit	0	Mvar	Reactive power points of the generator capability diagram

Dynamics

Parameter	Default	Unit	Description
Rotor	turbo		Rotor type
Rg	0	pu	Stator resistance
Xl	0	pu	Leakage reactance
Xd	0	pu	Synchronous reactance, d-as
Xq	0	pu	Synchronous reactance, q-as
X0	0	pu	Zero sequence reactance
Xd'	0	pu	Transient reactance, d-as
Xq'	0	pu	Transient reactance, q-as
Xd"	0,2	pu	Sub-transient reactance, d-as
Xq"	0	pu	Sub-transient reactance, q-as
Type	short-circuit		Time constant type
Td'	0	s	Transient time constant, d-as
Tq'	0	s	Transient time constant, q-as
Td"	0	s	Sub-transient time constant, d-as
Tq"	0	s	Sub-transient time constant, q-as
H	0	s	Inertia
KD	0	pu	Mechanical damping constant

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the generator fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences thet the generator is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

Load flow

Cos-phi controlled synchronous generator:

In a load flow calculation, a synchronous generator with cos-phi control is represented as a negative constant power load:

$$P_{load} = -P_{ref}$$

and

$$Q_{load} = -P_{ref} * \sqrt{(1 - \cos(phi)^2)} / \cos(phi) \quad (capacitive)$$

or

$$Q_{load} = +P_{ref} * \sqrt{(1 - \cos(phi)^2)} / \cos(phi) \quad (inductive)$$

Voltage controlled synchronous generator:

U_{ref} is used to give the voltage at the node in pu and is a factor of the U_{nom} of the node given in the form. The following applies:

$$|U| = U_{ref} * U_{nom,node}$$

The voltage control determines the reactive power output (within the limits Q_{min} and Q_{max}) to obtain the voltage U_{ref}.

the Voltage-Reactive power droop is taken into account here. The trend of the function $U = f(Q_{generator})$ with droop and the limits Q_{min} and Q_{max} is shown in the graph $U = f(Q_{generator})$ in the form.

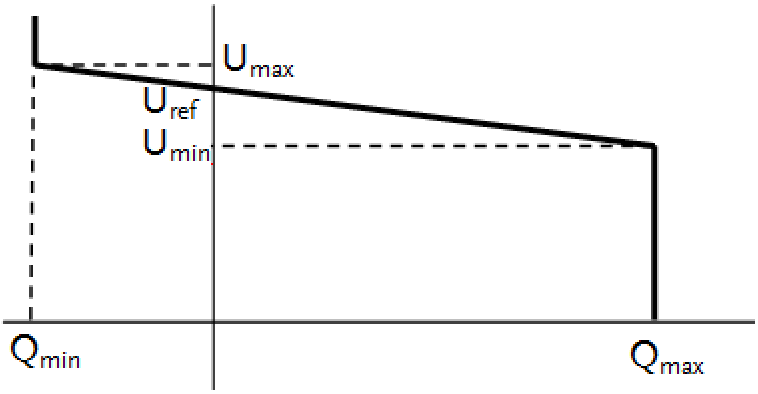
The following applies for a load flow calculation:

$P_{generator}$ equals P_{ref}

$Q_{generator}$ depends on U_{ref}, Q_{min}, Q_{max} and the voltage-reactive power droop and follows from the state of the network.

If $Q_{generator}$ is within the limits Q_{min} and Q_{max}, then $U_{generator}$ will be between U_{min} and U_{max}. The relationship between U and Q is then given by the U/Q-droop:

$$droop = - (dU / U_{nom}) / (dQ / S_{nom}) * 100\%$$



For a 10 MVA generator with a U/Q-droop of 10% at a node with a voltage of 10 kV, this means the following: At a voltage dip of 0.1 kV, the generator will supply 1 Mvar of additional reactive power.

If several generators with voltage control are present at a single node, an "average" U_{ref} is determined in proportion to S_{nom}.

If the value of the U/Q-droop is not specified (thus: zero), a value of 0,1% will be used in the calculations for numerical reasons.

Island mode

A synchronous generator with governor control and voltage control can participate to the regulation in island mode. For efficient regulation, the governor droop must be larger than zero and the summed capacity (P and Q) of all participating generators must be sufficient for the system load.
Synchronous generators with a zero governor droop are considered as constant power generators and do not contribute to the frequency control. Also generators with a fixed cos-phi control do not contribute.
For more information, see: Loadflow: Island mode 250.

Motor start

During the motor start calculation the synchronous generator is modelled as an equivalent voltage behind its sub-transient impedance:

$$U_{equivalent} = U_{ref} + I_{load\ flow,pre} * Z_{generator}$$

IEC 60909

In modelling of synchronous generators, a distinction is made between the following three cases in accordance with IEC 60909:

- generators directly connected to the network
- generators connected to the network via a step-up transformer
- power station unit (PSU), whereby the impedance of generator and step-up transformer is considered as a whole

The latter possibility is not supported in Vision. However, it is possible to incorporate a generator into the network via an extra node and a step-up transformer (whether a transformer functions as a step-up transformer is indicated in the transformer form). Where a step-up transformer is used, U_{nom} of the generator must be equal to U_{nom} of the node.

In IEC 60909 calculations, a synchronous generator is represented as a passive impedance to earth. (IEC 60909, clause 3.6)

This impedance is corrected with a factor K. This correction is significant, as the network load is not taken into consideration in IEC 60909. The factor K is determined as follows:

$$K = c_{max} * (U_{nom,node} / U_{nom,generator}) / (1 + Xd'' * \sin(phi)_{nom}))$$

where:

c_{max} maximum voltage factor (including in a minimum short-circuit current calculation) associated with the U_{nom} of the generator node

Xd'' saturated sub-transient reactance of the generator (pu)

The R_g of the generator, as can be indicated in the generator form, is used exclusively for the sequential fault analysis. For IEC 60909 calculations, R_g is derived from X_d". Depending on the nominal generator voltage and the nominal power, the following apply for $R_{generator}$ and $X_{generator}$:

$U_{nom,generator} <= 1$ kV: $R_{generator} = K \cdot 0.15 * Xd''$
$X_{generator} = K \cdot Xd''$

$U_{nom,generator} > 1$ kV:
$S_{nom} < 100$ MVA: $R_{generator} = K \cdot 0.07\ Xd''$
$X_{generator} = K \cdot Xd''$
$S_{nom} >= 100$ MVA: $R_{generator} = K \cdot 0.05\ Xd''$
$X_{generator} = K \cdot Xd''$

For synchronous generators, in contrast to static network components, the normal impedance differs from the inverse impedance (Z_2 not equal to Z_1). For the two-pole synchronous machine, however, Z_2 is approximately equal to Z_1.
IEC 60909 makes no specification for inverse impedances (modelling of inverse impedances is currently in preparation), so that Vision also applies $Z_2 = Z_1$ here.
The zero sequence impedance Z_0 is infinite with a floating neutral point and $3*R_e+j(3*X_e + 0.5*X_1)$ with an earthed neutral point.

Fault analysis
In the sequential fault analysis, the synchronous generator is represented as a Norton equivalent. The following applies for the source impedance of this equivalent:

$$Z_{generator} = R_g + jX_d''$$

For the inverse impedance, the following applies: $Z_2 = Z_1$.
The zero sequence impedance Zo is infinite with a floating neutral point and $3*R_e+j(3*X_e + 0.5*X_1)$ with an earthed neutral point.

5.3.3 Synchronous motor

PARAMETERS

General

Parameter	Default	Unit	Description
Name			Name of the motor
Pref	0	MVA	Set real power
Profile	Default		Name of the motor power profile
cos phi	0.85		Set power factor
Q	absorb		Reactive power direction (absorb / supply)

Motor

Parameter	Default	Unit	Description
Type			Type of the motor
Unom	1)	kV	Nominal voltage of the motor
Snom	0	MVA	Nominal apparent power
cos phi nom	0.85		Nominal cos phi
xd"	0.2	pu	Sub-transient reactance 2)
rg	0	pu	Fictitious resistance
R/X			
Ia/Inom			

1) Unom of the node. In case a step up transformator is applied Unom must be equal to Unom of the node.
2) For the calculation of the short-circuit current the saturated value of x_d" is taken

Type

The type list contains all generators from the component type database with a U_{nom} of 80 - 120% of the node nominal voltage. See also: Type 76

Connection

Parameter	Default	Unit	Description
Star point earthing	none		Indicates whether the star point is earthed
Re	0	Ohm	Earthing resistance with earthed star point
Xe	0	Ohm	Earthing reactance with earthed star point
External node			Name of the external node with a common ground
No SC contribution	no	yes/no	Indicator that the machine does not contribute to a short-circuit (in case of inverter connected synchronous motor)

External node

Possibility to connect the neutral point of the generator to the earthing electrode at another node .

No SC contribution

Can be used to make the motor act like a load during a fault analysis or IEC 60909 calculation.

Dynamics

Parameter	Default	Unit	Description
Rotor	turbo		Rotor type
Rg	0	pu	Stator resistance
Xl	0	pu	Leakage reactance
Xd	0	pu	Synchronous reactance, d-as
Xq	0	pu	Synchronous reactance, q-as
X0	0	pu	Zero sequence reactance
Xd'	0	pu	Transient reactance, d-as
Xq'	0	pu	Transient reactance, q-as
Xd"	0,2	pu	Sub-transient reactance, d-as
Xq"	0	pu	Sub-transient reactance, q-as
Type	short-circuit		Time constant type
Td'	0	s	Transient time constant, d-as
Tq'	0	s	Transient time constant, q-as
Td"	0	s	Sub-transient time constant, d-as
Tq"	0	s	Sub-transient time constant, q-as
H	0	s	Inertia
KD	0	pu	Mechanical damping constant

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the motor fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences thet the motor is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

Loadflow

In load flow calculations, a synchronous generator with cos phi control is represented as a negative load.

$$P_{load} = P_{ref}$$

and

$$Q_{load} = P_{ref} * \sqrt{(1 - \cos(\varphi)^2)} / \cos(\varphi) \qquad (absorb)$$

or

$$Q_{load} = - P_{ref} * \sqrt{(1 - \cos(\varphi)^2)} / \cos(\varphi) \qquad (supply)$$

Motor start

The starting current to rated current ratio is equal to $1/(R_g+X_d")$.

IEC 60909 and Fault analysis

Modelling of the synchronous generator with cos-phi control is identical to modelling of a synchronous generator with voltage control 174.

IEC 60909 minimum short circuit calculation without synchronous motors

In the calculation of $I_k"_{min}$ according to IEC 60909 the partial short circuit current from synchronous motors is neglected. This is in accordance with neglecting the partial short circuit current of asynchronous motors.

5.3.4 Asynchronous generator

PARAMETERS

General

Parameter	Default	Unit	Description
Name			Name
Pref	0	MW	Actual electrical power
Profile	Deafult		Name of the generator power profile

Generator

Parameter	Default	Unit	Description
Type			Generator type
Unom	1)	kV	Nominal voltage
Pnom	0	MW	Rated electrical power
Cos phi nom	0.85		Power factor at nominal power
R/X	0.1		R/X ratio
Is/Inom	5		Quotient of starting current and nominal current
Poles	2		Number of poles

1) Unom of the node. Also with a step up transformer Unom must equal Unom of the node.

Type

The type list contains all asynchronous generators from the component type database with a U_{nom} between the 80 and 120% of the U_{nom} of the node. See also: Type 76.

Cos-phi nom

After a modification of the nominal power factor (cos phi) the curve has to be adapted. If the curve is not adapted, the model parameters of the machine can not be determined with sufficient accuracy. Also it can occur that the curve fitting process can not find the correct model parameters (P-cos-curve does not fit).

Curve

The curve describe the behaviour of the machine (cos phi) for other then nominal loads. Each modification is directly graphically reflected in the curve.

Parameter	Default	Unit	Description
Standard curve			Button to use a predefined standard curve, corresponding to the specified nominal power factor
P	array	pu	Electrical power nominal value and 4 user specified points of the curve
Cos phi = f(P)	array		Power factor as a function of rated power

The asynchronous machine parameters are determined using the power factor curve. Using curve fitting, the Heyland-diagram will be constructed, from which the internal impedances follow. For more information, see: http://www.phasetophase.nl/pdf/Asynchronous_machine_model.pdf.

To simplify the addition of an asynchronous generator, default values are given in the form for most parameters. These values will be adequate in most cases. As the function $cos(phi) = f(P_{e,ref}/P_{e,nom})$ is known for an asynchronous generator, this can be given if necessary. At least three points must be given for this function. After exiting the form via **OK**, curve fitting is performed on the entered points. In case the curve fitting fails, a message will pop-up to indicate this.

Connection

Parameter	Default	Unit	Description
Star point earthing	no		Indicates whether the star point is earthed
Re	0	Ohm	Earthing resistance with earthed star point
Xe	0	Ohm	Earthing reactance with earthed star point

Dynamics

Parameter	Default	Unit	Description
Locked rotor torque	0	%	
Critical torque	0	%	
Nominal speed	0	rpm	
Nominal efficiency	0	%	
Inertia	0	kg*m²	
k2	0	%	
k1	0	%	
k0	0	%	
Model			
User-defined parameters			
Rs	0	pu	
Rr	0	pu	
Rr2	0	pu	
Xsl	0	pu	
Xrl	0	pu	
Xr2l	0	pu	
Xm	0	pu	

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the generator fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences thet the generator is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

Load flow

The Heyland-diagram is used as a basis for load flow calculations. This is determined from the curve $Cos(phi) = f(P)$ via curve fitting. The actual power is kept constant:

$$P_{load} = - P_{e\ ref}$$

Q_{load} depends on the Heyland-diagram and the node voltage.

IEC 60909

In IEC 60909 calculations, an asynchronous generator is represented as a passive impedance in the form of R + jX to earth.

This impedance is determined using the nominal voltage, the starting current, the rated power and the number of pole pairs. The generator impedance is then determined in accordance with the following:

$$Z_{generator} = (U_{nom\ generator})^2 / (I_a/I_{nom} * P_{e\ nom} / cos(phi)_{nom})$$

The R/X ratio depends on the power per number of pole pairs:

$$P_{nom} / (number\ of\ pole\ pairs) = P_{nom} * (speed / nmax)$$

where:

$n_{max} =$ 3000 r/min. at 50 Hz

After which the following is determined using the nominal generator voltage and the power per number of pole pairs R and X:

$U_{nom\ generator}$ <= 1 kV:

$X_{generator} = 0.992 * Z_{generator}$

$R_{generator} = 0.42 * Z_{generator}$

$U_{nom\ generator}$ > 1 kV:

P_{nom} / (number of pole pairs) < 1 MW:

$X_{generator} = 0.989 * Z_{generator}$

$R_{generator} = 0.15 * X_{generator}$

P_{nom} / (number of pole pairs) >= 1 MW:

$X_{generator} = 0.995 * Z_{generator}$

$R_{generator} = 0.10 * X_{generator}$

For rotating machines, in contrast to static network components, normal impedance generally differs from inverse impedance (Z_2 not equal to Z_1). For the asynchronous generator, however, Z_2 is approximately equal to Z_1. In accordance with IEC 60909, Vision applies $Z_2 = Z_1$.

The zero sequence impedance Z_0 is assumed to be infinite (floating neutral point).

Fault analysis

In sequential fault analysis, the asynchronous generator is represented as a Norton equivalent circuit. The source impedance of this equivalent is determined in the same way as in an IEC 60909 calculation.

5.3.5 Asynchronous motor

PARAMETERS

General

Parameter	Default	Unit	Description
Name			Name
Pshaft	0	MW	Actual mechanical power
Profile	Default		Name of the motor power profile

Motor

Parameter	Default	Unit	Description
Type			Motor type
Unom	1)	kV	Nominal voltage
Pshaft nom	0	MW	Rated mechanical power
Efficiency	95	%	Efficiency at nominal power
Cos phi nom	0.85		Power factor at nominal power
R/X	0.1		R/X ratio (for short-circuit studies)
cos phi start	0.1		Power factor during motor start (for short-circuit studies)
Is/Inom	5		Quotient of starting current and nominal current
Poles	2		Number of poles

1) Unom of the node. Also with a step up transformer Unom must equal Unom of the node.

Type

The type list contains all asynchronous generators from the component type database with a U_{nom} between the 80 and 120% of the U_{nom} of the node.
See also: Type 76.

Efficiency and Cos-phi nom

After a modification of the efficiency or the nominal power factor (cos-phi) the curves must be adapted. If the curves are not adapted, the model parameters of the machine can not be determined with sufficient accuracy.

Also it can occur that the curve fitting process can not find the correct model parameters (P-cos-efficiency curve does not fit).

R/X and Cos-phi during motor start

The cos-phi during a motor start is calculated from the R/X ratio and vice versa.

Is/Inom

The quotient of the starting and nominal currents is used for the motor impedance calculation. This value will not be used for the motor starting calculation.

Curves

The curves describe the behaviour of the machine (efficiency and cos-phi) for other then nominal loads. Each modification is directly graphically reflected in the curves.

Parameter	Default	Unit	Description
Standard curve			Button to use a predefined standard curve, corresponding to the specified nominal efficiency and power factor
Pshaft	array	pu	Mechanical power nominal value and 4 user specified points of the curves
Efficiency = f(Pshaft)	array	%	Efficiency as a function of rated mechanical power
Cos phi = f(Pshaft)	array		Power factor as a function of rated mechanical power

The asynchronous machine parameters are determined using the efficiency and power factor curves. Using curve fitting the Heyland-diagram will be constructed, from which the internal impedances follow. For more information, see: http://www.phasetophase.nl/pdf/Asynchronous_machine_model.pdf.

To simplify the addition of an asynchronous motor, default values are given in the form for most parameters. These values will be adequate in most cases. As the function $cos(phi) = f(P_{e,ref}/P_{e,nom})$ is known for an asynchronous motor, this can be given if necessary. At least three points must be given for this function. After exiting the form via **OK**, curve fitting is performed on the entered points. In case the curve fitting fails, a message will pop-up to indicate this.

Connection

Parameter	Default	Unit	Description
Motor starter	direct		Motor start configuration: direct on line (DOL); always short-circuit contribution soft starter; always short-circuit contribution VSDS (variable speed drive system); short-circuit contribution is optional
Is/Inom	5		Quotient of starting current and nominal current; to be used for motor start
No SC contribution	no	yes/no	No contribution to a short circuit
Star point earthing	no		Indicates whether the star point is earthed
Re	0	Ohm	Earthing resistance with earthed star point
Xe	0	Ohm	Earthing reactance with earthed star point

Starter

There are three possible configurations:

- direct on line (DOL): I_s/I_{nom} has the same value as specified on the Motor input tab; the motor always has a contribution to a short-circuit
- soft starter: I/I_{nom} is smaller than the value of I_s/I_{nom} as specified on the Motor input tab; the motor always has a contribution to a short-circuit
- Converter (VSDS, variable speed drive system): I_s/I_{nom} has a value of about 1; the motor contribution to a short-circuit is optional

Is/Inom

The quotient of the starting and nominal currents is used for the motor starting calculation. This value may differ from the quotient I_s/I_{nom} from the motor data, e.g. for modelling a soft starter.

No SC contribution

This prohibits an asynchronous motor to contribute to a short circuit. If enabled, the motor is modelled as a load in the short circuit calculation.

Dynamics

Parameter	Default	Unit	Description
Locked rotor torque	0	%	
Critical torque	0	%	
Nominal speed	0	rpm	
Inertia	0	kg*m²	
k2	0	%	
k1	0	%	
k0	0	%	
Model			
User-defined parameters			
Rs	0	pu	
Rr	0	pu	
Rr2	0	pu	
Xsl	0	pu	
Xrl	0	pu	
Xr2l	0	pu	
Xm	0	pu	

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the motor fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences thet the motor is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

Harmonics

Application of a harmonics type. See: Harmonics, Calculation 282.

MODELLING

Load flow

The Heyland-diagram is used as a basis for load flow calculations. This is determined from the curves $Efficiency = f(Pm)$ and $Cos(\varphi) = f(Pm)$ via curve fitting. The actual power is kept constant:

$P_{load} = - P_{e\ ref}$

Q_{load} is dependent on the Heyland-diagram and the node voltage.

IEC 60909

Asynchronous motors contribute to the initial symmetrical short-circuit current I_k'', to the peak short-circuit current i_p, to the symmetrical short-circuit breaking current I_b and, for unbalanced short circuits, also to the steady-state short-circuit current I_k.

Reversible static converter-fed drives are considered for three-phase short circuits only, if the rotational masses of the motors and the static equipment provide reverse transfer of energy for deceleration at the time of the short circuit. Then they contribute only to the initial symmetrical short-circuit current I_k'' and to the peak short-circuit current i_p. They do not contribute to the symmetrical short-circuit breaking current I_b and the steady-state short-circuit current I_k.

The next table summarises the contribution to a short-circuit current.

Asynchronous motor	IEC 60909 clause	ip	Ik"max	Ik"min	Ib	Ik
Without converter	3.8.1	+	+	-	+	+
Converter, reversible	3.9	+	+	-	-	-
Converter, not reversible	3.9	-	-	-	-	-

In IEC 60909 calculations, an asynchronous motor with generating capacity (enabling possible contribution to a short circuit) is represented as a passive impedance in the form of $R + jX$ to earth. (IEC 60909, clause 3.8)

This impedance is determined using the nominal voltage, the starting current, the nominal (mechanical) power and the number of pole pairs. The power is given in electrical terms in Vision, so that the following applies for electrical power:

$$P_{e\ nom} = P_{m\ nom} / Efficiency$$

The motor impedance is then determined in accordance with the following:

$$Z_{motor} = (U_{nom\ motor})^2 / (I_a/I_{nom} * P_{e\ nom} / cos(\varphi)_{nom})$$

The R/X ratio is dependent on the (mechanical) power per number of pole pairs:

$$P_{m\ nom} / (number\ of\ pole\ pairs) = P_{m\ nom} * (\ speed / n_{max}\ )$$

where:

$nmax = 3000\ r/min.$ at $50\ Hz$

After which the following is determined using the nominal motor voltage and the power per number of pole pairs R and X:

$U_{nom\ motor} <= 1\ kV$:

$$X_{motor} = 0.992 * Zmotor$$
$$R_{motor} = 0.42 * Zmotor$$

$U_{nom\ motor} > 1\ kV$:

$P_{nom\ mech} / (number\ of\ pole\ pairs) < 1\ MW$:

$$X_{motor} = 0.989 * Z_{motor}$$
$$R_{motor} = 0.15 * X_{motor}$$

$P_{nom\ mech} / (number\ of\ pole\ pairs) >= 1\ MW$:

$$X_{motor} = 0.995 * Z_{motor}$$
$$R_{motor} = 0.10 * X_{motor}$$

For rotating machines, in contrast to static network components, normal impedance generally differs from inverse impedance (Z_2 not equal to Z_1). For the asynchronous motor, however, Z_2 is approximately equal to Z_1. In accordance with IEC 60909, Vision applies $Z_2 = Z_1$.

The zero sequence impedance Z_0 is assumed to be infinite (floating neutral point).

Fault analysis

In sequential fault analysis, the asynchronous motor is represented as a Norton equivalent. The source impedance of this equivalent is determined in the same way as in an IEC 60909 calculation.

5.3.6 Asynchronous motor group

PARAMETERS

General

Parameter	Default	Unit	Description
Name			Name
Number of motors	0		Number of motors in the group
Number in service	0		Number of motors in service in the group
Load rate	100	%	Load factor of motors that are in service
Profile	Default		Name of the motor group power profile

Number in service

Only motors that are in service, are connected to the grid. Out of service motors have are not taken into account in the calculations.

Load factor

The load factor applies to all motors that are in service. A load factor of 0% means the motors are running at no-load (without losses).

Motor

Parameter	Default	Unit	Description
Type			Motor type
Unom	1)	kV	Nominal voltage
Pshaft nom	0	MW	Rated mechanical power
Efficiency	95	%	Efficiency at nominal power
Cos phi nom	0.85		Power factor at nominal power
R/X	0.1		R/X ratio (for short-circuit studies)
Is/Inom	5		Quotient of starting current and nominal current
Poles	2		Number of poles

1) Unom of the node. Also with a step up transformer Unom must equal Unom of the node.

Type

The type list contains all the asynchronous motors from the component type database.
See also: Type 76.

Efficiency and Cos phi nom

After a modification of the efficiency or the nominal power factor (cos-phi) the curves must be changed. If the curves are not changed, the model parameters of the machine can not be determined with sufficient accuracy. Also it can occur that the curve fitting process cannot find the correct model parameters. In that case an error will be generated: P-cos-efficiency curve does not fit.

Curves

The curves describe the behaviour of the machine (efficiency and cos-phi) for other then nominal loads. Each modification is directly graphically reflected in the curves.

Parameter	Default	Unit	Description
Standard curve			Button to use a predefined standard curve, corresponding to the specified nominal efficiency and power factor
Pshaft	array	pu	Mechanical power nominal value and 4 user specified points of the curves
Efficiency = f(Pshaft)	array	%	Efficiency as a function of rated mechanical power
Cos phi = f(Pshaft)	array		Power factor as a function of rated mechanical power

The asynchronous machine parameters are determined using the efficiency and power factor curves. Using curve fitting the Heyland-diagram will be constructed, from which the internal impedances follow. For more information, see: http://www.phasetophase.nl/pdf/Asynchronous_machine_model.pdf.

To simplify the addition of an asynchronous motor, default values are given in the form for most parameters. These values will be adequate in most cases. As the function $cos(phi) = f(P_{e,ref}/P_{e,nom})$ is known for an asynchronous motor, this can be given if necessary. At least three points must be given for this function. After exiting the form via **OK**, curve fitting is performed, and an error is generated if this fails.

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the motor group fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences thet the motor group is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

Load flow

The Heyland-diagram is used as a basis for load flow calculations. This is determined from the curves $Efficiency = f(P_m)$ and $Cos(\varphi) = f(P_m)$ via curve fitting. The actual power is kept constant:

$$P_{load} = P_{m,nom} * Number\ in\ service * Load\ factor / 100\%$$

Q_{load} depends on the Heyland-diagram and the node voltage.

IEC 60909

Asynchronous motors contribute to the initial symmetrical short-circuit current I_k'', to the peak short-circuit current i_p, to the symmetrical short-circuit breaking current I_b and, for unbalanced short circuits, also to the steady-state short-circuit current I_k.
Reversible static converter-fed drives are considered for three-phase short circuits only, if the rotational masses of the motors and the static equipment provide reverse transfer of energy for deceleration at the time of the short circuit. Then they contribute only to the initial symmetrical short-circuit current I_k'' and to the peak short-circuit current i_p. They do not contribute to the symmetrical short-circuit breaking current I_b and the steady-state short-circuit current I_k.
The next table summarises the contribution to a short-circuit current.

Asynchronous motor	IEC 60909 clause	ip	Ik"max	Ik"min	Ib	Ik
Without converter	3.8.1	+	+	-	+	+
Converter, reversible	3.9	+	+	-	-	-
Converter, not reversible	3.9	-	-	-	-	-

In IEC 60909 calculations, an asynchronous motor is represented as a passive impedance in the form of $R + jX$ to earth. (IEC 60909, paragraph 3.8)

This impedance is determined using the nominal voltage, the starting current, the nominal (mechanical) power and the number of pole pairs. The nominal power is given in electrical terms in Vision, so that the following applies for electrical power:

$$P_{e,nom} = P_{m,nom} / Efficiency$$

The motor impedance is then determined in accordance with the following:

$$Z_{motor} = (U_{nom,motor})^2 / (I_a/I_{nom} * P_{e\ nom} / cos(\varphi)_{nom})$$

The total motor group impedance is calculated by the parallel connection of all separate impedances of the motors that are in service.

The R/X ratio is dependent on the (mechanical) power per number of pole pairs:

$$P_{m\ nom} / (number\ of\ pole\ pairs) = P_{m\ nom} * (speed / n_{max})$$

where:

n_{max} = 3000 r/min. at 50 Hz

After which the following is determined using the nominal motor voltage and the power per number of pole pairs R and X:

$U_{nom\ motor} <= 1\ kV$:

$X_{motor} = 0.992 * Z_{motor}$

$R_{motor} = 0.42 * Z_{motor}$

$U_{nom\ motor} > 1\ kV$:

$P_{nom\ mech}$ / (number of pole pairs) < 1 MW:

$X_{motor} = 0.989 * Z_{motor}$

$R_{motor} = 0.15 * X_{motor}$

$P_{nom\ mech}$ / (number of pole pairs) >= 1 MW:

$X_{motor} = 0.995 * Z_{motor}$

$R_{motor} = 0.10 * X_{motor}$

For rotating machines, in contrast to static network components, normal impedance generally differs from inverse impedance (Z_2 not equal to Z_1). For the asynchronous motor, however, Z_2 is approximately equal to Z_1. In accordance with IEC 60909, Vision applies $Z_2 = Z_1$.

The zero sequence impedance Z_0 is assumed to be infinite (floating neutral point).

Fault analysis

In sequential fault analysis, the asynchronous motor is represented as a Norton equivalent. The source impedance of this equivalent is determined in the same way as in an IEC 60909 calculation.

5.3.7 Load

A load can be defined in four different ways with P,Q,I,S, cos phi. The button **Appearance** is used for switching between them and for converting parameters.

PARAMETERS

General

Parameter	Default	Unit	Description
Name			Name of load
P	->		Absorb/supply real power
Q	->		Absorb/supply reactive power
P	0	MW	Real power
Q	0	Mvar	Reactive power
S	0	MVA	Apparent power
I	0	A	Current
cos phi	0		Power factor
Behaviour	Default		Name of voltage dependent load behaviour
Growth	None		Growth rate of the load
Profile	Default		Name of the load profile

Behaviour

A pre-defined load behaviour 227 can be selected under behaviour to model the voltage dependency of the load.

Growth

Seven fixed load growth scenarios are built into Vision: No growth, 1%, 1.5%, 2%, 3%, 4% and 5%, exponentially per year. In addition, a user-defined load growth 229 scenario can be chosen.

Profile

A pre-defined load profile 230 can be selected. The default load profile solely consist of values of 1, yielding a constant load over the profile time.

Simultaneity of loads

The stated load is multiplied by the simultaneity of loads (coincidence) factor g. This factor can be specified at the node to which the load is connected and applies for all loads and load part of all transformer loads present at the node.
See also: Simultaneousness 235.

Controls

Parameter	Default	Unit	Description
P(U) control			P(U)-control present
P(I) control			P(I)-control present
P(f) control			P(f) control present
U		pu	Input of the P(U) function
I		pu	Input of the P(I) function, directional
f		Hz	Input of the P(f) function
P		pu	Output of the P(U) or P(I) or P(f) function
Measurement unit			Measuring field where the current is measured

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the load fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences thet the load is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

Customers

Parameter	Default	Unit	Description
Number of large customers	0		Number of large customers
Number of generous cust.	0		Number of generous customers
Number of small cust.	0		Number of small customers
System element			The type of generation or consumption
Power	0	MWp	The connected power of this system element

Harmonics

Parameter	Default	Unit	Description
Type			Harmonic source type
h	3 to 99		Harmonic number
Current	0	%	Harmonic current, relative to rated load
Angle	0	degrees	Harmonic current angle, relative to load flow voltage

Current and angle:

The harmonic current injection is related to the nominal load current, in percentages:
$Current\ (h) = I\ (h) / I\ (1) \times 100\%$

The angle of the harmonic current injection is related to the angle of the voltage in the nominal load flow situation:
$Angle\ (h) = Angle\ (h) - Angle\ (1)$, in degrees

MODELLING

Load flow

Modelling of the load is described under: Load behaviour 227

IEC 60909
Loads are not taken into consideration in IEC 60909 calculations.

Fault analysis
In sequential fault analysis, the load is modelled as an impedance. This impedance is determined using the pre-fault node voltage and load current, determined in advance by means of a load flow calculation.

5.3.8 Transformer load

To enable simpler modelling of a network, it is possible to apply a transformer with load as an element at a node. In load flow calculations, the transformer load provides insight into the secondary voltage, and saves one node each time.

The load and generation can be given in four different ways (P,Q,I,S, cos phi). The button **Appearance** is used to switch between them, and convert parameters.

PARAMETERS

General

Parameter	**Default**	**Unit**	**Description**
Name			Name of the transformer load
P	0	MW	Real power
Q	0	Mvar	Reactive power
S	0	MVA	Apparent power
I	0	A	Current
cos phi	1		Power factor
Behaviour	Default		Voltage dependent load behaviour
Growth	None		Growth rate of the load
Profile	Default		Name of the transformer load profile
Pnom	0	MWp	The nominal power of the PV
Tap	0		Actual tap changer set point

Simultaneousness
The stated load is multiplied by the simultaneousness factor g. This is given in the node form and applies for the load part of all transformer loads present at the node. See also: Simultaneousness 235
The generation and PV in the transformer node are not multiplied with the simultaneousness factor.

Behaviour
A pre-defined load behaviour 227 can be selected under behaviour. This load behaviour is also applicable for the generation.

Growth
Seven fixed load growth scenarios are built into Vision: No growth, 1%, 1.5%, 2%, 3%, 4% and 5%, exponentially per year. In addition, a user can define a custom load growth 229 scenario.

Profile
At profile a defined profile 230 can be selected.

Transformer

Parameter	Default	Unit	Description
Type			Transformer type
Short name			Short type name
Snom	0	MVA	Nominal apparent power
Unom	1)	kV	Nominal winding voltage
Connection		d/y/yn/z/zn	Secondary windings configuration
Tap side	w1		Winding where the tap changer is located
Uk	0	%	Relative short-circuit voltage
Pk	0	kW	Short-circuit loss
Pnull	0	kW	No-load loss
Tap size	0	kV	Tap size of the tap changer
Tap min	0		Tap with the smallest number of windings
Tap nom	0		Tap with nominal transfer ratio
Tap max	0		Tap with the greatest number of windings

1) The prime winding default voltage corresponds the corresponding node nominal voltage.

Type

The type list contains all transformers from the component type database whereby $U_{nom,w1}$ lies between 0.8*U_{nom} and 1.2*U_{nom} of the node. See also: Type 76

Tap changer

The designation of the tap position can be fully defined by the user by indicating the minimum, nominal and maximum tap. Take care that the minimum tap, for example, is defined as the tap with the smallest number of windings, and thus gives the greatest transfer ratio (depending on the tap side).

Copy and paste type data

Transformer and transformer load type data can be copied and pasted by right mouse clicking on the component's type data form. A pop-up menu appears with ***Copy type data*** and ***Paste type data***. The copied data can be used for a new or an existing transformer (load). This can be helpful when a transformer has to be changed into a transformer load or vice versa.

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the transformer load fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences thet the transformer load is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

Harmonics

Parameter	Default	Unit	Description
Type			Type of harmonic source
h	3 t/m 99		Harmonic order number
Current	0	%	Harmonic current as percentage of the fundamental current
Angle	0	degree	Angle of the harmonic current with respect to the fundamental current

Current and angle:

The harmonic current injection is related to the nominal current in percent:

$$Current(h) = I(h) / I(1) \times 100\%$$

The angle of the harmonic current injection is related to the angle of the voltage in the nominal loadflow situation:

$$Angle(h) = Angle(h) - Angle(1)$$, in degree

Customers

Parameter	Default	Unit	Description
Number of large customers	0		Number of large customers
Number of generous cust.	0		Number of generous customers
Number of small cust.	0		Number of small customers
System element			The type of generation or consumption
Power	0	MWp	The connected power of this system element

MODELLING

Load flow
After completion of the load flow calculation, the secondary voltage is calculated using the calculated load current, the impedance of the transformer, and the tap setting. The behaviour of the load is dependent on the voltage and defined in Behaviour. Modelling of the load is described under: Load behaviour 227

IEC 60909
In IEC 60909 calculations, the transformer load is not taken into consideration. Zero sequence impedances of the transformer are also not taken into consideration with asymmetrical short-circuits.

Fault analysis
In the sequential fault analysis, the transformer load is modelled as a normal load impedance, without taking account of the influence of the transformer. The impedance is determined using the pre-fault node voltage and load current, determined in advance by means of a load flow calculation.
In the case of asymmetrical faults, zero sequence impedances of the transformer are not taken into consideration.

Costs
The transformer load is not involved in the cost calculation.

Reconfiguration of a transformer load
A transformer load can be decomposed into a transformer, a secondary node and a load. All properties are transformed into the new configuration. Select the transformer load and choose: **Start | Edit | Split**.

5.3.9 Shunt capacitor

The rating of a shunt capacitor can be given in µF (per phase) or in Mvar/kvar (three-phase). The button **Appearance** is used to switch between the two different input possibilities and to convert between them.

PARAMETERS

Capacitor

Parameter	Default	Unit	Description
Name			Name
Unom	1)	kV	Nominal voltage
Q	0	Mvar	Reactive power
C 2)	0	µF	Capacity
Profile	Default		Name of the capacitor power profile

1) Unom of the node
2) Converted from Q and vice versa

Connection

Parameter	Default	Unit	Description
Star point earthing	no	yes/no	Indicates whether the star point is earthed
Re	0	Ohm	Earthing resistance with earthed star point
Xe	0	Ohm	Earthing reactance with earthed star point
External node			Node with neutral earth connection

External node

Possibility to connect the neutral point of the shunt capacitor to the earthing electrode at another node.

Voltage control

Parameter	Default	Unit	Description
Voltage control on	off	on/off	Indicates whether the voltage control has been switched on or off
Uoff	0	kV	Voltage above which the capacitor switches off
Uon	0	kV	Voltage under which the capacitor switches on

Uon < Uoff

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the capacitor fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences thet the capacitor is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
Maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

Harmonics

Parameter	Default	Unit	Description
Frequency	0		Harmonic filter frequency
Quality	0		Filter quality

MODELLING

Load flow and fault analysis

The shunt capacitor is modelled with three capacitors in Wye connection. The rating is given for one capacitor between phase and neutral. The reactive power is always the three-phase power.

For the load flow and the sequential fault analysis, a capacitor is represented as a load with:

$$P_{load} = 0$$

and

$$Q_{load} = -\ Q_{capacitor}$$

or

$$Q_{load} = -\ U_{nom,capacitor}^{\ 2} \times \omega\ C$$

where:

Q_{load}	constant X = 100 %
$Q_{capacitor}$	supplied reactive power at U_{nom} of the shunt capacitor
$U_{nom,capacitor}$	nominal phase to phase voltage of the shunt capacitor
ω	Angular frequency ($2\pi f$)

The capacitor is modelled as a constant negative impedance load. This means that the capacitor supplies the nominal reactive power at nominal voltage only. The supplied reactive power depends quadratically on the voltage.

IEC 60909

Capacitors are not taken into consideration in IEC 60909 calculations.

Harmonics

A shunt capacitor can be applied as a harmonic filter. The harmonic filter frequency and filter quality can be specified. The capacitor reactive power is specified on the first tab. The filter resistance and inductance are calculated from the filter input parameters.

The base for the filter parameters is the capacitor reactive power at rated frequency: Q_c. The capacitor reactance at the rated frequency (50/60 Hz) is calculated as follows:

$$X_c = \frac{U_{nom}^2}{Q_c} \cdot \frac{h_f^2}{h_f^2 - 1} \qquad [Ohm]$$

where h_f is the quotient of the filter frequency and the system frequency.
The induction of the coil at the nominal frequency is calculated as follows:

$$X_L = \frac{Q_c}{h_f^2} \qquad [Ohm]$$

The filter resistance R is determined from the filter quality factor q. Its value is usually between 20 and 30.

$$R = \frac{h_f \cdot X_L}{q} \qquad [Ohm]$$

The filter admittance for a frequency with harmonic order h will be:

$$y_{filter}(h) = \frac{1}{R + j(hX_L - X_C/h)} \cdot Z_{base} \qquad [pu]$$

5.3.10 Shunt reactor

A shunt reactance coil can be given in mH (per phase) or Mvar/kvar (three-phase). The button **Appearance** is used to switch between the two different input possibilities and to convert between them.

PARAMETERS

Shunt reactor

Parameter	Default	Unit	Description
Name			Name
Unom	1)	kV	Nominal voltage
Q	0	Mvar	Reactive power
L 2)	0	mH	Induction
Profile	Default		Name of the coil power profile

1) Unom of the node
2) L is converted from Q and vice versa

Connection

Parameter	Default	Unit	Description
Star point earthing	no	yes/no	Indicates whether the star point is earthed
Re	0	Ohm	Earthing resistance with earthed star point
Xe	0	Ohm	Earthing reactance with earthed star point
External node			Node with neutral earth connection

External node

Possibility to connect the neutral point of the reactance coil to the earthing electrode at another node.

Voltage control

Parameter	Default	Unit	Description
Voltage control on	off	on/off	Indicates whether the voltage control has been switched on or off
Uon	0	kV	Voltage above which the shunt reactor switches off
Uoff	0	kV	Voltage under which the shunt reactor switches on

Uon > Uoff

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the coil fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the coil is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

Load flow and fault analysis

The shunt reactor is modelled with three coils in Wye connection. The rating is given for one coil between phase and neutral. The reactive power is always the three-phase power.

For the load flow and the sequential fault analysis, a shunt reactor is represented as a load with:

$$P_{load} = 0$$

and

$$Q_{load} = - Q_{reactor}$$

or

$$Q_{load} = - U_{nom,reactor}^{2} \times \omega C$$

where:

Q_{load}	constant X = 100 %
$Q_{capacitor}$	supplied reactive power at U_{nom} of the shunt reactor
$U_{nom,capacitor}$	nominal phase to phase voltage of the shunt reactor
ω	Angular frequency ($2\pi f$)

The shunt reactor is modelled as a constant negative impedance load. This means that the shunt reactor supplies the nominal reactive power at nominal voltage only. The supplied reactive power depends quadratically on the voltage.

IEC 60909

Shunt reactor are not taken into consideration in IEC 60909 calculations.

5.3.11 Zigzag transformer

The zigzag coil is the general model for a grounding transformer. It is usually used to improve the voltage of the neutral or to introduce a ground in a non-grounded network.

PARAMETERS

General

Parameter	Default	Unit	Description
Name			Name of the zigzag coil

Zigzag coil

Parameter	Default	Unit	Description
Name			Name of the zigzag coil
R0	0	Ohm	Zero sequence resistance
X0	0	Ohm	Zero sequence reactance

External node

Possibility to connect the neutral point of the zigzag coil to the earthing electrode at another node.

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the zigzag coil fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the zigzag coil is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

The impedance of the zigzag transformer is measured by applying a voltage to the three parallel connected phases of the transformer. The measured current is then three times as large as the current per phase. The zero sequence impedance per phase is then determined from:

$$Z_0 = (U_0 / I_0) = 3\ (U_0 / I_{measured})$$

IEC (60) 909 and fault sequential

For an IEC (60) 909 calculation and fault analysis, a zigzag transformer is represented as a zero sequence impedance to ground. Including the impedance of the star point earthing, the zero sequence impedance is equal to:

$$Z_0 = (R_0 + 3R_a) + j\ (X_0 + 3X_a)$$

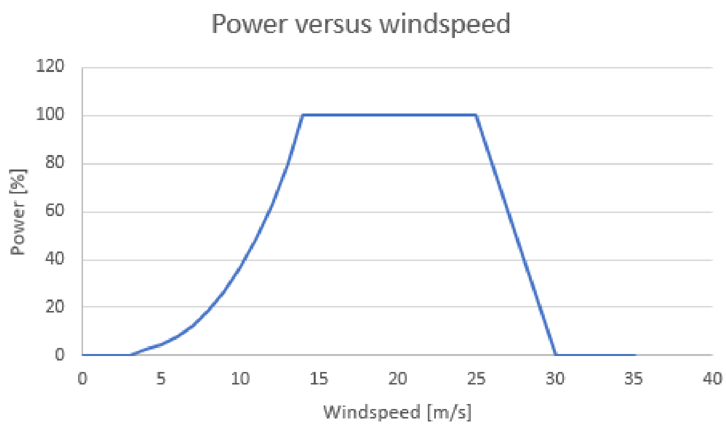
5.3.12 Wind turbine

A wind turbine is an element that delivers power based on the wind speed.

The power of the wind turbine

The electrical power supplied by the wind turbine is a function of the wind speed.
At a wind speed between cut-in and nominal, the power is a third power function of the wind speed.
At a wind speed between nominal and cutting-out, the power is the nominal power.
At a wind speed between cutting-out and cutted-out, the power decreases from nominal to zero with increasing speed.

The wind speed is given at a height of 10 meters.
The wind speed at the height of the hub is calculated according to: $v_{as} := v_{10} * (\text{hubheight}/10)^{0,143}$.



PARAMETERS

General

Parameter	Default	Unit	Description
Name			Wind turbine name
Wind speed	14	m/s	Actual wind speed at 10 meter height
Profile	Default		Wind speed profile
Hub Height	30	m	Height of the wind turbine hub
Pref	0	MW	Active power

Wind turbine

Parameter	Default	Unit	Description
Type			Type of the wind turbine
Unom		kV	Nominal voltage
Snom	0	MVA	Nominal power
Ik/Inom	1		Relation between nominal power and short-circuit power
R/X	0,1		R/X-ratio during short-circuit
Cut-in windspeed	3	m/s	Windspeed for which the wind turbine cuts in
Nominal windspeed	14	m/s	Windspeed for which the wind turbine delivers nominal power
Cutting-out windspeed	25	m/s	Windspeed for which the wind turbine starts reducing the output power
Cutted-out windspeed	30	m/s	Windspeed for which the wind turbine cuts out

Controls

Parameter	Default	Unit	Description
Q-control	const. cos		Type of reactive power control
cos phi	1		Power factor
U		pu	Input van de Q(U)-function or P(U)-function
I		pu	Input of the P(I)-function; directional
f		Hz	Input of the P(f)-function
P		pu	Input of the Q(P)-function or output of the P(U)- or P(I)-function
Q		pu	Output of the Q(U)-function or Q(P)-function
No P, then no Q	not		No Q if P<1 %
P(U) control			P(U) control present
P(I) control			P(I) control present
P(f) control			P(f) control present
Measure field			Measurement field where the current is measured (maximum 3; the most restrictive one prevails)

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the zigzag coil fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the zigzag coil is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

Short circuit calculations

The wind turbine contributes to the short-circuit current.

Harmonics

The wind turbine is modelled with the corresponding machine-impedances. The harmonic currents of the converter based wind turbine configurations are not yet taken into account.

5.3.13 Battery

The battery (storage system) is an element for the storage of electrical energy. In a load flow calculation using profiles, the battery stores or releases energy, according to the specified battery profile. The state of charge depends on the starting value, the storage capacity and the battery profile. During the charging and the discharging processes, the state of charge will not exceed the physical limits.

PARAMETERS

Battery

Parameter	Default	Unit	Description
Name			Name
C-rate	0,5	/h	1 hour nominal discharge rate
Capacity	0	MWh	Storage capacity
P	0	MW	Generation of active power (*)
Profile	Default		Name of the load profile for the active power
SoC	50	%	Initial State of Charge

(*) The battery positive power direction is according to the load convention. This implies that a positive P indicate that the battery receives power from the network.
Only the active power P can be used for energy storage.
The voltage dependent behaviour is: constant power.

Profile

Each load flow calculation respects the battery state of charge. The load flow calculation without profile respects the physical limits of a fully charged or discharged battery.
A previously defined load profile 230 can be assigned to the battery. Only in loadflow calculation with profile, the time aspect is taken into account, charging and/or discharging the battery.
Th***default*** profile exists of all values of 1 and produces a constant load.

Inverter

Parameter	Default	Unit	Description
Snom		MVA	Nominal power of the inverter
Cos phi	1		Cos phi
Charging efficiency type	0,1..1 pu: 95 %		Type of the discharging efficiency
Discharging efficiency type	0,1..1 pu: 95 %		Type of the charging efficiency
Ik/Inom	1		Relation between the short circuit current and the nominal current

Control

The battery can be equipped with a control to control charging and discharging. A P(U) or P(t) or P(I) control can be selected. The P(U) and P(I) control overrules the generally specified P and profile. The P(t) control overrules these values only when the time is known.

Parameter	Default	Unit	Description
Sort	Geen		Sort P control: none, P(U) of P(t) or P(I)
Begin time			Start time of the day as input of the P(t) function
End time			End time of the day as input of the P(t) function
U		pu	Input of the P(U) function
I		pu	Input of the P(I) function; directional
P		pu	Output of the P control in relation to capacity*C-rate; negative is discharging

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the battery fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the battery is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
Maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

Load flow

The battery positive power direction is according to the load. This implies that the powers P and Q are positive if the battery draws power from the network. The voltage dependent behaviour is: constant power.

In a load flow calculation without profile the battery behaves like a general load, according to the defined power P and Q, with respect to the state of charge.

The state of charge changes in a load flow calculation with a profile. The value depends on its initial value, the storage capacity and the amount and duration of charging and discharging power. The charging and discharging power are with respect to the network. The actual stored power depends on the battery efficiency.The battery behaves in the following way near the bounds of the SoC:

- at a SoC of 99 % no active power is drawn from the network.
- at a SoC of 1 % no active power is delivered to the network.

Fault analysis

In sequential fault analysis, the battery is modelled as an impedance. This impedance is determined using the pre-fault node voltage and load current, determined in advance by means of a load flow calculation.

5.3.14 PV

The PV (photovoltaic) is an element for generation of electric energy by means of sun (a solar panel). The basic property of the PV is the nominal power of the (maximal three) sets of panels. Other static properties are the orientation and tilt of the sets of panels. The generated power depends on the sun intensity and the date and time. The output power is limited by the nominal power of the inverter.

PARAMETERS

PV

Parameter	Default	Unit	Description
Name			Name
Pnom	0	MW	Nominal power
Orientation	180	°	Compass angle of the PV panel (azimuth angle) North is 0°
Tilt	36	°	Tilt angle of the PV panel 0° is flat
Latitude	52	° NB	Latitude
Longitude	5	° OL	Longitude
Scaling	1000	‰	Scaling factor
Profile	Default		Name of the profile (factors of the entered scaling)
Snom	0	MVA	Nominal output power of the inverter
Ik/Inom	1		Relation between the short circuit current and the nominal current
Efficiency type	0,1 pu: 93%; 1 pu: 97%		Inverter efficiency type
Q ctrl			Type of reactive power control
Cos phi	1		Fixed cosine phi
U		pu	Input of the Q(U)-function or P(U)-function
I		pu	Input of the P(I)-function; directional
f		Hz	Input of the P(f) function
P		pu	Input of the Q(P)-function or output of the P(U) of P(I)-function
Q		pu	Output of the Q(U)-functie or Q(P)-function
No P, no Q	false		No Q if P<1 %
P(U) ctrl.Present	false		P(U)-control present
P(I) ctrl.Present	false		P(I)-control present
P(f)-c.Present	false		P(f) control present
Measure			Measurement field where the current is measured (maximum 3; the most restrictive one prevails)

Profile

Here a predefined profile 230 can be coupled with the PV. The profile consists of scaling factors which are applied at the corresponding profile time instance. When using a time oriented profile, the time has two functions:

- the scaling is scaled by the factor belonging to a time stamp;
- the production of the panel depends on the time, according to the position of the sun as calculated within the program

Reliability

Parameter	Default	Unit	Description
Failure frequency	0	per year	Mean number of occurrences that the PV fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Maintenance frequency	0	per year	Mean number of occurrences that the PV is in maintenance
Maintenance duration	0	minutes	Mean duration of maintenance
Maint. cut-off duration	0	minutes	Mean duration of cancellation of maintenance in case of emergency

MODELLING

Loadflow

The PV installation uses the generator convention: a positive value denotes the delivery of power to the network. The voltage dependent behaviour of the PV installation is of constant power.

Fault analysis

The PV installation is modeled as an impedance, the value of which is computed by dividing the load flow bus voltage U_{node} with the PV-current.

5.4 Switches and protections

The following switches and protection devices have been integrated in Vision:

- Load switch 201
- Fuse 202
- Circuit breaker 203
- Current protection 205
- Earth fault protection 211
- Voltage protection 212
- Differential protection 213
- Distance protection 214
- Unbalance protection 219
- Thermal protection 219
- Earth fault differential 221
- Short circuit indicator 221
- Measurement unit 222

The characteristics of selected protection relays can be depicted together in one graph. See: Protections 101

5.4.1 Load switch

A load switch can be placed on either side of a branch or on an element.
To add a load switch, select a branch or element and the corresponding node and choose **Insert | Switches and protections | Load switch**.

A load switch can not occur in a field together with a circuit breaker.

A load switch that has been copied can be pasted in several places at the same time. To do this, select the relevant feeders (a feeder is defined as a branch or element with the connecting node) and choose **Start | Clipboard | Paste special | Paste load switch in all selected feeders.**

PARAMETERS

General

Parameter	**Default**	**Unit**	**Description**
Name			Load switch name.
Disconnectors			Indicates the presence of one or two disconnectors

Load switch

The load switch has been equipped with a type specification, with the following parameters:

Parameter	**Default**	**Unit**	**Description**
Type			Load switch type name.
Short			Load switch short name.
Unom	0	kV	Rated voltage
Inom	0	A	Rated current
Ik,make	0	kA	Maximum making current
Ik,dynamic	0	kA	Maximum dynamic current
Ik,thermal	0	kA	Maximum thermal short circuit current
at t	0	s	Maximum thermal short circuit duration

Reliability

The switch reliability parameters are listed below.

Parameter	**Default**	**Unit**	**Description**
Failure frequency	0	per year	Mean number of occurrences that the switch fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Remote control	no	yes/no	Presence of remote control

The presence of remote control influences the fault isolation and switching times (short/long) in the reliability calculation.

5.4.2 Fuse

A fuse can be placed on either side of a branch or on an element.
To add a fuse, select the branch or element and the connecting node and select: **Insert | Switches and protections | Fuse**.

A fuse can not occur in a field together with a circuit breaker.

A fuse that has been copied can be pasted in several places at the same time. To do this, select the relevant feeders (a feeder is defined as a branch or element with the connecting node) and choose **Start | Clipboard | Paste special | Paste load switch in all selected feeders.**

A fuse in the primary side of a transformer also shows two points representing the inrush current and time: 12*Trafo.I_{nom} at 0.1 s and 25*Trafo.I_{nom} at 0.01 s.
In addition to the current-time diagram of a fuse, it is also possible to see the curves of other selected fuses and/or current protection devices in the same graph. To do this, click with right in the graph and choose ***Show all selected current protections*** or ***Idem, at this voltage***.

PARAMETERS

General

Parameter	Default	Unit	Description
Name			Fuse name.

Fuse

The fuse is described by its current-time diagram, with the following parameters:

Parameter	Default	Unit	Description
Type			Predefined type from the component database
Short			Short name. Maximum 10 characters.
Unom	1)	kV	Nominal voltage
Inom	0	A	Nominal current
Switches three phases	no	yes/no	Designation that the fuse switches three phases simultaneously
I1 ... I16	0	A	16 possible current values for the current-time diagram
t1 ... t16	0	s	16 possible time values for the current-time diagram

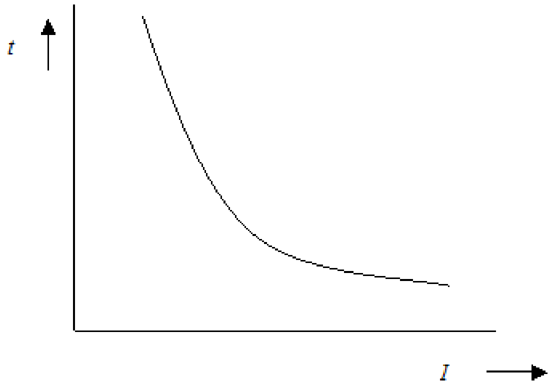
Type

All fuses with a U_{nom} of 80% to 150% of the U_{nom} of the node are listed.

MODELLING

Curve

A general fuse characteristic is given below.



Each fuse has its own characteristic curve. The data describing the curve can be found in the manufacturer's data sheets.

Reliability
The fuse is infinitely reliable. This means that the fuse is no source of an active failure. A short circuit current will always be switched off.

5.4.3 Circuit breaker

The circuit breaker can be applied at both sides of a branch and at an element.

The circuit breaker can be used in combination with a protection relay. More than one circuit breakers can be combined with a single differential protection relay.
The circuit breaker cannot be used in combination with another switching or protecting device in the same field.

The circuit breaker can be added by selecting a branch or an element together with the corresponding node and choose **Insert | Switches and protections | Circuit breaker**.

A circuit breaker that has been copied can be pasted in several places at the same time. To do this, select the relevant feeders (a feeder is defined as a branch or element with the connecting node) and choose **Start | Clipboard | Paste special | Paste load switch in all selected feeders.**

PARAMETERS

General

Parameter	Default	Unit	Description
Name			Circuit breaker name
otection			
Current 1	no		First overcurrent protection present, active and directional sensitivity RCA
Current 2	no		Second overcurrent protection present, active and directional sensitivity RCA
Earth fault 1	no		First earth fault protection present, active and directional sensitivity RCA
Earth fault 2	no		Second earth fault protection present, active and directional sensitivity RCA
Voltage	no		Voltage protection present, active and directional sensitivity RCA
Differential	no		Differential protection present and active
Distance	no		Distance protection present and active
Unbalance	no		Unbalance protection present and active
Thermal	no		Thermal protection present and active
Earth fault diff.	no		Earth fault differential protection present and active
Vector-jump	no		Vector-jump protection present and active
Frequency	no		Frequency protection present and active
Transfer tripping ability	no		Transfer tripping present, directional sensitivity and delay time
Reserve ability	no		Reserve ability present
Blocking ability	no		Blocking ability present

Directional sensitivity

The directional sensitivity can be defined by the parameter *RCA*, rotating the "measured" voltage. As a consequence the protection trips if the current vector angle with reference to the voltage vector angle lies between *RCA+90°* and *RCA-90°*. In the case of a regular overcurrent protection, the angle is calculated between the phase voltage and phase current. In the case of an earth fault protection, the angle is calculated between zero sequence voltage and current.

Transfer trip

A transfer trip signal is optionally available when a circuit breaker is protected. Surrounding circuit breakers can be switched off (with a delay) if this circuit breaker trips.
As soon as 'Transfer trip ability' is checked, the 'Tools' tab becomes visible. The connections to protections in other circuit breakers can be entered on this tab. This works best when the connected circuit breakers are also selected.

Reserve

A reserve circuit breaker is optionally available. In the case of a reserve circuit breaker, a protection can open other specific circuit breakers at the moment a circuit breaker refuses to open. An additional time delay can be defined.
As soon as 'Reserve ability' is checked, the 'Tools' tab becomes visible. The connections to protections in other circuit breakers can be entered on this tab. This works best when the connected circuit breakers are also selected.

Blocking

A blocking circuit breaker is optionally available. A protection in this circuit breaker can block a protection in another circuit breaker at the moment the protection is triggered.
As soon as 'Blocking ability' is checked, the 'Tools' tab becomes visible. The connections to protections in other circuit breakers can be entered on this tab. This works best when the connected circuit breakers are also selected.

Circuit breaker

The circuit breaker has been equipped with a type specification, that has the following parameters:

Parameter	Default	Unit	Description
Type			Circuit breaker type name.
Short			Circuit breaker short name.
Unom	0	kV	Rated voltage
Inom	0	A	Rated current
Switch time	0	s	Duration for the switch to isolate
Ik,make	0	kA	Maximum making current
Ik,break	0	kA	Maximum breaking current
Ik,dynamic	0	kA	Maximum dynamic current
Ik,thermal	0	kA	Maximum thermal short circuit current
at t,thermal	0	s	Maximum thermal short circuit duration

Protection

One or more of the following protection relays can be added to the circuit breaker. See:

- Current protection 205;
- Earth fault protection 211;
- Voltage protection 212;
- Distance protection 214;
- Differential protection 213;
- Unbalance protection 219;
- Thermal protection 219;
- Earth fault differential 221
- Vector-jump;
- Frequency.

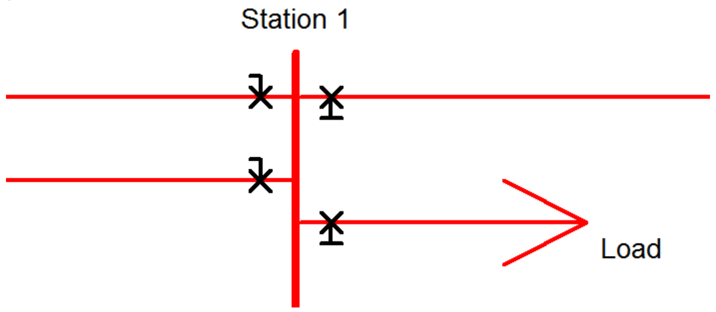
Reliability
The circuit breaker reliability parameters are listed below.

Parameter	Default	Unit	Description
No operation probability	0		Possibility that the switch refuses to isolate in case of a short circuit
Failure frequency	0	per year	Mean number of occurrences that the switch fails (short circuit)
Repair duration	0	minutes	Mean duration of repair or replacement
Remote indication	no	yes / no	Presence of remote status indication
Remote control	no	yes / no	Presence of remote control

The remote indication influences the fault observation and fault location time (short/long) in the reliability calculations and the remote control influences the fault isolation and switching times (short/long).

Presentation
The circuit breaker is shown on the screen with a cross or with two points.
If the circuit breaker is equipped with a active protection relay, the cross is extended with one transverse line for each protection relay.
The graphical representation can be further defined on this tab. See also: Presentation Components 248

Extended protection indication
In the circuit diagram, each active protection relay on a circuit breaker is represented by a little transverse line on the circuit breaker symbol. For directional sensitive relays, this line points into the corresponding direction. The picture below shows two directional sensitive and two non-directional sensitive protection devices.



5.4.4 Current protection

A current or overcurrent protection in Vision is part of a circuit breaker 203. For each circuit breaker two current protective devices can be defined. In this way different directional sensitivity settings (forward, backward and undirected) can be combined in a flexible way.

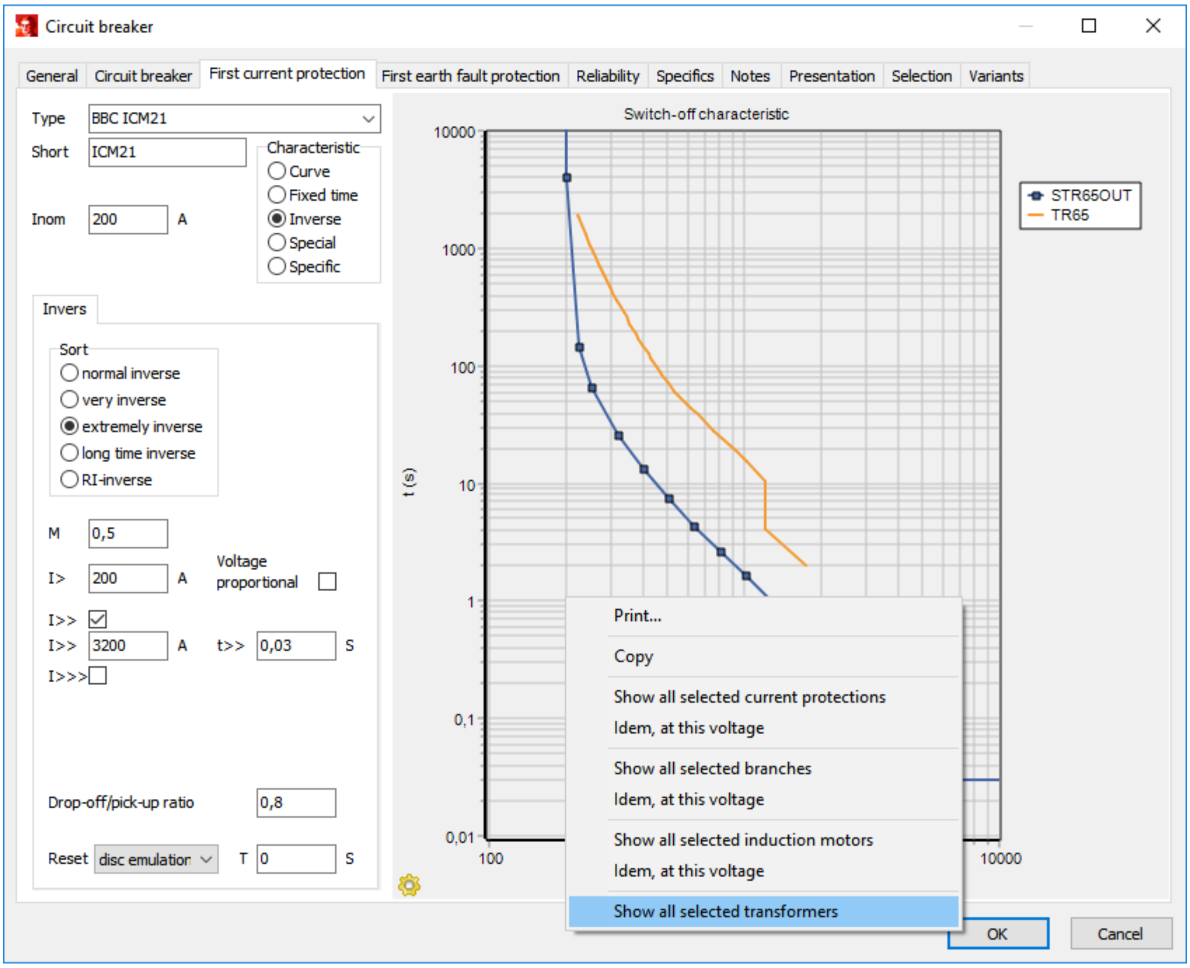
Directional sensitivity of an current protection can be defined as:
- backward (<), directed away from the branch or element as seen from the node
- undirected (<>)
- forward (>), directed towards the branch or element as seen from the node

The directional sensitivity can be set at the level of the circuit breaker under tab **General**.

For current protection time-current characteristic can be defined. The protective devices are divided in 6 different sorts:
- curve (current-time)
- fixed time
- inverse
- special
- specific
- LSI

PARAMETERS

Besides the time-current curve of respective protection device it is also possible to visualize on the plot the curves/characteristics of other selected current protections, cables and lines, motors and transformers. Click with the right mouse button on the plot of the characteristic and for instance choose **Show all selected current protections** or **Idem, at this voltage** in the pop-up window that will appear. See also: Protections 101.



Parameter	Default	Unit	Description
Type			Predefined type from component database
Short			Short description of type, maximum 10 symbols
Inom	0	A	Nominal current of protective device (used only for info)
t,input	0	s	Pickup time
t,output	0	s	Operation output time
Characteristic	Curve		Sort of characteristic (curve, definite time, inverse, special, specific)
urve			
I1 ... I16	0	A	Current values of 16 points on the time-current curve
t1 ... t16	0	s	Time values of 16 points on the time-current curve
efinite time			
I>	0	A	Current value of slow protection stage
t>	0	s	Time value of slow protection stage
I>>	0	A	Current value of medium protection stage (in case of 2 or 3 stages)
t>>	0	s	Time value of medium protection stage (in case of 2 or 3 stages)
I>>>	0	A	Current value of fast protection stage (in case of 3 stages)
t>>>	0	s	Time value of fast protection stage (in case of 3 stages)
Drop-off/pick-up ratio	1		Ratio of the drop-off current value of the relay to the pickup value
t,reset		s	Reset time (0 = instant)
verse			
Sort	normal		Sort of inverse characteristic: normal / very / extremely / long time / RI-inverse
M	1		factor m (Time Multiplier Setting)
I>	0	A	Current value of slow protection stage
I>>	0	A	Current value of medium protection stage
t>>	0	s	Time value of medium protection stage
I>>>	0	A	Current value of fast protection stage
t>>>	0	s	Time value of fast protection stage
Id	20		Factor of I> from where the protection starts to behave as definite time
Voltage proportional	0		Voltage dependency of inverse overcurrent characteristic
Drop-off/pick-up ratio	1		Ratio of the drop-off current value of the relay to the pickup value
Reset	Disc emulation		Reset of inverse characteristic (disc emulation, fixed time)
T	0	s	Reset time (0 = instant)
ecial			
alfa	1		factor alfa
beta	1		factor beta
c	1		factor c
d	1		factor d
e	0	s	factor e (extra time)
m	1		factor m (Time Multiplier Setting)
I>	0	A	Current value of slow protection stage
I>>	0	A	Current value of medium protection stage
t>>	0	s	Time value of medium protection stage
I>>>	0	A	Current value of fast protection stage
t>>>	0	s	Time value of fast protection stage
Id	20		Factor of I> from where the protection starts to behave as definite time
Drop-off/pick-up ratio	1		Ratio of the drop-off current value of the relay to the pickup value
t,reset	0	s	Reset time (0 = instant)
ecific			
HV-fuse			Specific characteristic of relay WIC1 (Woodward SEG)
FR-fuse			Specific characteristic of relay WIC1 (Woodward SEG)
LSI			
I>	0	A	Current for slow tripping
t	0	s	Time at @I in I^2t, from slow tripping
@I	0	A	Current at t in I^2t, of slow tripping
alfa	2		Exponent of I in $I^{alfa}t$
I>>	0	A	Current for medium tripping
t>> of t	0	s	Time of medium tripping or time at @I in I^2t, of medium tripping
@I	0	A	Current at t in I^2t, of medium tripping
I>>>	0	A	Current for quick tripping
t>>>	0	s	Time of rapid tripping
Drop-off/pick-up ratio	1		Ratio of the drop-off current value of the relay to the pickup value

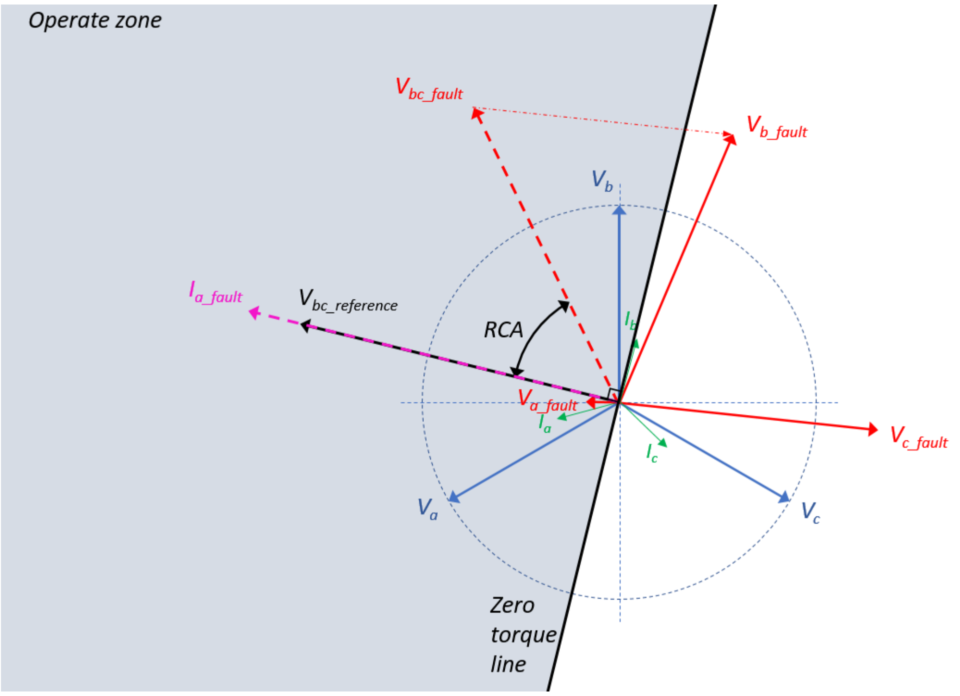
The parameters starting from I> are applicable/not applicable depending on the characteristic.

MODELLING

Directional sensitivity

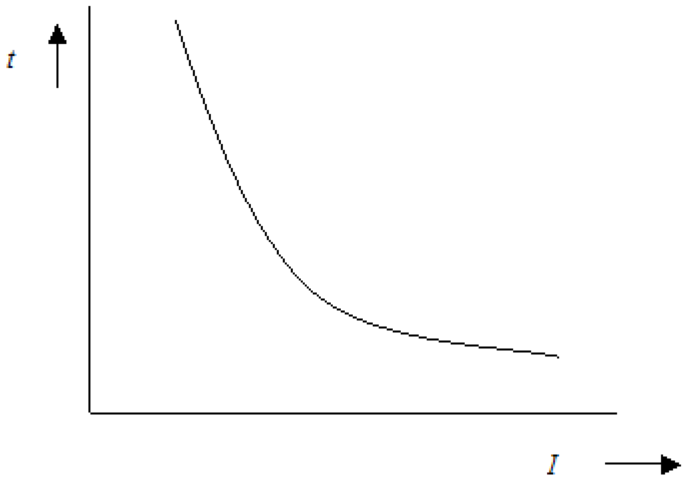
The directional sensitivity is specified in the general parameters of the circuit breaker. The direction can be set there as *forward*, *backward* or *undirected*. In case the protection is directional, the RCA (Relay Characteristic

Angle) can be specified. Different ways exist to determine the direction of the current, based on the measured currents and voltages. For a directional current protection the '90° Quadrature Connection' is the standard connection method. The measurement of the voltage takes place in the undisturbed phases, in this manner a sufficiently large voltage is available (phase to phase voltage), as the voltage in the disturbed phase can drop to zero. For instances, for the protection of phase a the phase current Ia and phase to phase voltage V_{bc} are used.
The phase to phase voltage is rotated with the RCA to ensure maximum sensitivity. In case of an earth fault protection the zero sequence voltage and current are considered (these are not rotated by 90°).

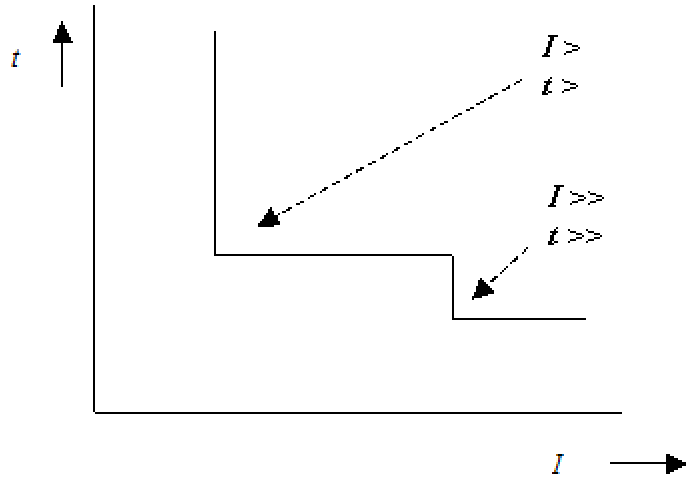


The maximum sensitivity of the directional power relays can be reached if the reference voltage is in phase with the fault current, in this example in phase with Ia_fault. The extra rotation angle, RCA, is in this case 50°. The directional element will allow the tripping of the relay if the current phase Ia_fault is located in the grey area of the above figure.

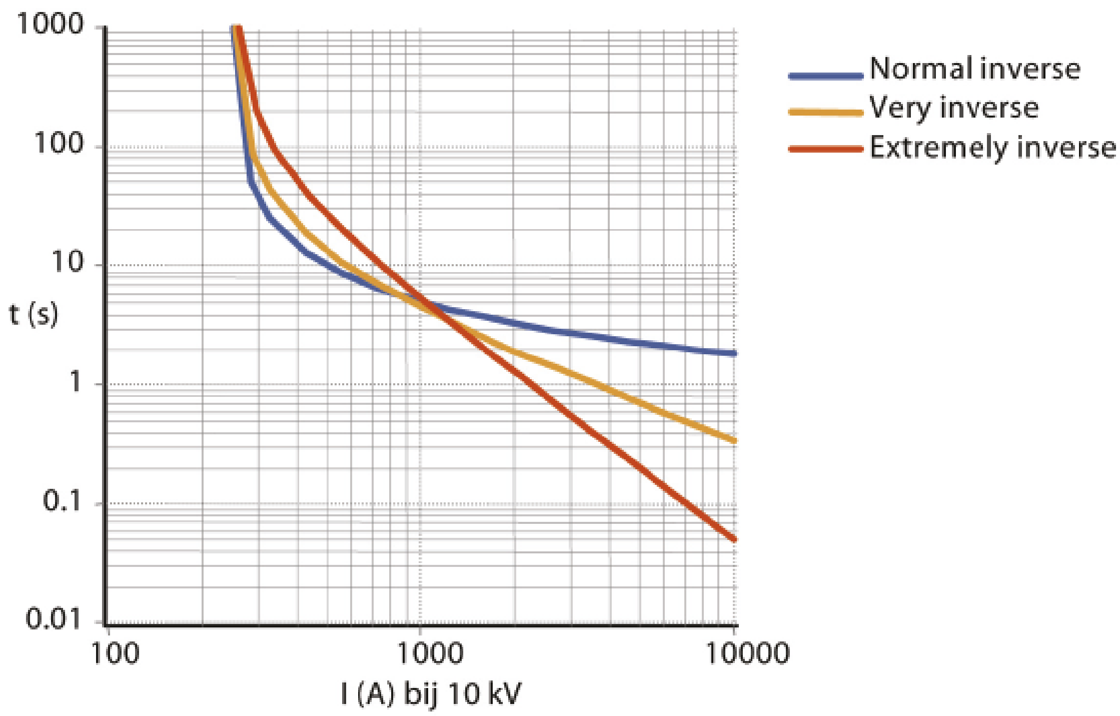
Curve
The curve is most often used to model the tripping behaviour of a fuse. The characteristic of a fuse is given in the diagram below. The points of the curve can be defined in the types file (up to a maximum of 16 points).



Fixed time
The characteristic of the fixed time protection is given in the diagram below. The characteristic is defined by one, two or three points. On the plot below a two point example is shown.



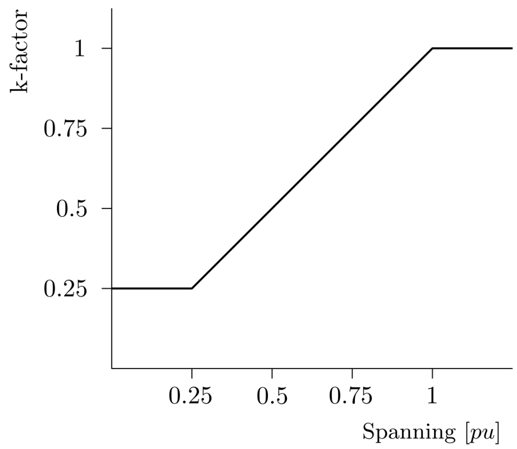
Inverse
The general form of the inverse characteristic is given in the diagram below. The final form of the curve is determined by the sort and the values of m, I> and, if specified, I>> and t>>.



The following parameters can be set for the protection devices above:

- Sort normal inverse, very inverse, extremely inverse
- I> current setting for the slow stage
- m time multiplier setting (TMS)
- I>> current setting for the medium stage
- t>> time setting for the medium stage
- I>>> current setting for the fast stage
- t>>> time setting for the fast stage

In case of a generator protection it can be necessary to make the time-current curve dependent of the voltage. This function can be selected by checking 'voltage proportional' checkbox. The k-factor in the equation below is determined using the following characteristic:



The inverse curve is calculated using the equation below:

$$t = m\left(\frac{\beta}{\left(\frac{I}{k*I_>}\right)^{\alpha} - 1}\right)$$

Parameters of the inverse curve are given in the following table:

Characteristic	α	β
Normal inverse	0.02	0.14
Very inverse	1	13.5
Extremely inverse	2	80
Long time inverse	1	120

The plots and equations for this sort of protection are standardized and described in IEC 60255-155. Besides these inverse curves there is RI-inverse curve available for older electromechanical relays, which can be calculated using the formula below:

$$t = \frac{m}{-0{,}236\left(\frac{k*I_>}{I}\right) + 0{,}339}$$

If the current comes below the pick-up current value I> after the pick-up of the relay, then the relay reset will be started. The reset function of a relay can be an important criterion for protection coordination in case of fast repetitive faults (for instance, due to automatic re-closing of circuit breakers or re-closers). The reset function can be implemented in three ways, namely: instant, fixed time and time dependent. Most commonly use is the time dependent option (disc emulation). This option and the instant reset are implemented in Vision. The reset function is defined conform to the following IEEE formula with the k-factor:

$$t_{reset}(I) = \frac{t_{reset}}{\left(\frac{I}{k*I_>}\right)^{2} - 1}$$

Please pay attention that the reset time in the equation above is given including the m-factor (TMS). Suppose, for instance, that the reset time of a relay is given to be 9.7 s and the TMS is set to 0.3 s, then the total reset time, which should be set in Vision, is equal to: 9.7 x 0.3 = 2.91 seconds.

Special
The tripping characteristic can be specified by the user using the following formula:

$$t = m\left(\frac{\beta}{c\left(\frac{I}{I_>}\right)^{\alpha} - d} + e\right)$$

The formula above is also known as the IEEE/IEC curve:

$$t_{trip}(I) = TMS\left(\frac{\beta}{\left(\frac{I}{I_>}\right)^{\alpha} - 1} + c\right)$$

Characteristic	α	β	**c**	**d**	**e**	**t**reset	αreset
IEC-A Normal/Standard inverse	0.02	0.14	1	1	0	*	*
IEC-B Very inverse	1	13.5	1	1	0	*	*
IEC-C Extremely inverse	2	80	1	1	0	*	*
Long time inverse	1	120	1	1	0	*	*
IEEE-D MOD Moderately inverse	0.02	0.0515	1	1	0.114	4.85	2
IEEE-E VERY Very inverse	2	19.61	1	1	0.491	21.6	2
IEEE-F XTRM Extremely inverse	2	28.2	1	1	0.1217	29.1	2

5.4.5 Earth fault protection

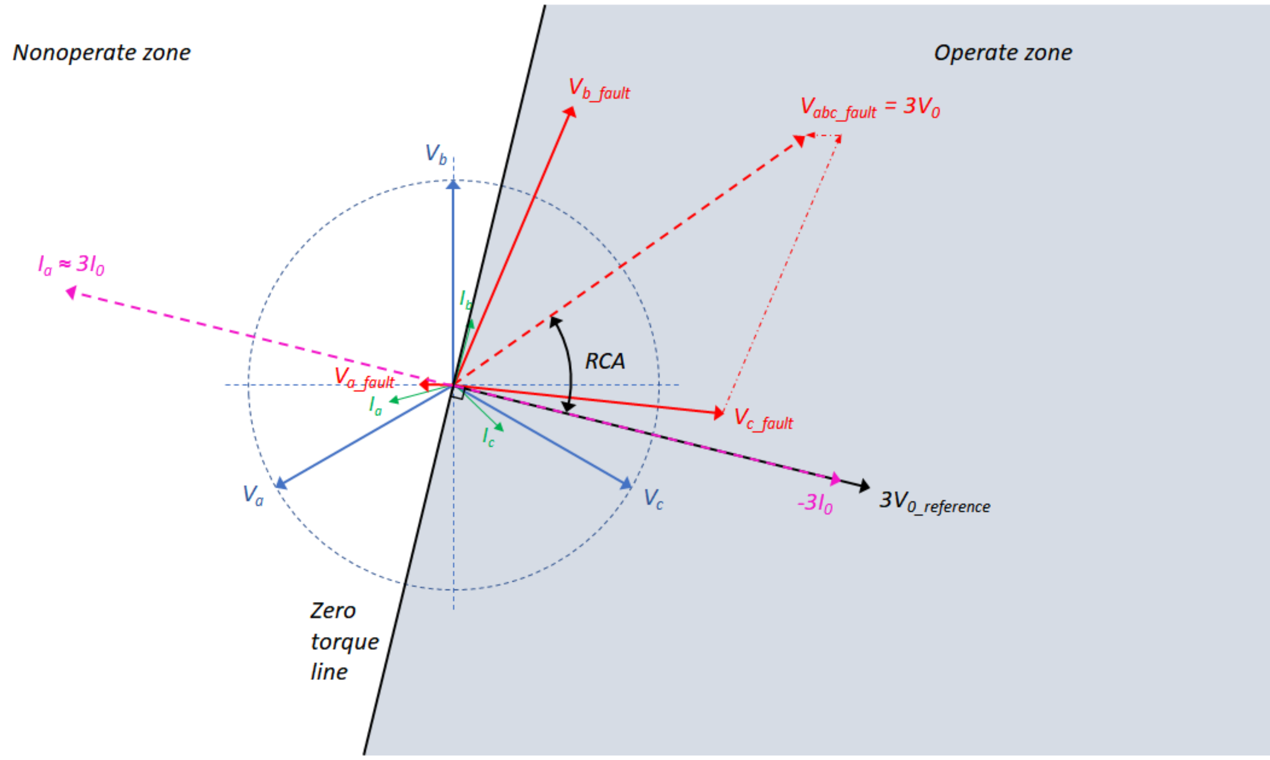
The earth fault protection detects whether the sum of the three phase currents is unequal to zero. The input of the earth fault protection is the phasor sum of the three measured phase currents ($I_a + I_b + I_c = 3I_0$), with zero sequence current I_0 present only in case there is path to ground available. The earth fault protection is a part of the circuit breaker 203 in Vision.

For earth fault protection a characteristic can be chosen. The procedure is the same as for the current protection 205.

MODELLING

Characteristics
Details about different characteristics is to be found in current protection description.

Directional sensitivity
The directional sensitivity can be specified at general parameters of the circuit breaker. There the direction can be set as *forward*, *backward* or *none* (undirected). In case the protection is directional, the Relay Characteristic Angle (RCA) can be specified. The direction of a fault current as a result of an earth fault is determined based on the angle between this current and the reference. In the figure below an illustration of a phase to earth short-circuit in phase a in a distribution network earthed via an zigzag transformer is given. The undisturbed phasors of both the voltage and current are drawn in blue and green, respectively. In case of a low resistance fault to earth in phase a the neutral point shifts and the voltage phasor of the disturbed phase rotates. As a consequence of these events the voltages in undisturbed phases increase and their phasors also rotate. The fault voltages are shown in red. The voltage is measured using open delta measurement, the input of the relay is the sum of three voltage phasors ($U_a + U_b + U_c$), which is equal to $3V_0$.



To guarantee the reliability of directional operation the voltage phasor $3V_0$ (that serves as a reference for the detection direction) is rotated such that it comes in phase with the zero sequence current $-3I_0$. This angle, RCA, is dependent on the zero sequence circuit and therefore has to be determined for each situation specifically. The location of the fault is determined by calculating the angle between the reference $3V_0$ and the zero sequence current $3I_0$. The maximum sensitivity of the relay is reached if the measured current is in phase with the reference phasor $3V_0$ rotated (maximum torque line).

5.4.6 Voltage protection

The voltage protection trips in case there is an undervoltage or overvoltage.
The voltage protection is part of a circuit breaker 203.

The voltage protection characteristic can not be chosen. The characteristic always is fixed time.

Directional sensitivity of an voltage protection can be defined as:
- backward (<), directed away from the branch or element as seen from the node
- undirected (<>)
- forward (>), directed towards the branch or element as seen from the node

The directional sensitivity can be set at the level of the circuit breaker under tab **General**. The implementation of the directional sensitivity of the voltage protection is equal to the directional sensitivity of the current protection 205.

PARAMETERS

Parameter	Default	Unit	Description
Type			Predefined type from the component database
Short			Short name
Unom		kV	Nominal voltage
t,input	0	s	Pickup time
t,output	0	s	Operation output time
U<	0	kV	Undervoltage (coupled voltage) for slow tripping
t<	0	s	Undervoltage slow tripping time
U<<	0	kV	Undervoltage (coupled voltage) for fast tripping
t<<	0	s	Undervoltage fast tripping time
U>	0	kV	Overvoltage (coupled voltage) for slow tripping
t>	0	s	Overvoltage slow tripping time
U>>	0	kV	Overvoltage (coupled voltage) for fast tripping
t>>	0	s	Overvoltage fast tripping time
Ue>	0	kV	Earth voltage (non-directional sensitivity)
te>	0	s	Earth voltage tripping time

5.4.7 Differential protection

Differential protection is part of a circuit breaker 203 and also refers to other circuit breakers and/or measurement fields, the other measuring points. In this way, an arbitrary object (rail, transformer, cable) or an arbitrary set of objects (direction) can be secured with the differential protection. The differential protection operates when the corresponding circuit breakers are no more than six branches apart. In that case the correct flow direction and transfer ratio of a possible intermediate transformer is taken into account.

Only this circuit breaker is tripped. Not the circuit breakers at the "other measurement points".

PARAMETERS

Parameter	Default	Unit	Description
Type			Type name of the differential protection
t,input	0	s	Pickup time
t,output	0	s	Operation output time
Sort			Sort
m			factor m (Time Multiplier Setting), at inverse characteristic
Other measurement points			List of circuit breakers and measurement units connected to this differential protection
dI >	0	A	First threshold value for activating the differential protection
t >	0	s	Time for trip signal
dI >>	0	A	Second threshold value for activating the differential protection
t >>	0	s	Time for trip signal
k1	0		Factor k1
k2	0	A	k2
k3	0		Factor k3
k4	0	A	k4
Release by the first current protection	no		The current has also to be bigger then I> of a fixed time characteristic
No own measurement			The circuit breaker itself does not provide a measurement

The operation is as follows. Suppose two currents I_1 and I_2 (as complex values) are measured, both directed towards the object to be protected. In the normal situation both flows are equal but opposite to each other: $I_1 = -I_2$. The absolute value of the sum of the measured flows *Diff* is then equal to zero.

$$Diff = | I_1 + I_2 |$$

In the event of a short-circuit in the object to be protected, *Diff* is no longer equal to zero, as there is current flowing from the object to the ground. If *Diff* is greater than the threshold value *dI>* for a time of at least *t>* a trip command will be given.

k1, k2, k3, k4

The values $k1$, $k2$, $k3$, $k4$ are used as an extra tripping criterions. Suppose that two currents I_1 and I_2 are measured as complex values. The sum of the absolute values will be calculated as follows:

$$Sum = | I_1 | + | I_2 |$$

The differential protection will only trip if the following three conditions are met:

$$Diff > dI>$$
$$Diff > k_1 \cdot Sum + k_2$$
$$Diff > k_3 \cdot Sum + k_4$$

5.4.8 Distance protection

The distance protection measures the impedance in the direction of the feeder. There are three zones with forward directional sensitivity and one zone with backward directional sensitivity.

The distance protection is a part of the Circuit Breaker 203.

PARAMETERS

Parameter	**Default**	**Unit**	**Description**
Type			Predefined type from component database
Short			Short name. Maximum 10 characters.
t,input	0	s	Pickup time
t,output	0	s	Operation output time
Pickup			
Ie >	0	A	Earth current activation threshold value
I >	0	A	Overcurrent activation threshold value (pick-up current)
U <	0	kV	Undervoltage activation threshold value
Z <	0	Ohm	Impedance zone activation threshold value
Kn	0		Factor K_N for asymmetric short circuits: absolute value and angle
rward:			
Number of zones	0	1/2/3	Number of zones (1, 2 or 3)
t1, t2, t3	0	s	First, second and third zone tripping time
end time	0	s	Forward directional final tripping time
ckwards:			
T	0	s	Reverse directional tripping time
ndirected:			
end time	0	s	Undirected final tripping time

Edit zone

Using the button Edit zone the characteristics of the three forward directional zones and the one reverse directional zone can be specified.

Parameter	Default	Unit	Description
Number of characteristic	1	1/2	1: for all fault types the same characteristic 2: different characteristics for phase-phase fault and phase-ground fault
Characteristic			Circle / Mho / Polygon
rcle:			
Z	0	Ohm	Circle radius
ho:			
Z	0	Ohm	Circle radius
R	0	Ohm	Circle centre R-coordinate
X	0	Ohm	Circle centre X-coordinate
olygon (max 5 lines):			
R	0	Ohm	R-coordinate of a point on the line
X	0	Ohm	X-coordinate of a point on the line
Direction	0	degrees	Slope angle of the line through the point R-X

Circle

A zone can be characterized with a circle diagram. The forward-facing zones 1 and 2 are provided with auxiliary buttons with the default of 85% and 115% for filling in the impedance. These values can be adjusted by right-clicking on them. For zone 1 there is then a choice of 70, 75, 80, 85, 90 and 95%. For zone 2 there is then a choice of 105, 110, 115, 120, 125, 130 and 85 (+85 ')%.

With the 85% button at Z_1, the value of 85% of impedance in the forward direction to the next node can be transferred to the input field of Z_1.

With the 115% button at Z_2, the value of 115% of impedance in the forward direction to the next node can be transferred to the input field of Z_2.

85 (+ 85 ')% means: 85% of impedance in the forward direction to the next node + 85% of impedance of the shortest non-mesh cable from that node.

Mho

A zone can be characterised using a circle diagram of which the centre is moved in the R-X plane. The circle radius is indicated with the impedance Z and the centre with R and X (in Ohm).

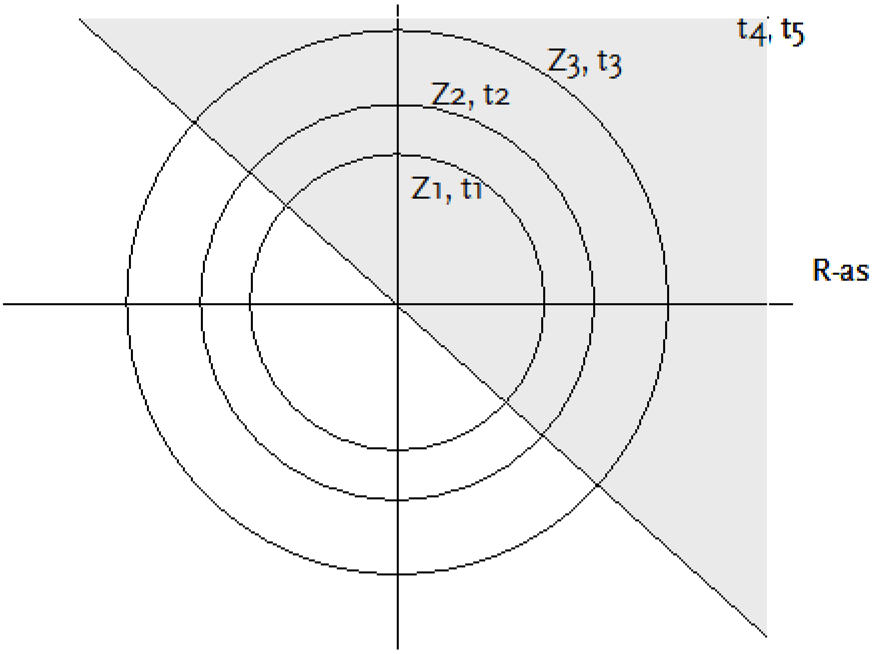
Polygon

A zone can be characterised using a polygon. It is defined by 3, 4 or 5 lines, crossing each other in such a way that they enclose an area. Each line is defined with a point where it runs through and a slope (in degrees).

MODELLING

Three zones of the impedance relay have a forward measurement, one zone has a reverse measurement. The final zone has the possibility of only a forward directional measurement or also a reverse directional measurement. If the reverse directional measurement is not to be used, the corresponding tripping time (undirected end time) must have a value of 0.

Circle characteristic



The forward directional measurement only lead to a trip if the measured impedance is located in the grey shaded area in the above figure. The slope of the slanted line in the R-X diagram is -45 degrees.

The next table applies:

Measured impedance	Action
|Zm| < Z1 and Zm in grey area	Trip on t = t1 s
|Zm| < Z2 and Zm in grey area	Trip on t = t2 s
|Zm| < Z3 and Zm in grey area	Trip on t = t3 s
|Zm| > Z3 and Zm in grey area	Trip on t = forward directed final time
|Zm| < Zreverse and Zm not in grey area	Trip on t = reverse time
Zm not in grey area	Trip on t = undirected final time

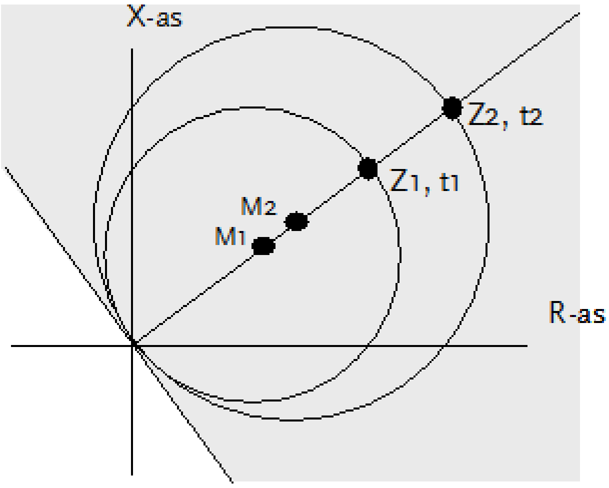
For the zone impedances the following applies:

$Z_1 < Z_2 < Z_3$

Mho characteristic

The forward directional measurement only lead to a trip if the measured impedance is located in the grey shaded area in the above figure. The slope of the slanted line in the R-X diagram is -45 degrees.

The zones are described by the circles, using the centre points (M_1, M_2) and their radii (Z_1, Z_2).



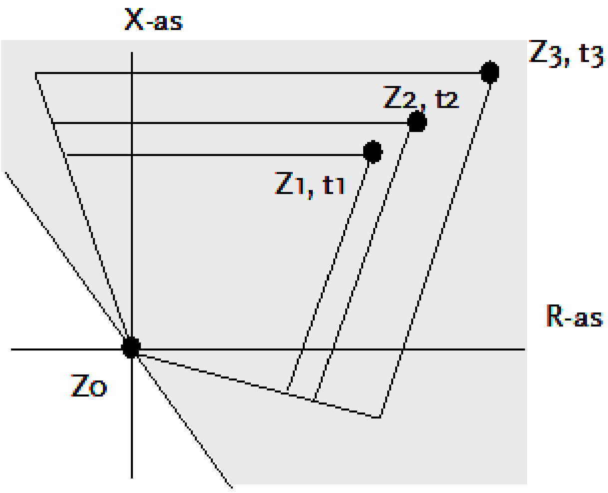
t4, t5

The next table applies:

Measured impedance	Action
Zm inside circle 1 and Zm in grey area	Trip on t = t1 s
Zm inside circle 2 and Zm in grey area	Trip on t = t2 s
Zm inside circle 3 and Zm in grey area	Trip on t = t3 s
Zm outside circle 3 and Zm in grey area	Trip on t = forward directed final time
Zm inside reverse circle and Zm not in grey area	Trip on t = reverse time
Zm outside reverse circle and Zm not in grey area	Trip on t = undirected final time

For the zone impedances the following applies:
$Z_1 < Z_2 < Z_3$

Polygon characteristic
The forward directional measurement only lead to a trip if the measured impedance is located in the grey shaded area in the above figure. The slope of the slanted line in the R-X diagram is -45 degrees.
The zones are described by the polygons, using the lines through the points Z_0, Z_1, Z_2, Z_3 and the angles of their slopes.



The following table applies:

Measured impedance	Action
Zm inside polygon 1 and Zm in grey area	Trip on t = t1 s
Zm inside polygon 2 and Zm in grey area	Trip on t = t2 s
Zm inside polygon 3 and Zm in grey area	Trip on t = t3 s
Zm outside polygon 3 and Zm in grey area	Trip on t = forward directed final time
Zm inside polygon circle and Zm not in grey area	Trip on t = reverse time
Zm outside polygon circle and Zm not in grey area	Trip on t = undirected final time

For the zone impedances the following applies:
$Z_1 < Z_2 < Z_3$

Measurement for diverse fault types
For asymmetrical phase to ground fault the factor K_N is introduced. In those cases a zero sequence current I_0 flows. The following applies:

$$K_N = \frac{Z_e}{Z_{fase}}$$

or

$$K_N = \frac{k-1}{3} = \frac{Z_0 - Z_1}{3Z_1}$$

where:

$$k = \frac{Z_0}{Z_1}$$

For a three phase fault:

$$U_m = U_a$$

$$I_m = I_a$$

$$Z_m = \frac{U_m}{I_m}$$

For a two phase fault (e.g. phases b and c)

$$U_m = U_b - U_c$$

$$I_m = I_b = -I_c$$

$$Z_m = \frac{U_m}{I_b - I_c}$$

For a two phase to ground fault (e.g. with phases b and c)

$$U_m = U_c$$

$$Z_m = \frac{U_m}{I_c + K_N \cdot 3I_0}$$

For a single phase to ground fault (e.g. phase a)

$$U_m = U_a$$

$$Z_m = \frac{U_m}{I_a + K_N \cdot 3I_0}$$

5.4.9 Unbalance protection

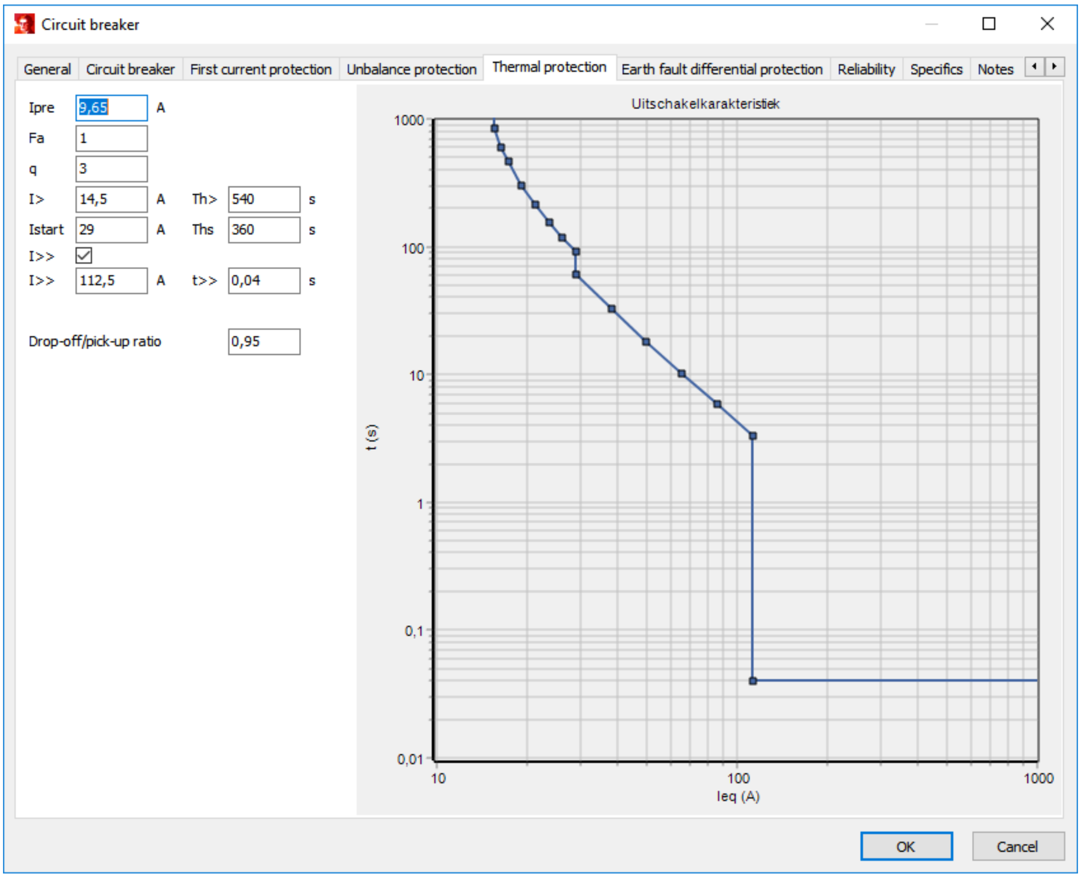
Negative sequence current appears due to unbalance in the network. This unbalance can be caused by unbalanced loads, a loss of a phase or a phase to earth fault. Unbalance protection relays are mostly applied to protect induction motors. An unbalance protection is a part of circuit breaker 203 in Vision.

The tripping characteristic can be defined in the same manner as for the current protection. The only difference is that the unbalance protection relay operates based on the negative sequence component of the current (I_2) instead of the positive sequence for the current protection.

5.4.10 Thermal protection

A thermal protection relay is usually applied to a motor in order to protect it against thermal effects. The relay generates a thermal equivalent of the machine as function of the positive and negative sequence component of the motor current. In this way both the stator and the rotor of machine are protected against overheating as a result of overloading or unbalance. Thermal protection is a part of a circuit breaker 203 in Vision.

PARAMETERS



Parameter	Default	Unit	Description
Ipre	0	A	initial loading current (loadflow result)
Fa	1		surrounding temperature factor
q	3		unbalance factor
I>	0	A	pickup current of the relay, I> = Inom · k (k = 1 .. 1,5)
Th>	0	s	thermal time constant, machine heating
Istart	0	A	current at which it is assumed that the motor is starting
Ths	0	s	thermal time constant, machine heating during start
I>>	0	A	current setting for medium protection stage
t>>	0	s	time setting for medium protection stage

Parameter	Default	Unit	Description
Drop-off/pickup ratio	1		ratio of the drop-off current value to the pickup value (only applicable if I>> has been specified)

MODELLING

The large variations in motors and their applications results in very complex thermal relations. It is therefore practically impossible to describe the thermodynamics of the motor exactly using a generic mathematical model. However, it is possible to consider the machine as a homogeneous mass and to represent its thermodynamics using first order differential equation. In time domain and solved for t as function of I_{eq} the following equation can be derived:

$$t_{trip}(I_{eq}) = \tau \cdot \ln\left(\frac{F_a \cdot I_{eq}^2 - I_{pre}^2}{F_a \cdot I_{eq}^2 - I_>^2}\right)$$

where:

t_trip(I_eq)	trip time as function of the equivalent current
I_eq	equivalent current
	thermal time constant
F_a	surrounding temperature factor
I>	pickup current of the relay, I> = Inom · k (k = 1 .. 1,5)
I_pre	initial loading current (loadflow result)

Using this equation the time-current characteristic can be plotted, which is used internally in the protection module of Vision. The thermal protection relay is afterwards treated as an current protection relay.

Machines are designed to operate at a specific surrounding temperature within a certain tolerance. If the real surrounding temperature is higher than the design temperature the windings can heat up more than the maximum temperature even if the machine operates within its loading limits. The thermal loading characteristic can be adjusted for a deviation in the surrounding temperature using the F_a coefficient. This coefficient is determined as follows:

$$F_a = \frac{T_{max} - T_{limit}}{T_{max} - T_a}$$

where:

F_a	surrounding temperature factor
T_max	maximum machine temperature conform IEC 60085
T_a	actual surrounding temperature
T_limit	maximum surrounding temperature, for which the machine is designed

Unbalance in the stator windings of the motor results in an additional production of heat in the rotor of the machine. This heating is not considered in the thermal loading characteristic. To take into account the effect of unbalance the equivalent current is used. This current can be determined as follows:

$$I_{eq} = \sqrt{I_1^2 + q \cdot I_2^2}$$

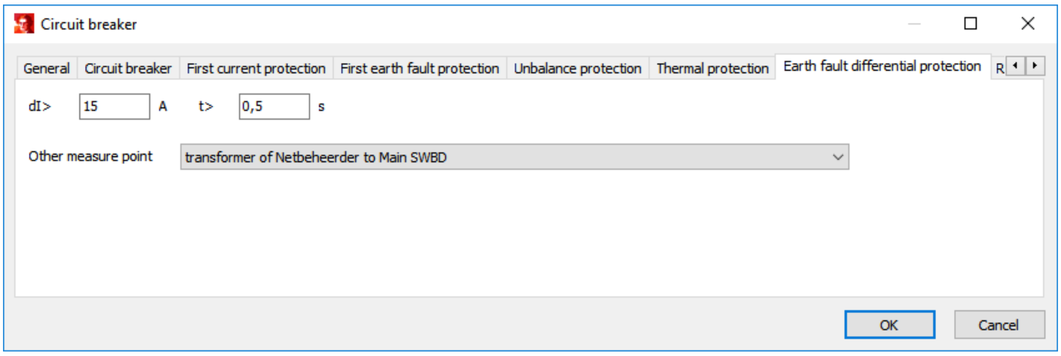
where:

I_eq	equivalent current
I_1	positive sequence current component
I_2	negative sequence current component
q	unbalance factor

5.4.11 Earth fault differential

A restricted earth fault (REF) protection or earth fault differential protection serves for fast, sensitive and directional protection of a transformer or machine in case of an earth fault in the windings. The restricted earth fault protection is coupled to one circuit breaker and one element or transformer with an grounded neutral point. The sum of the currents through the circuit breaker and the sum of the currents at the point of connection of an element or transformer is used for the equation, instead of the real current through the neutral point. It is possible to define additional circuit breakers that will be tripped using the transfer trip ability (which can be specified at the level of the circuit breaker, not in the specific protection function tabs).

PARAMETERS



Parameter	Default	Unit	Description
dI>	0	A	threshold value for pickup
t>	0	s	time setting for trip signal
Other measurement point			element with earthed neutral point

5.4.12 Short circuit indicator

This element simulates the short circuit indicator in a distribution network. This indicator operates when performing a single node IEC short circuit calculation and a fault analysis with a single fault. The currents in the network in case of a short circuit at a single node are compared with the trigger currents of the short circuit indicators. The symbol colour changes if the calculated current is larger than the trigger current.

The short circuit indicator is represented by one or more little balls, placed on a transverse dash. The number of balls depends on the trigger current:

- 0 - 150 A: one ball
- 150 - 250 A: two balls
- 250 - 500 A: three balls
- from 500 A: four balls

A short circuit indicator can be placed at both ends of a branch or at an element.

To add a short circuit indicator: select one branch or element together with the corresponding node and choose: **Insert | Short circuit indicator**.
The symbol of the short circuit indicator can be moved to the other side of the branch by dragging it with the mouse.

One copied short circuit indicator can be pasted into more feeders (combinations of a nodes and branches and\or elements). Select the feeders to which the short circuit indicator should be copied and choose: **Start | Clipboard | Paste special | Paste switch in all selected fields**.

Signalling a short-circuit current by a short-circuit indicator can be implemented with a directional sensitivity. This is used by the protection calculation - single fault, which shows which short circuit indicators have 'tripped'.

PARAMETERS

General

Parameter	**Default**	**Unit**	**Description**
Name			Name
Phase current	0	A	Phase trigger current
Directional			Directional sensitivity; into the branch
Phase Response time			Response time for phase currents
Earth current	0	A	Earth fault trigger current
Earth Response time	0	s	Response time for earth currents
Remote indication			Remote indication
Auto reset			Auto reset

5.4.13 Measure field

The presence of one or two or three current measurement transformer(s) and a single voltage measurement transformer can be specified. A measure field can be placed at a node or in a field on both sides of a branch or on an element.
To add a measure field, select a single node or select a branch or an element and the corresponding node and choose: **Insert | Switches and protections | Measure field**.

The measure transformer has the following attributes:
- function
- class
- transformer ratio
- rated power (VA)
- I_{nom}: rated current of the current measurement transformer (A)
- $I_{k,dynamic}$: dynamic short-circuit current (kA)
- $I_{k,thermal}$ and $t_{thermal}$: thermal short-circuit current (kA) and duration (s)

The rated current of the current measurement transformer is used in the load flow calculation and the protection analysis.
The $I_{k,dynamic}$ is tested when applying the IEC 60909 short-circuit calculation.
The $I_{k,thermal}$ and $t_{thermal}$ are used to calculate the t_{max} in the IEC 60909 short-circuit calculation.

Measurements
A list of dates with corresponding measurement values can be entered. If the value ends with 'A', 'kW', 'MW', 'kVA' or 'MVA', a date-current graph or a date-power graph is displayed. With the button **...** you can switch between these two options. Only the last 12 measurements are displayed.
The graph can be shown as a bar graph or as a line graph by means of two buttons. A point graph is used instead of a line graph if a time interval is greater than twice the average time interval.
Selected measurements can be removed with **Delete**. Select multiple measurements with Shft+cursor-keys.
All measurements can be copied to the clipboard as text with **Copy**.

Measurement files
A list of Excel-measurement files can be imported. For the time being, this is only for illustrative purposes.
In the **Column(s)** field, one or more columns can be specified that contain the measured values. This can be done in two ways:

- By entering the column letter (s), e.g. A, B, C, etc.
- By filling in the text that is in the cell of the first row of the relevant column, e.g. Imeasured.

If this column only applies to a particular worksheet, the name of that worksheet can be placed in front of the column, with an exclamation mark between them (in accordance with Excel), for example: MySheet!G or ThisSheet!Current.
Multiple columns can be entered consecutively, separated by a semicolon.

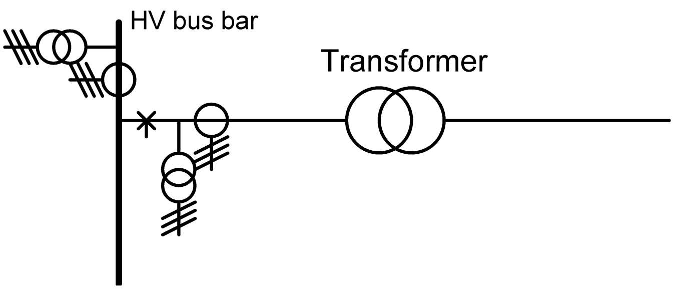
The worksheet is deemed to contain a date-time column or a date column and a time column. These are automatically detected by searching for "date" and "time" in the first two rows. If this is not successful, the first column is considered to be the date-time column.

The **Graph** button displays a line and/or a scatter plot of all the measurement files with indicated columns.
The **Graph + make profile type** button also generates non-standard profile types that can be included in the object type file after normalisation.

If a load flow with profiles has been executed, the result is also shown as a series in the graph, provided the measurement files show a quantity that is also available as a load flow result.

A copied measurement unit can be pasted into multiple feeders at the same time. Select the feeders to which the measurement unit should be copied and choose: **Start | Clipboard | Paste special | Paste switch in all selected**

The symbol of the measurement field can be flipped to the other side of the branch or the node by dragging it with the mouse. The symbol can be moved along a node.



5.5 Other

A number of supporting objects has been defined. See:

- Text 224
- Frame 225
- Legend 226
- Load behaviour 227
- Load growth 229
- Profile 230
- Selection 235
- Feeder 236

See also:

- Specifics 246
- Note 248
- Presentation Components 248

- Prepare 80

5.5.1 Text

Text can be used to place extra information anywhere in the network. A text field may contain text or the result from a macro 365. A combination of text and macro language is not allowed.

PARAMETERS

Text

Parameter	**Default**	**Unit**	**Description**
Text			Text

MACRO

Input data and calculated results can be shown on the network diagram. Also arithmetic operations on results can be shown. In order to do this, a macro language has been defined. For a more extensive description of the macro, see: Macros 365.

Only operations on variables are allowed in text field macros. It is not possible to alter input data from the text field. The macro commands which are available in a text field are:

- operation commands
  - o set 394
  - o add 395
  - o subtract 396
  - o multiply 396
  - o divide 397
- conditional command
  - o if ... end 403
- loop commands
  - o while ... end 405
  - o repeat ... until 405
  - o for ... end 406
- reporting command
  - o text 418

Using the **Text** command a user defined text between single quotes or a variable can be printed.

If a macro is defined before a calculation is carried out, a message is printed on screen:

```
'Attribute value not available at execution of line .......'
```

Therefore it is recommended to insert an if-statement to check whether loadflow results are available.

Example:

```
if(network.result,=,'LF')
      set(mytext,'The voltage on node Station 4 is:')
      add(mytext,Node('Station 4').Upu)
      add(mytext,' pu and ')
      add(mytext,Node('Station 4').U)
      add(mytext,' kV')
      text(mytext)

      set(mytext,'And the load on that node is:')
      add(mytext,Transformerload(':Station 4').PL)
```

```
        add(mytext,' MW as input and ')
        add(mytext,Transformerload(':Station 4').P)
        add(mytext,' MW calculated.')
        text(mytext)

        set(myp,0)
        set(mytext,'Total load in selection MV-network is:')
        forselection(load('MV-network'),myload)
              add(myp,myload.p)
        end
        add(mytext,myp)
        add(mytext,' MW')
        text(mytext)
end
```

Yields:

```
The voltage on node Station 4 is: 1.042 pu and 156.3 kV
And the load on that node is: 0.255 MW as input 0.277 MW calculated.
Total load in selection MV-network is: 10.308 MW
```

Text colour of text boxes in Result mode

If the text in the diagram is a macro generated text, its colour can be set using the command: TextResultColor(i), where i is an integer value between 0 and 14, representing the colours: black, grey, light grey, navy, blue, aqua, purple, fuchsia, green, lime, teal, maroon, red, yellow and white.

5.5.2 Frame

A frame is a rectangle, a polygon or an ellipse in the one-line diagram, indicating that some components belong to each other, for example components of a sub-station. Nodes and texts which are placed entirely in a frame, are kept together when dragging that frame if the **Container** checkbox is on.
The frame has no influence on calculations.

Defining a frame

A frame is defined in the one-line diagram using **Insert | Illustrations | Frame** or by clicking with the right mouse button in the one-line diagram and choosing **Frame**. On the **General** tab the name of the frame is filled in.
The upper left corner of a frame comes on the place of the last mouse click in the one-line diagram. The initial size of the frame is fixed. By moving one of the corners with the left mouse button pressed the frame can be enlarged or reduced. The whole frame can be moved by moving the edges with the left mouse button pressed.

Frame as polygon, ellipse of picture

The frame is a rectangle, a polygon or an ellipse. A polygon corner can be added by clicking a line segment and choosing **Bend** from the right-mouse pop-up menu. A corner can be moved with the pressed left mouse button. A corner will be removed automatically if the line segments are (almost) in the same direction.
A frame can also have an elliptical shape. An elliptical frame can be changed by left-mouse dragging the ellipse part that touches the virtual horizontal and vertical axes.
The frame may contain a picture. In that case the frame size is determined by the picture size. At **Presentation** a picture scaling factor can be defined.

Placing components into a frame

Nodes, texts, frames and legends can be placed into a frame by dragging them into the frame. A node must fit in its whole within the frame. Of a text only its upper left corner must be within the frame. A node or a text can also be placed into a frame by moving the frame over these components. Also smaller frames can be placed into a larger frame.

Removing components from a frame
A node, text or smaller frame can be removed from a frame by dragging them. Components can also be removed from a frame by reducing the size of the frame. If a frame is deleted, the placed components will not be deleted.

Dragging a frame with components
When a frame is dragged, its nodes, texts and smaller frames will be dragged along, in case the **Container** checkbox is checked. The elements will be dragged along with the nodes. A branch will be dragged along entirely if both connected nodes are within the frame.

PARAMETERS

Parameter	Description
Name	Name of the frame
Text	Free text
Picture	Location and name of the picture file
Frame	Whether the encapsulated objects need to be kept together

By default the frame keeps all objects together. If the checkbox **Container** is unchecked, all objects will be released and the frame can be moved independently of the objects inside the frame.

On the tab **Presentation** the graphical presentation of the frame can be defined: the shape, the colour, de thickness and style of the line and the size of the text displaying the name of the frame..
The frame has been enhanced with a number of user text lines.
The frame can be filled with a background colour.

5.5.3 Legend

A legend can be included in the network for information about the design, the client, revisions and logos. The legend consists of a grid that can be freely defined by a number of rows and columns. A text or image (bitmap) can be displayed in a cell. Cells can be combined.

PARAMETERS

General

Parameter	Default	Unit	Description
Number of rows	5		Number of rows in the table (1..9)
Number of columns	5		Number of columns in the table (1..9)

Merging cells
This indicates which cells must be merged. The procedure is comparable with Excel, where the range is indicated with the upper-left cell and the bottom-right cell, with a colon in between. The example below shows the merging of three cell blocks:

```
C1:E2
B4:D4
C5:D5
```

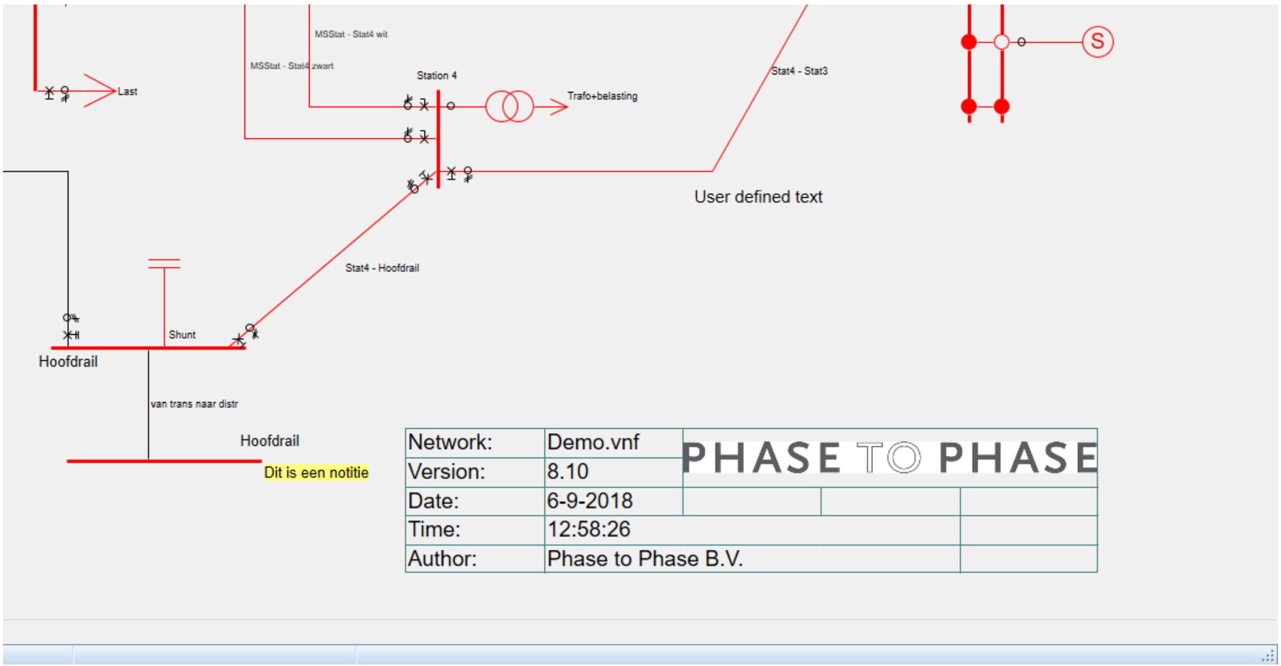
Cell
The contents of a cell can be specified by first choosing the cell from the table and hereafter typing the text in the text field. The text size can be adjusted.

A number of system variables can be included, like file name and date/time. The method is the same as printing macro-results in a text 224 field. The available system variables can be found in the Macro standard objects 369.
Examples:

```
text(Network.FilePath, Network.FileName)
text(System.Date)
text(System.Time)
```

In addition to text, an image can also be displayed in a cell.A reference to the image as a bitmap file, should be inserted into the cell.

In the case of merged cells, only the content of the first cell is presented in the legend.



5.5.4 Load behaviour

A load behaviour is used to establish the voltage dependence of a load. A load behaviour is defined separately, and can be used for several (transformer) loads.

Adding a load behaviour is done with **Insert | Trends | Load behaviour**.
Editing a load behaviour is done with **Start | Edit | Trends | Load behaviour**.
Deleting a load behaviour that is not in use is done with **Start | Edit | Delete | Load behaviour**.

Parameter	Default	Unit	Description
Name			Name of the load behaviour
Active power			
Const P	100	%	Percentage of constant power
Const R 1)	0	%	Percentage of constant impedance
Reactive power			
Const Q	100	%	Percentage of constant power
Const X 1)	0	%	Percentage of constant impedance

1) The parameters Const R en Const X are always equal to respectively: 100 - Const P and 100 - Const Q.

Seven types of load behaviour have been predefined:

Name	Behaviour	Voltage dependency of the power
Constant admittance	0% constant P and Q	quadratic
~Constant current	50% constant P and Q	linear
Constant power	100% constant P and Q	constant
Default	100% constant P and Q	constant
Industry	90 % constant P en 15 % constant Q	
Business	35 % constant P en 10 % constant Q	
Residential	30 % constant P en 5 % constant Q	

MODELLING

Load flow

Subdivision into constant power (P and Q) and constant impedance (R and X) is possible for both the actual and the imaginary part of the load. By then selecting a particular ratio between constant P and constant R, or constant Q and constant X, the voltage dependence of the load can vary between 0 and quadratic. The following applies to the load:

$$P_{load} = P * [\ (const.P / 100) + (const.R / 100)(\ |U| / U_{nom})^2\ ]$$
$$Q_{load} = Q * [\ (const.Q / 100) + (const.X / 100)(\ |U| / U_{nom})^2\ ]$$

where:

P, Q	load at nominal node voltage
$\|U\|$	current node voltage
U_{nom}	nominal node voltage
$const.\ P$	proportion of constant real power in %
$const.\ Q$	proportion of constant imaginary power in %
$const.\ R$	proportion of constant real impedance in %
$const.\ X$	proportion of constant imaginary impedance in %

and

$const.\ P + const.\ R = 100\ \%$

$const.\ Q + const.\ X = 100\ \%$

Constant power

At constant power, the rated power will always remain constant, independently of the calculated node voltage $|U|$. The following then applies in a load flow calculation:

- if $|U|$ increases : I_{load} decreases
- if $|U|$ decreases: I_{load} increases

Constant impedance

At constant impedance, the Z_{load} is determined at nominal node voltage using P_{load} and Q_{load}. The following then applies in a load flow calculation:

- if $|U|$ increases : I_{load} increases
- if $|U|$ decreases: I_{load} decreases

Application

The modelling of loads is complicated because a typical load is composed of a large number of devices such as motors, fluorescent and incandescent lamps, air conditioners, household devices, electro-chemical devices, heaters, furnaces, etcetera. The exact composition of load is difficult to estimate. Also, the composition changes on time (season). The active and reactive power, consumed by the devices, depend on the actual voltage. Some examples:

- Asynchronous motors: the active power is constant at a voltage not exceeding 10% of the nominal value; the reactive power follows approximately the constant current model.
- Incandescent light bulbs: the active power changes with the deviation from the nominal voltage, to the power 1.5. This is achieved with 25% constant power and 75% constant admittance; virtually no reactive power is absorbed, so that the model does not matter.
- Resistive heating: the active power is quadratic depending on the deviation of the nominal voltage. This is achieved with 100% constant admittance; virtually no reactive power is absorbed.

In literature (Kundur, 1994) describes the load characteristics for a number of typical load classes. The following table has been derived from this:

Load class	Power factor cos(φ)	Constant P (%)	Constant Q (%)

Residential	0,95	30	0
Commercial	0,90	35	0
Industrial	0,85	90	0
Power plant auxiliaries	0,80	95	20

In HV-network models it is custom to use the constant P and Q model for all general loads, because in fact these loads are connected at lower voltage levels to voltage regulated transformers.
In distribution networks the load behaviour tends to constant current or constant admittance, however with the increase in power electronic driven loads this is also shifting towards constant power.

Convergence

The increase in the load current at low node voltage, as occurs with a load which comprises constant power, can lead to divergence of a load flow solution. The increased load current causes a further lowering of the node voltage in this case. Increasing the proportion of constant impedance in the load behaviour will increase the chance of convergence. A load flow calculation almost always converges when the load behaviour for P and Q comprises 100 % constant impedance.

5.5.5 Load growth

Load growth defines a load scaling factor and a growth percentage for each year. These numbers can be specified for a scenario of maximum 30 consecutive years.

Scaling

The load is always multiplied by the scaling factor.

Growth

When performing a load flow calculation, it is possible to indicate which period the growth should be determined. This growth can be calculated linearly or exponentially. A "negative growth" is also possible.
A load growth is defined in % per year. This allows the load to be calculated over a number of years. In Vision the growth and scaling can be set per year. The formulas below show the calculation of the power $P(n)$ in year n, with a percentile growth $g(i)$ in each year i and scaling factor $f(n)$ in year n :

linear:

$$P(n) = P(0) \cdot \left[1 + \sum_{i=1}^{n} g(i)/100\right] \cdot f(n)$$

exponential:

$$P(n) = P(0) \cdot \prod_{i=1}^{n} \left[1 + g(i)/100\right] \cdot f(n)$$

In the **Options** at **Network | Default trends | Growth** one or multiple load growths can be specified, which will subsequently be added to each new network.

There are seven predefined load growths

Name	Scaling	Growth	Type
None	1	0 %/year	exponential
1 % per year	1	1 %/year	exponential
1,5 % per year	1	1,5 %/year	exponential
2 % per year	1	2 %/year	exponential
3 % per year	1	3 %/year	exponential
4 % per year	1	4 %/year	exponential
5 % per year	1	5 %/year	exponential

5.5.6 Profile

A profile defines the power of a load or a generator as a function of the time. Also the source voltage profile can be defined. Using an option in the load flow calculation the profiles are processed. The results can be reported as a function of the time.

The profiles have a time related sort. This implies that profile values can be related to months, weeks, days, hours or quarters of an hour.
The following profile sorts have been defined:

Profile sort	**Number of calculations**
Hours of one day	24
Half hours of one day	48
Quarters of hours of one day	96
Five minutes of one day	288
Hours of working day, Saturday and Sunday (7 days)	168
Half hours of working day, Saturday and Sunday (7 days)	336
Quarters of hours of working day, Saturday and Sunday (7 days)	672
Five minutes of working day, Saturday and Sunday (7 days)	2016
Hours of one week	168
Hours of one week + 12 months factors	8736
Hours of one week + 52 week factors	8736
Hours of working day, Saturday and Sunday for all months	8736

The free profile sort remains for not explicitly time-related values. A maximum of 300 values can be defined by the user.

In addition to this internal profile, an external profile 232 defined outside the program can also be used. The external profile is always strictly time-related. The external profile must be supplied as an Excel file.

The profiles are used by the load flow calculation. The period to be calculated is automatically determined from the above profile sorts. If multiple sorts have been used, the sort with the largest number of calculations (and hence the largest time span) will be leading. Other values will be interpolated or extrapolated.

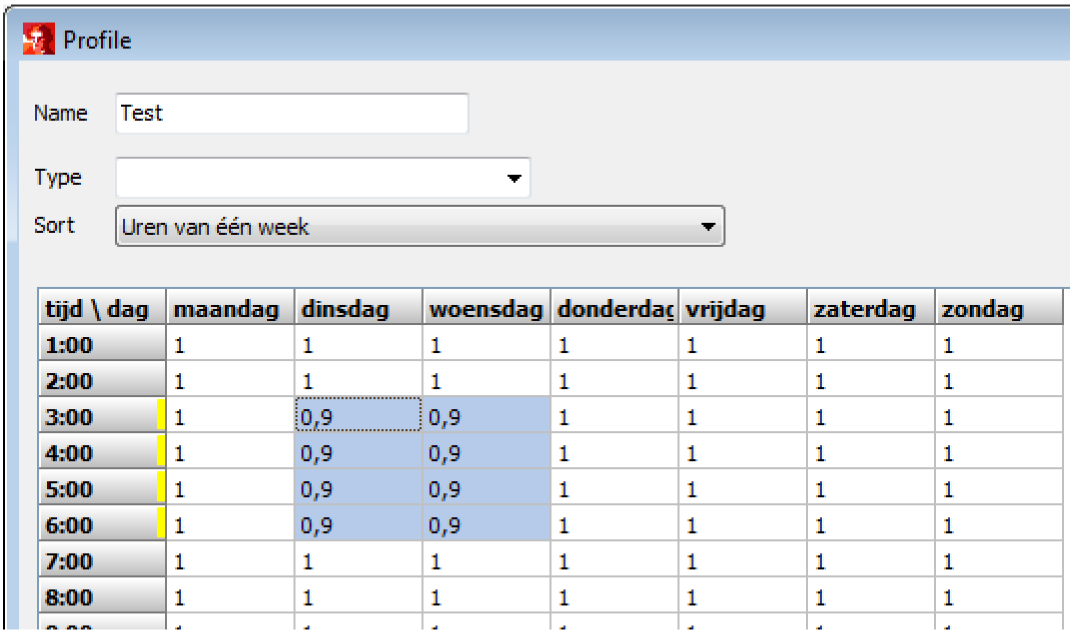
A profile can be defined in the component types'*Types.xlsx*' on the tab **Profile**.

A profile must be produced firstly at **Insert | Trends | Profile** before it can be added to an element. An existing profile can be chosen from the component types and edited or an entirely new profile can be defined. The profile is stored in the network file. The profiles can be used by means of the elements forms or by means of **Start | Edit | Collective | Element**.

Method:
- Optionally create one-time custom profile types in *Types.xlsx* .
- Create profiles in the network by choosing from these profile types or by defining new ones.
- Assign the profiles to (transformer) loads and generators: individually or via **Start | Edit | Collective | Element**.

It is also possible to assign a voltage profile to the grid.

Define and edit a profile with Excel
A profile that has been opened to define via Insert | Trends Profile or to edit via Start | Edit Trends Profile can easily be filled from Excel. To do this, the area with the data in Excel is copied and pasted into the form. The upper-left corner of the data area in Excel corresponds to the upper-left corner of the area where the data is pasted. In the example below, an area of 2 columns and 4 rows with values of 0.9 is pasted in the columns 'Tuesday' and 'Wednesday' from 3:00 to 6:00.



An area with data can also be copied and pasted in Excel. The area is selected in the form by dragging with the left mouse button pressed or with the cursor keys with the Shift key pressed.

PARAMETERS

Profile

Parameter	Default	Unit	Description
Name			Name of the profile
Type			Name of the profile type from component types
Sort	free		Profile sort (free or in hours, days, weeks, months)
f1 ... f3456	1		Maximum 3456 factors between -10 and 10

The factors can be input with values between -10 and 10. However, for most of the applications, such as calculating a daily load profile, values between 0 and 1 are usually applied. In all cases a factor equal to 1 yields the nominal power, as specified in the element form.

In the **Options** at **Network | Default trends | Profile** one or multiple profiles can be specified, which will subsequently be added to each new network.

CALCULATION

The calculation with profiles will be performed with **Calculate | Basic | Loadflow | Profile**. The ranges of the profiles to be calculated can be specified in the load flow form, on the tab ***Profile*** , as well as whether the simultaneousness factors of the nodes should be taken into account.

The results can be examined in the one line diagram, as a table and as graph.

- In the one line diagram the minimum and maximum values are shown of the attributes that were defined for the current **View**.
- At **Calculate | Results | Overview** a table presents the powers for all calculated time values. Both for the selection and for the whole network, the powers for Source, Generation, Load and Losses are presented.
- At **Calculate | Results | Details** with the button **'Details'** for the concerning component a table is shown of the results for all 250 factors.
- At **Calculate | Results | Graph** the voltage, current and flow bands are shown as bar a chart for all selected components.

- At **Calculate | Results | Detailed graph** the voltage, current and powers through time are shown for all selected components.

MODELLING

Default profile
The built in profile "**Default**" consists of 300 factors equal to 1. This profile cannot be altered.

Load flow
The defined load or generation powers are multiplied by the factor values. The number of load flow calculations performed, depend on the profile sort.

The factors influence the power of all elements, except the source and the zigzag coil.
The actual power of a load or a transformer load on time *t* in year *i*:

$$P(t) = P \cdot scaling \cdot growth(i) \cdot f(t)$$
$$Q(t) = Q \cdot scaling \cdot growth(i) \cdot f(t)$$

or, if the setting 'Take simultaneousness into account for (transformer)loads' has been selected before the calculation of the loadflow the following holds:

$$P(t) = P \cdot simultaneousness \cdot scaling \cdot growth(i) \cdot f(t)$$
$$Q(t) = Q \cdot simultaneousness \cdot scaling \cdot growth(i) \cdot f(t)$$

The actual power of a generator or motor on time *t*:

$$P(t) = P_{ref} \cdot f(t)$$

The actual power of a motor group on time *t*:

$$P(t) = number \cdot loadrate/100 \cdot P_{nom} \cdot f(t)$$

The actual power of a coil or capacitor on time *t*:

$$Q(t) = Q \cdot f(t)$$

The actual source voltage on time *t*:

$$U(t) = U_{ref} * f(t)$$

5.5.7 External profile

Apart from the internal profiles 230, a load flow calculation can also be executed using an externally generated file of time related factors for loads, generators and batteries. Also transformer tap settings can be influenced by an external profile. The external profiles can be defined using Excel. They may be generated from measurement data or other external sources. The external profile can be activated on the tab ***Profile*** of the load flow calculation settings.

Unlike the profiles, the external profiles have a strict relation to the time. The time stamps (date and time) and the factors for consumed or generated power are linked in the file records. The actual power can be given as an factor of the elements nominal power or as absolute values, both as function of time. The ratio of active and reactive power is fixed.
The external profile is leading with respect to the built-in profiles and other settings. Each element with external profile data will be evaluated according to the external load data in the load flow calculations and internal profile data of that element will not be used.

Each element with no external profile data will be evaluated according to the attribute specifications in Vision. The next applies:
- If the default profile (only constants values of 1) is used, the actual value of the load is constant.

- If a time related internal profile is used, the profile values will be tuned to the external profile time stamps. Values will be interpolated to fit between the external profile's time stamps.
- If a free (not time related) profile is used, the calculation will not execute, because time related and free profiles do not mix.

DEFINITION

An external profile has a header and value records. The header record is located at the first row of the spreadsheet. The value records are located from the second row onwards.

Header record
The header record consists of the definition of date and time and the specification of the element names. The date and time can be defined together in one column or in two separate columns.
- Date and time: the first column header has the text "Date & Time" or "Datum & Tiijd". The following columns are indicated by <NodeName>.<ElementName>, so separated by a point. If <NodeName> or < ElementName> is an asterisk, then this corresponds to each name, which allows a profile to be linked to multiple elements at once. The <NodeID>.<ElementName> notation can also be used.
- Date: the first column is indicated by the text "Date" or "Datum". The second column is indicated with the text "Time" or "Tijd". The following columns are indicated by <NodeName>.<ElementName> or <NodeID>.<ElementName>.
- Because a transformer load can contain three items, an addition can be made in the header: <NodeName>.<Transformer Load Name>.Load or <NodeName>.<Transformer Load Name>.Generation or <NodeName>.<Transformer Load Name>.PV.
- For the definition of a column for transformer tap settings, the column should be headed with <Transformer Name>.

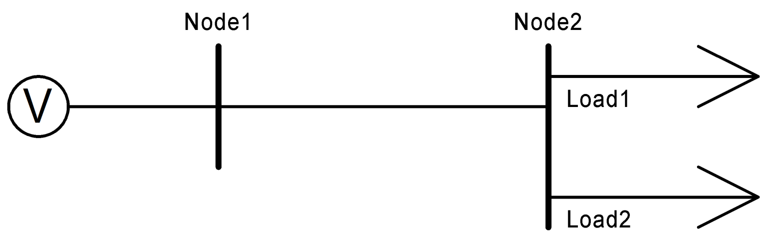
Optionally, the units that apply to the values can be included in the second row. If no units are specified, the values below are interpreted as factors of the set element values. The identified units are: V, kV, A, A, VA, kVA, MVA, VA, KVA, MVA, W, kW, MW, W, kW, MW, var, kvar, Mvar, var, kvar, mvar, m/s, pu,%, ‰ and percentage points. The unit must correspond more or less with the requested value for a particular component type. A minus at the end of a unit means that the values should be applied with the opposite sign.

Value records
- Date and time together: the column is filled with an ascending range for date and time.
- Date and time separated: the first two columns are filled with an ascending range for date and time.
- Factors: each value column (with element name header) contains the factors to calculate the actual power for the corresponding element on the specific time stamp. The factors may be positive and negative.
- For transformer tap changers, the column contains the absolute tap changer setting.

The range of the value records does not need to be closed with a special marker. After the last value record, the spread sheet must be empty.

EXAMPLE

The next network contains the elements “Load1” and “Load2”, both connected to the node “Node2”.



In this example, the external profile defines the factors for the powers of both loads, on a certain date, from 12:00 h to 18:00 h. The external profile can be defined on two ways, depending on the choice of the time stamp format:

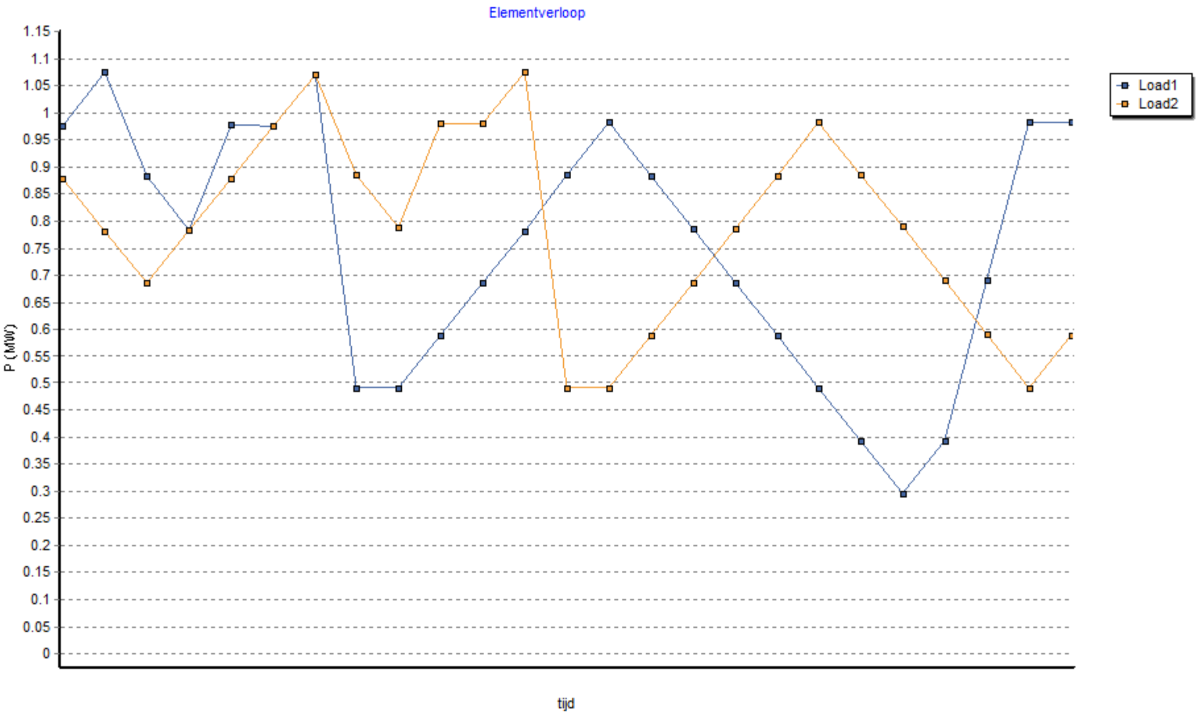
Method 1:

date & time	Node2.Load1	Node2.Load2
15-8-2011 12:00	1	0.9
15-8-2011 12:15	1.1	0.8
15-8-2011 12:30	0.9	0.7
15-8-2011 12:45	0.8	0.8
15-8-2011 13:00	1	0.9
. . .		
15-8-2011 17:00	0.3	0.8
15-8-2011 17:15	0.4	0.7
15-8-2011 17:30	0.7	0.6
15-8-2011 17:45	1	0.5
15-8-2011 18:00	1	0.6

Method 2:

date	time	Node2.Load1	Node2.Load2
15-8-2011	12:00	1	0.9
15-8-2011	12:15	1.1	0.8
15-8-2011	12:30	0.9	0.7
15-8-2011	12:45	0.8	0.8
15-8-2011	13:00	1	0.9
. . .			
15-8-2011	17:00	0.3	0.8
15-8-2011	17:15	0.4	0.7
15-8-2011	17:30	0.7	0.6
15-8-2011	17:45	1	0.5
15-8-2011	18:00	1	0.6

Result of the load flow calculation:



5.5.8 Simultaneousness

Simultaneousness is the fraction of the total maximum connected load expected to be active at the time of the peak usage. The simultaneousness is also known as the coincidence factor. Its reciprocal value is also known as the diversity factor.
A simultaneousness can be given for each node, at this node all the loads and transformer loads are multiplied by the simultaneousness . This simultaneousness makes it possible to make use of the results of the individual maximum current measurements at a transformer or load.
The simultaneousness factors can be collectively changed for the selected nodes (for example all nodes of an MV feeder) using **Start | Edit | Collective | Node**.

Semi-automatic calculation of simultaneousness factors
The node simultaneousness factors can be calculated automatically in such a way that the calculated current through a selected branch matches a user specified value. This is especially helpful for calculating the simultaneous load in a distribution network feeder. To perform this the following function is available: **Start | Edit | Special | Simultaneousness.** For more information, see: Edit, Special, Simultaneousness 92.

5.5.9 Selection

A component (node, branch, element) may be present in one or more selections.

A selection of components can be saved in the network file.

Insert | Miscellaneous | Selection is used to add a selection to the network.

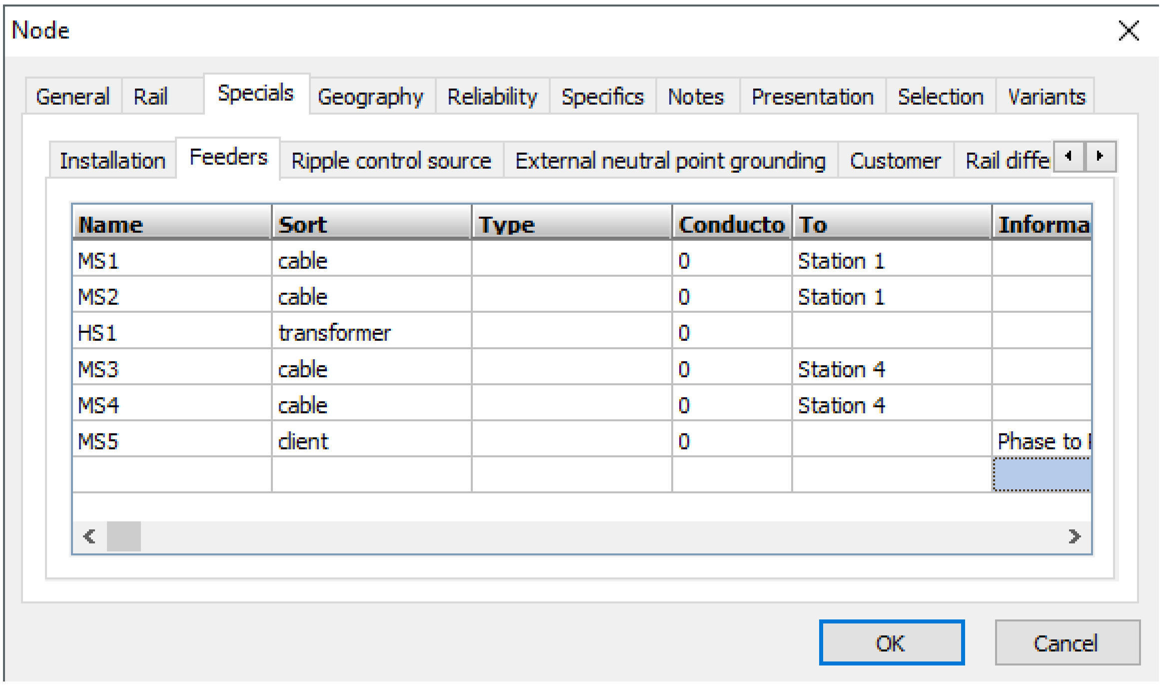
To add a selection:
- select the network components which should be added to the new selection
- click using the right mouse button
- choose **Selection**

Start | Edit | Selection is used to change the name and content of a defined section.

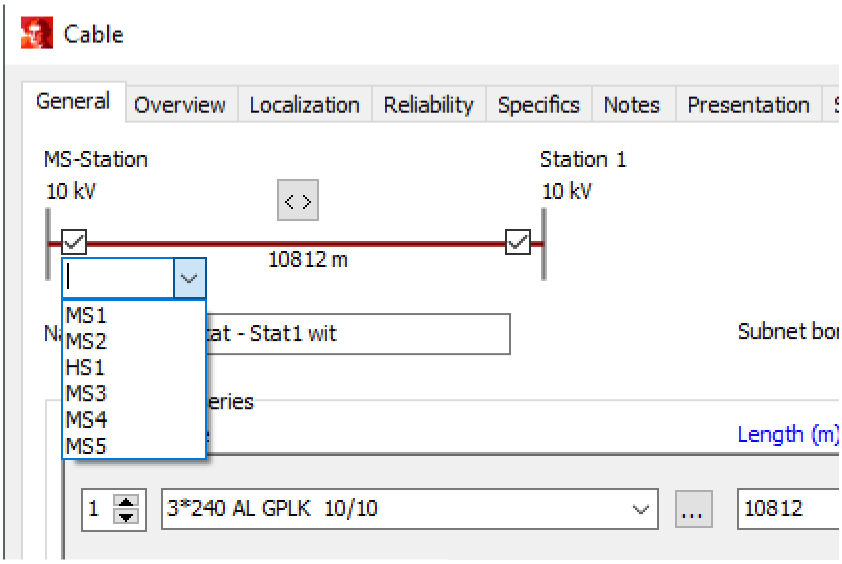
Start | Edit | Delete | Selection can be used to delete a selection. If a selection is deleted the components are unaffected.

5.5.10 Feeder

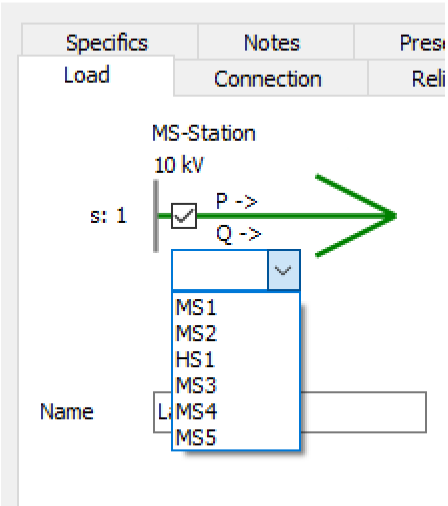
For a node[138], feeders/bays can be defined, by specifying their names on the tab **Specials | Feeders**. The order of the names of the feeders should match the order of the feeders on the node.



After the feeder names have been specified, each branches[144] and element[171] can be assigned to a certain feeder on their input form.



Load



For a node with all the feeders assigned, the bus bar currents can be calculated for a load flow and a protection calculation.

- After a load flow calculation the largest bus bar current between two feeders will be compared to the rated current I_{nom} of the bus bar.
- After a protection calculation in single fault mode, the largest I^2t between two feeders will be compared to $I_{k,thermal}$ and the corresponding time of the bus bar.

If any of these comparisons result in an violation of the limits, the node will be presented in a different colour 131.

5.5.11 Variant

In each power network bottlenecks emerge, e.g. caused by load growth. Also, frequently network components have to be substituted by new ones, probably having different electrical parameters. In those cases the power network will be modernised and enhanced. Each network modification can be made in more than one ways, called ***variants*** .

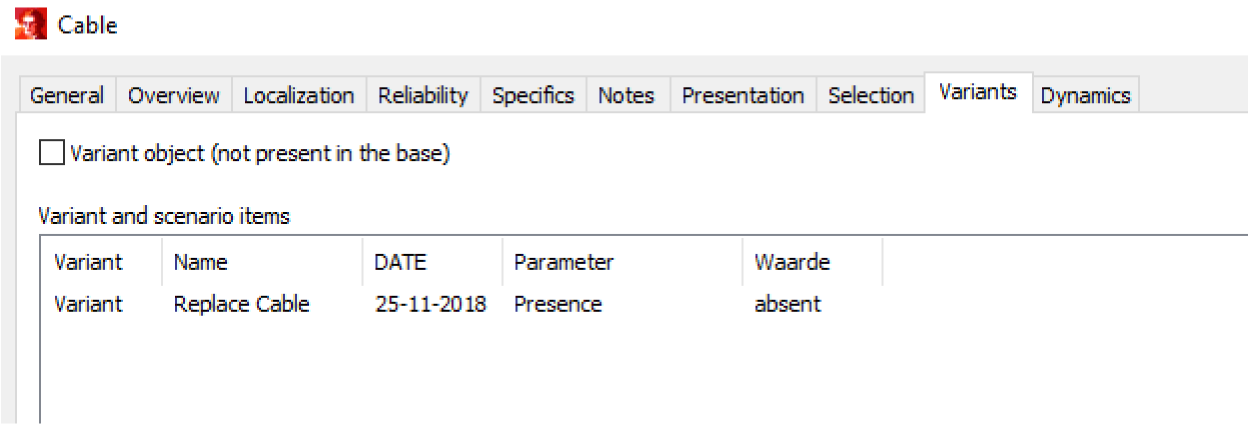
A variant describes modifications to a network model that will occur on specific dates (in the future). Using variants, all stages of commissioning and decommissioning of network components can be evaluated. A ***variant*** is a list of events, specifying the dates when objects will be put into or taken out of operation.

The starting point is always the current state of the network, in which no variant event occurred yet: the base case. All modifications occur from this base case. For each object it can be specified that the object does not belong to the base case, but is a variant object and will only becomes active at a later time. Similarly, objects can be taken out of operation at a later time. Objects that are not present in the combination of chosen variant and time are not visible in the standard view.

In a network model more than one variants can be defined. For the calculations, one or more variants can be active. To activate variant(s) choose the variant and the evaluation date in the ribbon at **Variants**. All calculations will be performed on the network adjusted to the variant(s).

Variant-object

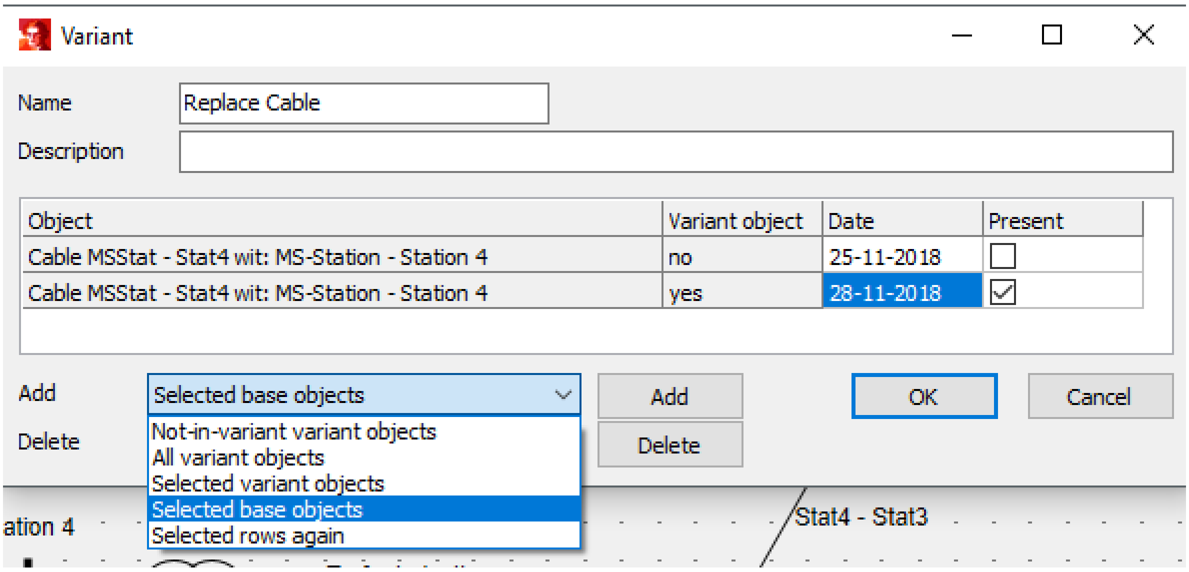
An object, that only exists in a variant from a specified date, and does not exist in the basic situation, is called a ***variant-object*** . This is specified on the object form on the ***Variants*** tab by ticking the ***variant-object*** checkbox. Hereafter, the variant-object disappears from the base case and, using the standard view, will only be visible if the appropriate variant and date have been chosen. The object has become ***variant-object*** . If the object is not included in any variant, it will no longer be visible after the ***variant-object*** has been checked in the standard view.



The object variations-form also lists all variants where the object will be taken into or out of service. The active items are displayed selected.

Inserting a variant

A variant will be inserted from the ribbon **Insert | Variations | Variant**. This opens the variant-form, where its name and description can be defined. In this form the objects can be added to the variant-list. Also, the dates for the events to take the objects into or out of service can be specified here. If the checkbox in the column ***Present*** is ticked, the object will be present from the corresponding specified date. If the checkbox is not ticked, the object will be taken out of service on the specified date. By adding objects to the variant, the variant list of events is created, this list is automatically sorted by date.



The message appears later when the variant is activated.
The scenarios (separated by a semicolon) are activated automatically after the user's consent when the variant is activated later.

There are six ways to add objects to the variant-list:
- Not-in-variant variant-objects: all ***variant-objects*** that do not yet occur on any variant-list
- All variant-objects: all ***variant-objects***
- Selected variant-objects: all selected ***variant-objects***
- Selected base objects: all selected objects that exist in the base case and that are not a variant-object.
- Selected rows again
- Copied items

If an object occurs in a variant list, it does not necessarily imply that it is ***variant-object***. As a consequence, an object that occurs in a variant-list and that not is ***variant-object***, exists in the base case. Eventually it may be taken out of service. Each object that has to be put into operation, according to the variant list, has to be taken out of service in the base case by designing it ***variant-object*** on the object variants form. In the variant form it is visible in the ***variant-object*** column, using the values 'yes' and 'no'.

Editing a variant

A variant can be edited from the ribbon **Variants** | **Edit** | **Variant**. The variant can be chosen from a list. Objects can be edited in the same manner as when inserting a new variant. The dates in the variant list can be edited and the actions (present/not present) can be altered. There are two ways to remove objects from the variant list:
- Selected rows: only objects where the date-field has been selected will be removed
- All rows

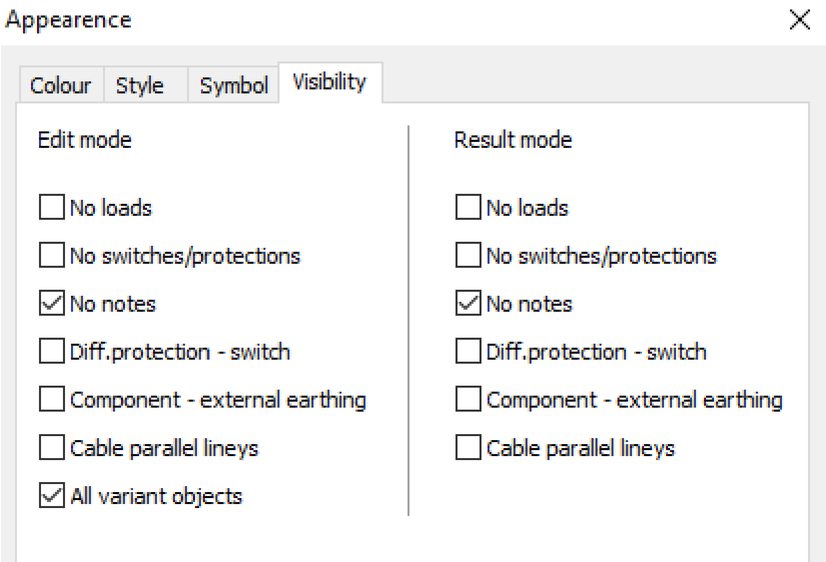
Deleting a variant

A variant can be deleted using ribbon **Variants** | **Edit** | **Delete** | **Variant**.

Viewing variant-objects and objects that occur in variants

In the standard view an object is not visible if:
- it is ***variant-object*** and it has not been assigned to a variant
- it is an object that, according to the chosen variant and date, is not in service.

These objects can be made visible in the Edit-mode, by choosing **View** | **Appearance all | Adjust Appearance | Visibility**, **All variant objects**.



All ***variant-objects*** can be shown in a specific colour. This can be enabled using **View** | **Appearance in edit mode** | **Colour** | **Variant**. This can also be enabled for the result-mode. The colour scheme is:

- green: all objects that according to any variant will be put into service at a specified date
- red: all objects that according to any variant will be taken out of service from a specified date
- yellow: all ***variant-objects*** that are not assigned to a variant.

Activating of one or more variants
One or more variants will be activated by using **Variants | Set | Variant**. The variant can be chosen from a list of existing variants. Via **Multiple...** you can select multiple variants from a multi select list. All variants can be deactivated by choosing ***None*** .
The events in the variants can be activated by specifying the ***Date*** . All events until that date will be in effect. In the standard view all the objects will be visible according to the variant and date specified here. ***Before*** means the the variant is active, but the time has been set before the first event in the variant list is activated.

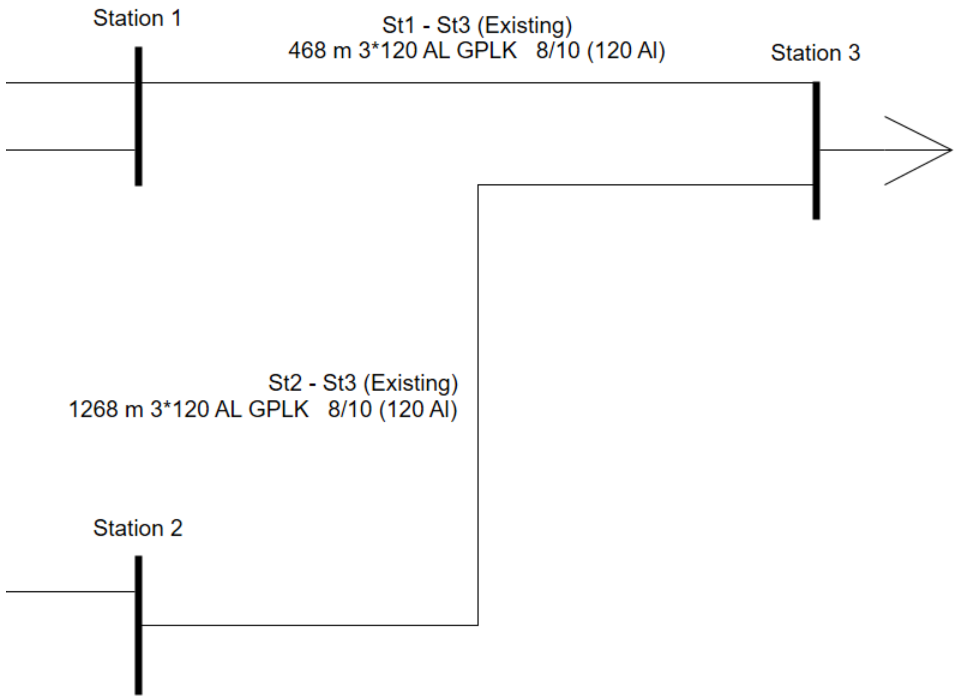
EXAMPLE

In the next example the node 'Station 3' is supplied by the two nodes 'Station 1' and 'Station 2'.
The feeder from 'Station 1' is an old 3x120 AL PILC cable.
The feeder from 'Station 2' is an old 3x120 AL PILC cable.

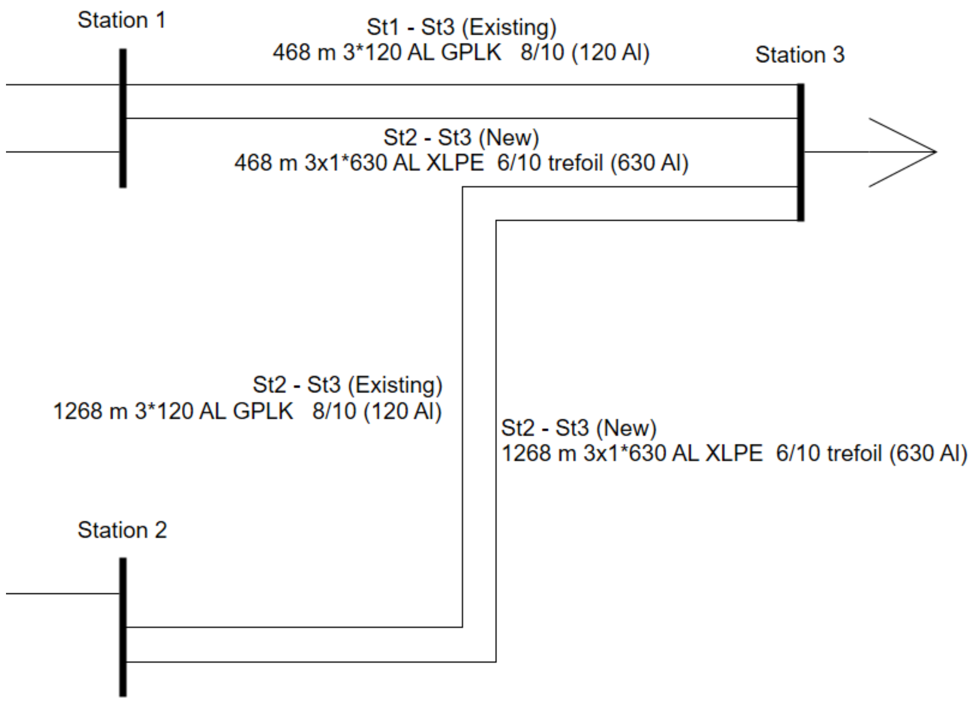
There are two variants for the network modification:

- Variant 1: replace the cable 'St2 - St3' by a new3x1*630AL XLPE cable
- Variant 2: replace the cable 'St1 - St3' by a new 3x1*630AL XLPE cable

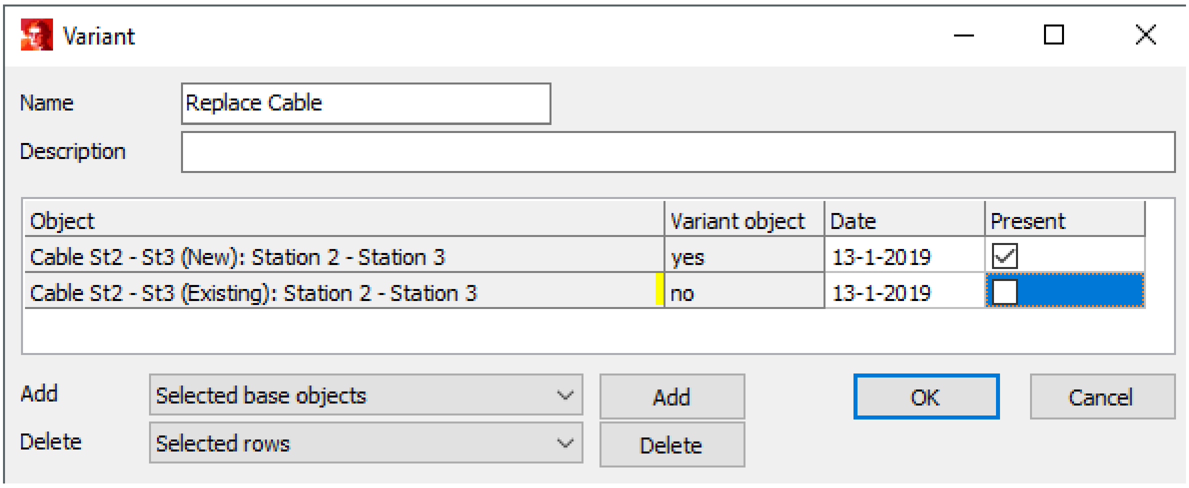
The starting point is the base case:



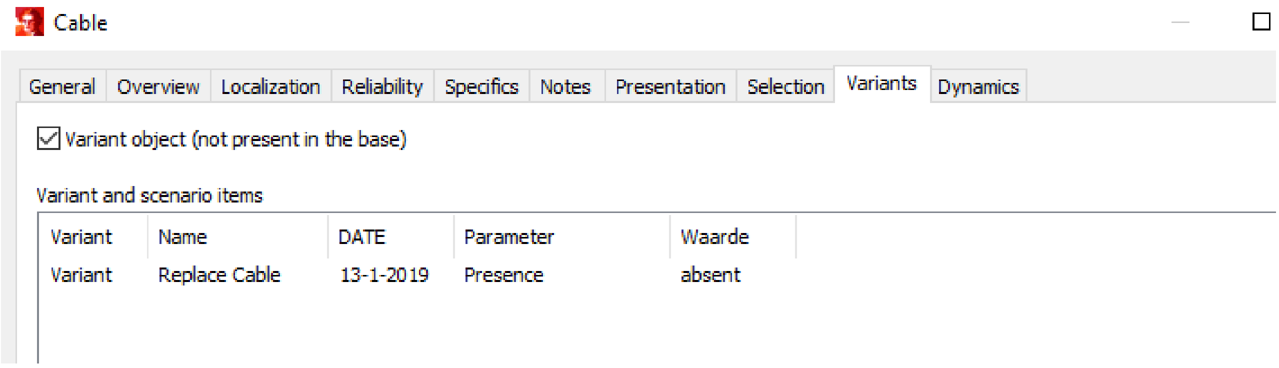
Next, the possible modifications will be added. At this moment the new cables are not yet ***variant-objects***. The network model shows the base case plus the new cables:



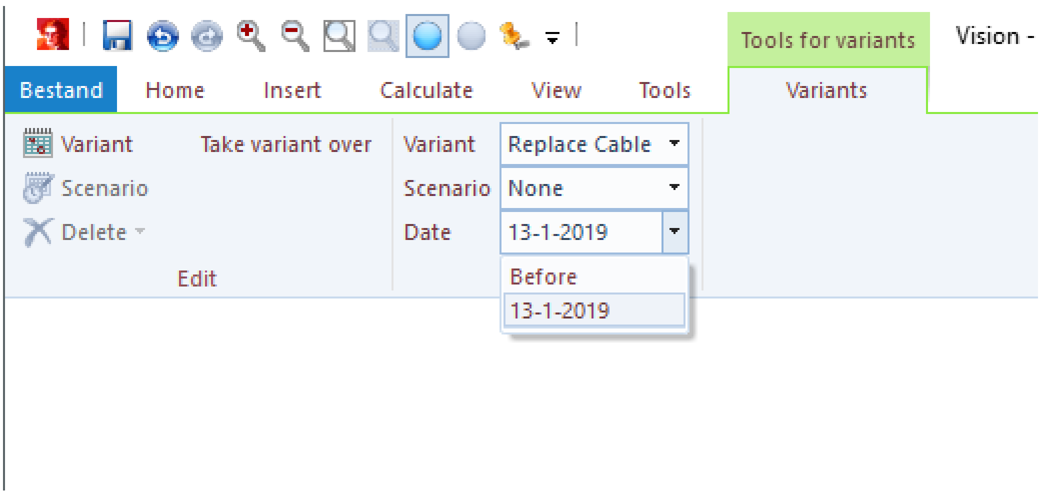
Next the first variant will be defined. In this variant the existing cable from Station 2 to Station 3 will be replaced by a new 3x1*630 AL XLPE cable. To do this, select both the existing and the new cable. Next, insert a new variant by choosing **Insert | Variants | Variant**. Fill in the variant name and its description. Next, add the selected basic objects. The new cable obtains the tick in the ***Present*** column checkbox; the existing cable not. Finally, the event dates will be specified.



From this moment, both cables have been assigned to the variant list, but none of both cables are ***variant-object***, meaning that both exist in the base case. Next both the new cable will be specified as ***variant-object***, and as a result they will disappears from the base case and becomes invisible.

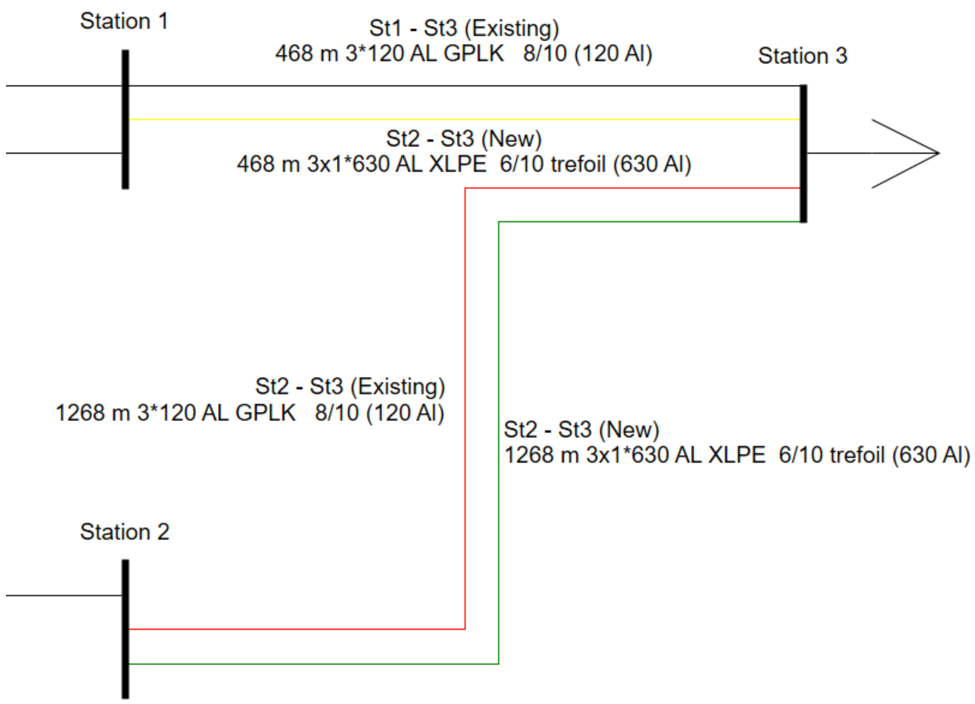


The new cable will become visible in the new situation, that occurs after the variant has been activated and the date has been selected for the corresponding event. **Variants | Set | Variant**.



By activating the variant, the existing cable has been taken out of service and the new cable has been taken into service.

All *variant-objects* and objects that appear in a variant list, can be presented in the Edit-mode, **View** | **Appearance in Edit-mode | Visibility**, **All variant objects**. The network presentation will be (green means present from a specified date; red means absent from a specified date; yellow variant objects not yet added to a variant):



The second new cable appears in yellow as the cable was already defined a *variant-object*, but the variant was not yet defined. The second variant can be defined in a similar way.

Take over one or more variants

One of more active variants can be taken over to the base using **Variations | Edit | Take over variant**.
The changes up to the set date are carried over into the *variant object* of the corresponding objects. An object can thus change from base object to variant object or vice versa.
The applied variant items are removed from the variant(s).

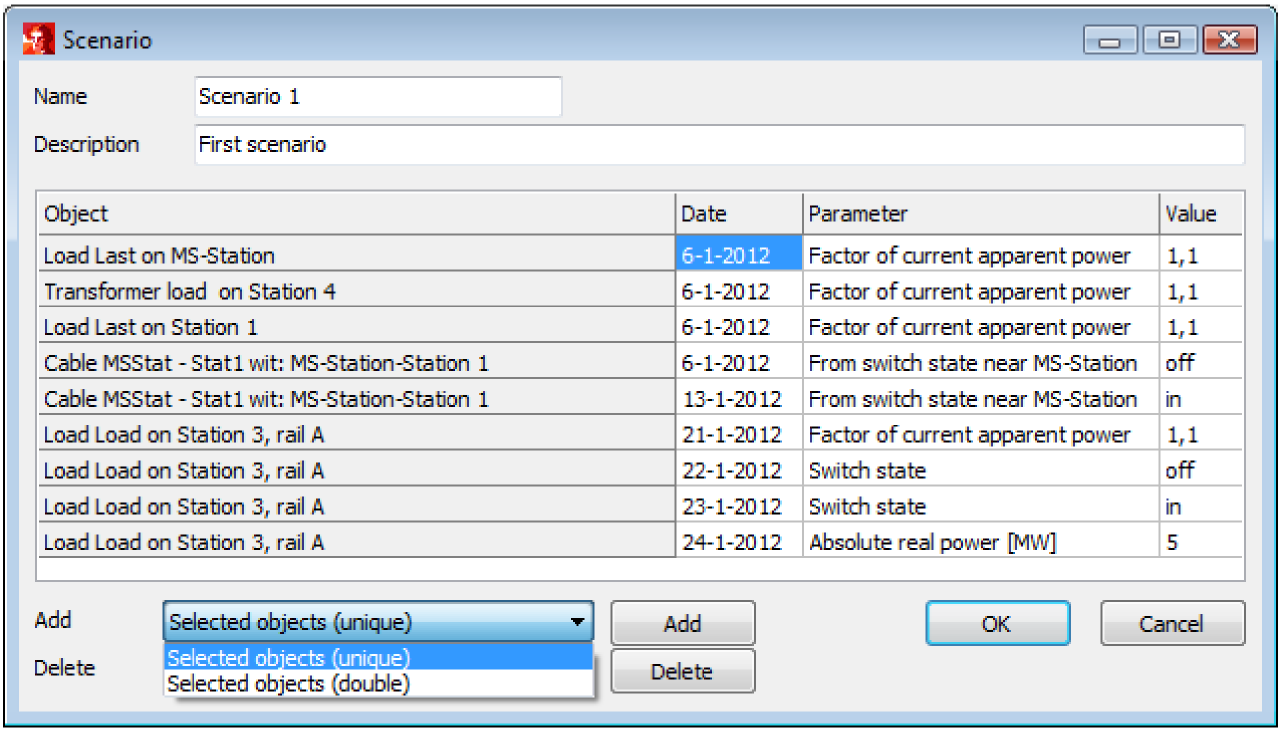
5.5.12 Scenario

In the process of network design, several load states and switch states have to be analysed. The state of a network is called *scenario*.

A scenario describes the settings and changes to objects parameters in the whole network. The changes can be independent of time but also a chronological list of events can be defined. The parameters that can be changed are: switch state, transformer tap setting, real power, reactive power and apparent power. Several scenarios can be defined for a network. One of more scenario's can be activated using the menu ribbon **Variants | Set | Scenario**. Using the selected scenario and date, all calculations will be performed for this network state.

Inserting a scenario

A new scenario is inserted using the **Insert | Variants** | **Scenario**. This opens the scenario form, where a name and description can be added. Next the objects and the parameters that should be changed are added to the scenario list. In the list a date for the parameter change can be defined. If no date is specified, the parameter change will be executed every time the scenario is activated, independent of the selected date.



The message appears later when the scenario is activated.
The variants (separated by a semicolon) are automatically activated after user approval when the scenario is activated later.

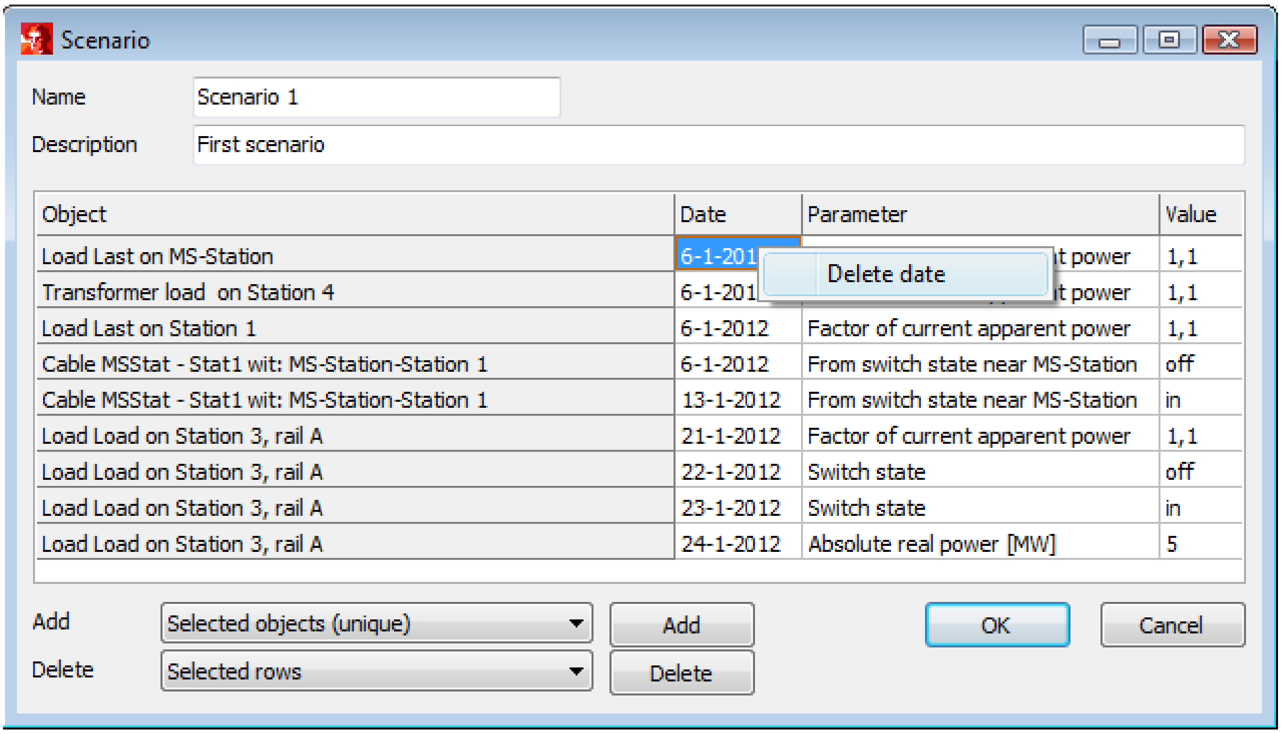
There are four ways of adding objects to the list:
- Selected objects (unique): selected objects will be added to the list, only if they do not already are in the list
- Selected objects (double): selected objects will always be added to the list.
- Selected rows again
- Copied items

The possibility to add objects more than once to the list has two purposes:
- to change more than one parameter of an object
- to change parameters on several time steps

Adding parameters and their properties
The following parameters can be changed, if applicable:
- Simultaneousness (nodes)
- Switch state (branches, elements)
- Tap changer state (transformer, transformer load)
- Absolute real power (elements)
- Absolute reactive power (elements)
- Absolute apparent power (elements)
- Number of motors in service (motor group)
- Absolute wind speed (wind turbine)
- Absolute Scaling (PV)
- Factor of nominal wind speed (wind turbine)
- Factor of current wind speed (wind turbine)
- Factor of current scaling (PV)
- Factor of load rate (motor group)

- Factor of nominal power (machines, transformer load, battery)
- Factor of current active power (machines)
- Factor of current apparent power (load, transformer load, battery)
- Factor of current reactive power (capacitor, coil)

Deleting a date from the scenario list
By deleting a date, the parameter manipulation will be executed any time the scenario has been activated. A date can be deleted by selecting the date field in the scenario list and right mouse-click in the date field. Also a range of dates can be selected and deleted this way.

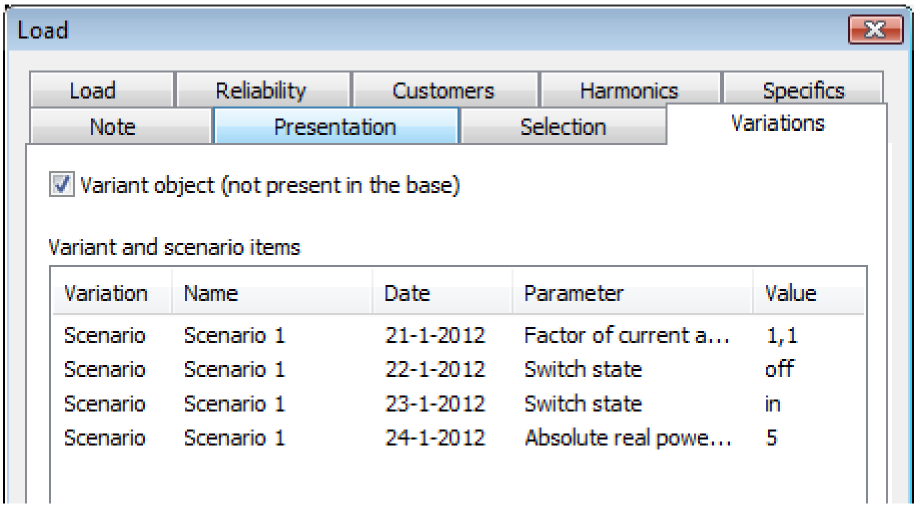


Editing a scenario
An existing scenario can be edited using **Variants | Edit | Scenario**. The scenario can be selected from a list. Objects can be added in the same way as when inserting scenarios. Also the parameters, dates and parameter changes can be altered. There are two ways of deleting objects from the scenario list:

- Selected rows: only objects whose date fields are selected will be deleted
- All rows.

Deleting a scenario
A scenario can be deleted with **Variants | Edit | Delete | Scenario**.

From the component forms it is possible to see in which scenario the object state is changed. The active items are displayed selected.



Activating one or more scenarios
The network can be set to one or more scenario's on a specific date in the scenario chronological table of events, using **Variants | Set | Scenario**.
Parameter changes without a specified date, will be implemented any time the scenario has been activated, independent of the chosen scenario date.
All scenario's can be deactivated by choosing ***None*** .

Take over one or more scenarios
One of more active scenarios can be taken over to the base using **Variations | Edit | Take over scenario**.
The changes up to the set date are carried over into the input values of the corresponding objects.
The applied scenario items are removed from the scenario(s).

5.5.13 Specifics

For almost all objects an user can input specific remarks. A specific remark consists of a **Characteristic** and a **Value**.
Specifics can be specified in the **Specifics** tab of a certain object. Specifics can be added by placing the cursor in a free input field or in the last entry and pressing the 'cursor down' key. For a new entry both its **Characteristic** and **Value** can be freely defined by the user.

Both the **Characteristic** and the **Value** of the specifics can be shown on the network by selecting it in Views 72.
If a **Characteristic** has been preceded by a /, only the **Value** will be shown.
If a **Characteristic** has been preceded by a //, neither the **Characteristic** nor the **Value** will not be shown.

With **Start | Select | Specific** all the specifics in the network can be listed. Selections can be made based on these specifics.

Removing Specific
Components Specifics can be removed by using **Start | Edit | Delete | Specific**. The specifics of all selected components are presented in a table. The contents of this table can be sorted by clicking the table headers.
Selected specifics are removed by pressing the **OK** button.
Deleting specifics using text
Objects can be deleted by means of a text, appearing in the characteristic or the value of a specific (remark). First, select all relevant objects. Secondly, choose **Start | Edit | Delete | Specific**. The functionality optionally uses case-sensitivity and wildcard characters.

Characteristic is a short text description of the specific.

Value is numbers, text or a reference to a file location or web address.
Besides a comment, also links to documents, spreadsheets, pictures and web addresses can be enclosed in the network file. The links are implemented as hyperlinks.
Examples:

```
'C\My documents\documentation.doc',
'C:\My pictures\substation.bmp',
'www.phasetophase.com'.
```

With the '**...**' button, a dialogue window opens and a file can be selected as **value**.

By selecting a link, the matching program is started by pressing the **[-->]** (go to) button.
The text **%name%** is first replaced by the name of the object.
The text **%id%** is first replaced by the ID of the node.
The text **%type%** is first replaced by the type name of the object.
The text **%<variable>%** is first replaced by the network variable value or the Vision variable value or the Windows environment variable value.
For example, for an object named "Node123" with the following value in the details:

```
'C: \ My pictures \% name% .bmp',
```

Pressing the **[-->]** button will open the file:

```
'C: \ My pictures \ Node123.bmp'
```

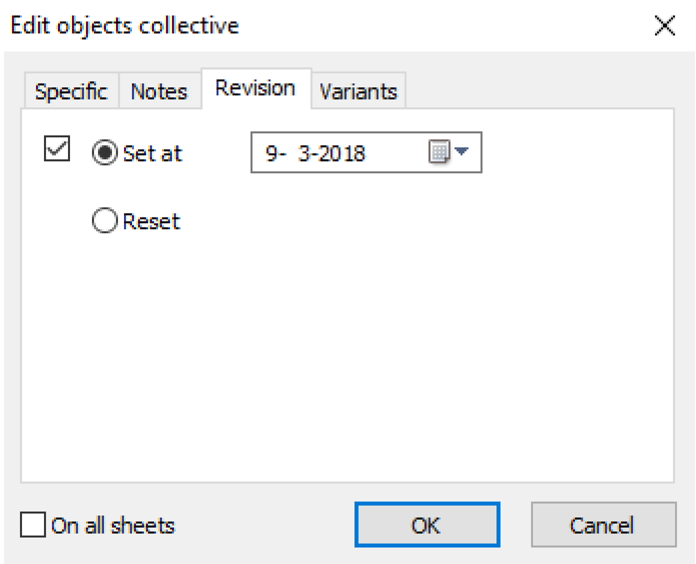
5.5.14 Revision date

All objects have the date attribute "revision date". This attribute is automatically set to the current date when an object is added or the name is changed. The purpose of the revision date is to support updating network files using external data sources. The revision date has been added to all objects and is stored in the network file.

The revision date is automatically set to the current date if an object is added or if its name or ID is changed. With cables, also if the cable type or length is changed.

The revision date is shown in each object form on the Specials tab at the bottom right. If the revision date does not exist, nothing will be shown.

The revision date can be manually set or reset for a number of selected objects with **Start | Edit Collective | Object**.



Objects can be selected based on their revision date, with **Start | Select | Special | Revision**.

5.5.15 Note

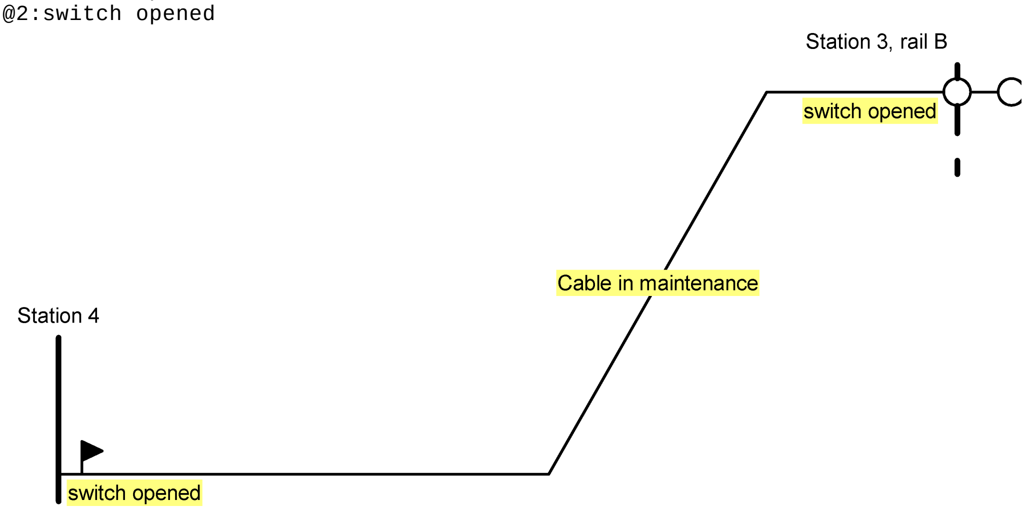
All objects can be augmented with a user-defined note. This note will be presented in a yellow frame, located close to the concerning object.
The frame can be moved and its size does not depend on the zoom level. This way to keep it always visible.

For branches the text @1: and @2: can be added, indicating whether the following characters should be placed at the beginning or the end of the branch.

The notes on a network can be suppressed; see View 69.

Example of a note at a cable:

```
Cable in maintenance
@1:switch opened
@2:switch opened
```



Notes can be selected from a list using: **Start | Select | Note**.

5.5.16 Presentation Components

The graphical representation of each object can be recorded in the object form on the **Presentation** tab:

- Colour: symbol colour, adjustable according to the same method as in Windows
- Size: symbol size; between 1 and 5
- Thickness: symbol thickness; between 1 and 5
- Style: line style of the symbol: continuous, dash, period, dash-point and dash-point
- Shape: symbol shape: vertical/horizontal line, closed/open circle, closed/open square, closed/open triangle, closed/open diamond or closed/open / half open rectangle
- Text colour: colour of the text with an object
- Text size: size of the text with an object; between 1 and 200
- Font: font of the text with an object
- Text style: style of the text with an object: bold, italic and/or underlined
- No text: no text with an object
- Upside down: display the text upside down

Text at nodes inclined
All texts that are printed at a node can be displayed at an angle of -90, -45, 45 or 90 degrees. This can be done by selecting -2 to 2 at "Inclined text".

Collective presentation operations via the menu
The presentation properties of selected objects can be changed collectively via **Start | Edit | Collective | Presentation**.

6 Calculations

In Vision a number of calculations can be performed. The calculations influence the network on all sheets, not just the active sheet. See:

- Load flow 250: regular load flow for calculating voltages and currents in any operating situation
- IEC 60909 262: calculation of short-circuit currents according to the international standard IEC 60909
- Fault analysis 273: analysis of specific fault situations
- Network load 277: calculation of load flows with different load/generation settings
- Harmonics 277: analysis of the behaviour of the currents and voltages at higher frequencies
- Costs 287: determining the cost of losses and for comparing the cost of different variants
- Reliability 289: calculation of reliability characteristics of a network
- Protection 294: analysis of the behaviour of the protection in case of a short circuit
- Voltage dip analysis 316: function for the analysis of the effects of short circuits on the voltage
- Failure analysis 319: function for the analysis of faults
- Normal open point optimization 323: calculation of the optimal location of the normally open points in a distribution network
- Data driven loadfow 362: load flow based on measurements
- Outage simulation 326: interactive resolution of a short circuit (available upon request)
- Dynamic analysis 330: insight into the dynamic behaviour of the currents, voltages and other variables
- Stability analysis 328: calculate system eigenvalues to determine whether a system is stable in case of deviations (small-signal stability analysis)
- IEC 61363 348: calculation of short circuit currents for ships
- Arc flash 352: calculates the arc flash energy
- Power generating module 358: calculate a wind or solar farm
- Switchability 360: analyzes the restoration of electricity supply during grid failures
- Frequency disconnection 361: calculating network parts to be switched off when frequency decreases.

Time
The time (year number) can be specified to set the time-dependent loads according to their eventually specified yearly growth 229. By choosing a year, in the ribbon menu **Start | Time**, the loads in the network are set to a value corresponding to the load growth. All calculations are now performed with these new load values.
The year setting does not function when a variant and/or a scenario is active.

Variant
A variant 237 describes modifications to a network model that will occur on certain specified dates (in the future). Using variants, all stages of the commissioning and decommissioning of network components can be evaluated. A variant can be activated by using **Variants | Set | Variant**. The variant can be chosen from a list of existing variants. A variant can be deactivated by choosing ***None*** .
The actions can be activated by specifying the ***Date*** . All events until that date will be in effect. In the standard view all objects will be visible according to the variant-list. ***Before*** means that the variant is active, but the time has been set before the first date of any event in the variant-list.

Scenario
A scenario 243 describes the settings and changes to objects parameters in the whole network. The changes can be independent of time but also a chronological table of events can be defined. The parameters which can be changed are: switch state, transformer tap setting, real power, reactive power and apparent power.
The network can be set to one scenario on a specific date in the scenario chronological table of events, using **Variants | Set**.
Parameter changes without a specific date, will be effective any time the scenario has been activated, not dependent on the chosen date.
A scenario can be deactivated by choosing ***None*** .

6.1 Loadflow

A regular loadflow calculates the voltages and currents in a certain operating situation. The settings are:

- Automatic voltage regulation for transformers
- Automatic voltage regulation for shunt elements
- Generation percentage for generators
- Load percentage for (transformer)loads and motors
- PV percentage for PV
- Wind percentage for wind turbines
- Calculation with starting currents of motors
- Calculation of the reserve capacity at nodes
- Calculation of an n-1 analysis
- Calculation of an n-2 analysis
- Calculation with profiles for loads and generators
- Calculation over a period (number of years)

6.1.1 General

The method used in Vision to calculate the voltages and currents in a power system is the loadflow according to the Newton-Raphson method. The method was first described in 1961 and 1967. The loadflow quickly converges to a solution and from the introduction of sparse matrix techniques and optimal ordering for the elimination process, memory space and computing time were no longer a problem. The Newton-Raphson loadflow has been successfully tested and accepted worldwide.
For more information, see: http://www.phasetophase.nl/pdf/newton-raphson.pdf (in Dutch).

Transformers and synchronous generators with voltage control exist in the network. The control actions of these components influences the voltage in the network and thus the current flows. During the solving of the network equations, it is assumed that the generators first control and then the tap switches of the transformers. The automatic control of the transformers can be switched off; the control of the generators is assumed to always be active.

Most of the networks are connected to an external network, from which the network to be studied is fed. That external grid is represented by an external grid, possibly with a reduced model (the most important transport connections) of the external grid. If a network is not connected to an external grid, the network is in island mode, if the network is powered by a synchronous generator with voltage control and frequency power droop. Vision controls the power of the synchronous generators present in such a way that the generation is in balance with the load in the network. For more information, see: Island mode 250.

6.1.2 Island mode

Most networks are coupled to a large interconnected power system. This interconnected power system mostly is represented by an external grid, possibly with a reduced order network model, representing the most important interconnections. In the case that a network is not connected to an external grid, it is considered an isolated network or an “island grid”.

The traditional loadflow technique is based on solving the nodal voltages from the system of network equations. Each system is modelled using as many network equations as there are nodes in that system. At each node a fixed complex power may be injected. The solution process for this set of equations requires the complex voltage on one node as a reference. This reference node is called the “Swingbus”. For this node the voltage is fixed, both in magnitude and angle.
In the standard loadflow calculations the swingbus is integrated in the external grid. Its voltage is the nominal voltage, multiplied by the per unit reference voltage (U_{ref}) as specified by the user. In most cases the reference voltage angle is zero, but this can be altered by the user.
Since the swingbus voltage is fixed, the complex power ($P+jQ$) can be freely chosen. This means that the difference between the total generated power and load plus the network losses within the whole system will be

absorbed/delivered by the swingbus. The external grid, containing this swingbus and is thus able to provide or absorb the active and reactive power shortage or surplus in the network. Without a swingbus a loadflow calculation cannot be performed.

Island networks exist aboard of ships and off-shore installations. Also an industrial network may sometimes become isolated from the external grid. In an isolated network, that is not connected to any interconnected system, there is no possibility of importing or exporting any power shortage and surplus, so this power has to be provided by the generators in the network. Any network calculation method, however, still needs a swingbus reference. The solution is to configure the generators in such a way that the swingbus does not provide or absorb any power. In that case the network generators should be in balance with the loads and the network losses.

Island mode calculation is done automatically. Vision controls the power of the existing synchronous generators in such a way that the generation is in balance with the load in the network. The power exchange with the swing bus is then reduced to zero.

Primary frequency control

The governor control of synchronous generators controls the generated power output, depending on any frequency changes in the system. The governor acts according to the power/frequency characteristic, determined by the governor droop. Each power disturbance involves a system frequency change. The governor control will respond with a change in prime mover input to the generator in order to restore the balance of generated power versus load and system losses.

Governor droop

A generating unit with governor control will produce more power after a frequency drop. The amount of extra power is determined by the power/frequency characteristic and the governor droop. The droop has been defined as the quotient of frequency change and power change.

$$S = -\frac{\Delta f / f_{nom}}{\Delta P / P_{nom}} * 100$$

The larger the governor droop, the smaller the contribution the generating unit makes to a change in power.

Governor control constant

The governor control constant is a derived quantity, indicating the amount of power change resulting from a system power change.

The generating unit power change will be derived from the frequency drop and the governor control constant.

$$K_T = \frac{P_{nom}}{f_{nom}} \cdot \frac{100}{S}$$

$$\Delta P = -\Delta f \cdot K_T$$

Power system control constant

The sum of all generating units governor constants is called the power system control constant (K_N). Using this system constant the frequency change after a power change can be calculated. The frequency change is equal to the quotient of the system power change and the power system control constant.

$$\Delta f = -\frac{\sum_{i=1}^{n} \Delta P_i}{\sum_{i=1}^{n} K_i} = -\frac{\Delta P_L}{\sum_{i=1}^{n} K_i} = -\frac{\Delta P_L}{K_N}$$

Even large interconnected systems, like the European UCTE system, are island networks. Every power change leads to a frequency change. All interconnected power generating units are equipped with a governor control and act according to this principle.

Parallel operation of interconnected generating units

The contribution ($Delta\ Pm$) of a single generating unit, after a frequency change (Δf), results from the corresponding governor control constant (K_m) and the power system control constant.

$$\Delta P_m = -\Delta f \cdot K_m = \Delta P_L \frac{K_m}{K_N}$$

Isochronous control

In case of generators with droop control the network frequency varies during load changes. There may be also generators present in the network that drive the frequency back to the nominal value. Active power of such generators is independent from the frequency (isochronous control). If there are multiple generators with isochronous control present in an island, an active power unbalance is split between these generators.

Load flow calculations

Every isolated part of the network can be solved in island mode. There are two conditions:
- Each island network must have one or more synchronous generators in service, equipped with voltage control and governor control (droop or isochronous).
- The generating power in the island network must be sufficient for the total island system load plus losses.

Synchronous generators with a zero governor droop and disabled isochronous control are considered as constant power generators and do not contribute to the frequency control. The principle used for sharing of active power unbalance between generators participating in primary frequency control is as follows. First, the unbalance is divided between the generators with isochronous control. If there is still active power unbalance present, it is split further between the generators with governor droop control. The frequency in this case will deviate from the nominal value.

As a consequence to the solution method, the proper choice of the system base power (S_{base}) has become more important. A general equation for a proper value can not be given. If the solution process might not converge or if the maximum number of iterations would be reached, another value of S_{base} should lead to a better calculation. In case links are present in the network, the value of the link impedance can have an influence on the convergence process. In situations with convergence problems the adjustment of the link impedance (Options, tab **Calculation | General**) can provide a solution.

Generated power not sufficient

In an isolated network, that is not connected to any interconnected system, there is no possibility of importing or exporting any power shortage or surplus, so this power has to be provided by the generators in the network. In all cases the following relation has to hold:

$$\sum S_{gem,nom} * cos(\varphi)_{gen,nom} \geq \sum P_{load} + P_{loss}$$

If the total load power is larger than the total available generator power, the extra power needed to solve the loadflow equations, will be delivered by the swingbus generators and a warning will be printed that the generated power is not sufficient.

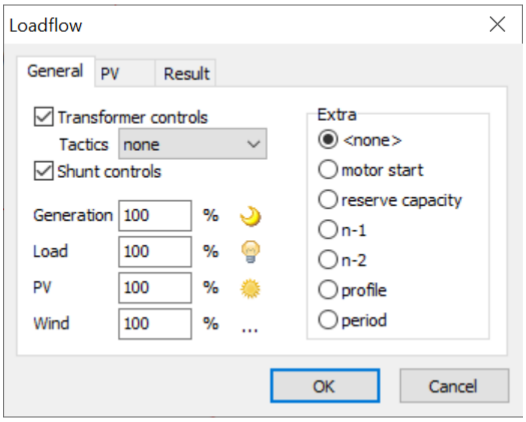
6.1.3 Calculation

For most loadflow calculations a minimum of one external grid must be present in the network. Several external grids are possible, but might give an unreliable results if they are connected through network components.

Prior to each calculation, Vision carries out an island test, and network components and network sections which are not linked to a source or an generator with power frequency droop are shown in the island colour after completion of the calculation. See: Island mode 250

Load flow

A load flow calculation is carried out as follows:
- choose **Calculate | Calculate | Loadflow**
- specify loadflow settings
- exit form via **OK**



Using the **F9** key the previous calculation is repeated with the specified settings.

Settings
The following parameters can be set for a load flow calculation.

Transformer controls
Transformers with voltage control can be "switched off" for a calculation. In this case, the value is used as indicated in the transformer form for the calculation. This can also be the calculated tap setting from of a previous load flow calculation.
If Vision has adjusted the tap settings during a calculation, the control actions of the relevant transformers are indicated in a list, with the question whether these tap settings should be adopted. With **Yes**, the tap settings are adjusted on the transformer form. With **No**, the new tap settings remain the "runtime" tap settings. A subsequent load flow will start from these "runtime" tap settings. Only after a change in the network the runtime tap settings are initiated again to the input tap positions.

Shunt controls
Shunt controls (e.g. capacitors) can be deactivated for a calculation. In that case, the shunt element is switched on.

Motor start
A starting motor causes a voltage dip in the network, which can be estimated using a load flow calculation. During the motor start the starting of the motors in the network is modelled with their short circuit impedance. The external grids and synchronous generators are modelled as equivalent voltage sources behind their sub-transient impedances.

After selecting motor start, the starting motors can be selected on the motor start tab.The results are displayed for three different calculations:
1 situation without selected motors
2 situation with selected motors starting (where the eventually chosen scenario is (also) active)
3 situation after motor start (with started motors)

Whenever a motor start is performed, all selected motors will be started together.

Reserve capacity
Calculation of the reserve capacity, for all nodes the maximum additional load which can be connected, for which the branches are not overloaded, is calculated.

n-1
Calculation of the loadflow, where a single object is not available. After selecting n-1, the unavailable objects can be selected from the n-1 tab.

n-2

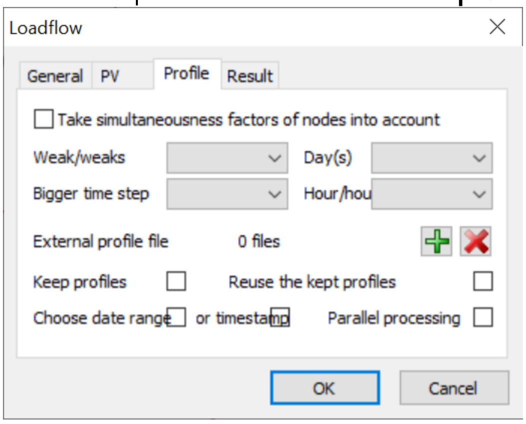
After selecting n-2, the loadflow is performed with all possible combinations of two objects which are unavailable. The objects to be considered can be selected in the n-2 tab.

Profile

A profile 230 specifies the load or generation for a number of consecutive time steps. A possible application is a daily load profile. The specified load or the generated power is multiplied by the factors recorded in the profile. Multiple load flow calculations are therefore performed, depending on the setting on the **Profile** tab. The profiles are processed in the calculation and the result can be reported for all the calculated time steps.
There are two ways to work with profiles:

- Profile 230: in Vision defined profile, stored in the network file.
- External profile 232: external Excel file which can be loaded for the profile loadflow calculation.

An external profile can be selected in the **profile** tab



Year

The choice of a year, with which the (transformer) loads get a different value through load growth (filled in at Load growth 229), can be set at the network level. By choosing a year, in the Ribbon **Start | Time | Year**, the loads in the network are set to a value corresponding to the load growth. With this value all calculations can now be performed.

Introduction of Inom' and Snom' for branches

For all branches the variables Inom' and Snom' have been introduced for a uniform overload indication in the load flow. For a cable the value of Inom' is obtained from the weakest cable part input data. For a connection the value of Inom' is obtained from the input data, in conformance with the options. For the other branches the values of Inom' and Snom' are obtained from the input data. All values are obtained as follows:

- Link: Inom' is set to infinite or to a user specified value.
- Cable: Inom' is set to the weakest cable part Inom (G) x rerating factor. G refers to the chosen soil heat resistance.
- Connection: Inom' is set to either Inom1 or Inom2, according to the options settings in: **Application menu | Options | Calculation | General**.
- Reactance Coil: Snom' is set to the Snom input
- Transformer: Snom' is set to the Snom input or to the special input (formerly Smax)
- SpecialTransformer: Snom' is set to the Snom input or to the special input (formerly Smax)
- Three windings transformer: Snom1', Snom2' and Snom3' are set to the Snom inputs or to the special inputs (formerly Smax)

Load flow convergence

The Newton-Raphson method is used to calculate the load flow. This method follows an iterative approach to obtain a solution, where in each iteration a derivative of the state of the network is used to determine the next state of the network. The Newton-Raphson method is widely used and is known for its computational speed and good convergence properties.

Nevertheless, it can sometimes happen that no solution is found. The message is given here: "maximum number of iterations reached" or "solution diverges". Networks where a solution diverges often have connections with relatively high impedances in combination with relatively large loads. It could also be that an input error has been made. For example, a kilo / mega-error makes the capital sometimes a thousand times too large.

There are various ways of detecting errors and getting a better loadflow convergence.

To detect errors:
- Check the network via **Bestand | Prepare** to check whether there are anomalies in the network. Large element capacities are reported.
- Let elements be drawn as circles via **View | Display in Edit mode Symbol, Power**. If almost all the circles are very small, there may be an input error with the biggest circle.

To force the load flow:
- Reduce the load and/or generation percentage in the load flow settings.
- Collect the load behaviour of all (transformer) loads collectively at constant impedance.
- Switch off a power supply by opening a switch
- Put S_{base} in the options successively on 1, 10 or 100 MVA.
- Increase the link impedance in the options.
- Adjust the advanced load flow options in the options.

If the load flow can be solved, it is important to look at overload and over- and undervoltage. Probably there are problems with large loads and/or small branches in the vicinity of these objects.

Load flow control parameters
The loadflow calculation follows an iterative process. The process stops when a sufficient accuracy has been reached. The process also stops when the solution does not converge. In that case a message will be generated. The cause of such an event is difficult to predict. One of the possible causes is an incorrect value of ***Sbase*** .
A number of control parameters has been defined for the experienced user, to obtain more information about the solution process and to control the accuracy.

Debuglevel
Feedback level about the iterative loadflow process.
Default is: 0.

0	No extra information
1	General information and error codes Warning at increasing power mismatch
2	Per iteration the name of the node with the largest power mismatch plus its power mismatch and voltage
3	Per iteration for all nodes: power mismatch and voltage

Max. number of Newton-Raphson iterations
Indicates The maximum number of iterations in the Newton-Raphson process.
Default is: 15.

Precision
Accuracy of the Newton-Raphson process. This is the maximum allowed power mismatch in p.u.
Default is: 10^{-5} p.u.

Divergence factor
Factor indicating the maximum increase of the power mismatch between two successive iterations.
Default is: 100.

6.1.4 Result

PRESENTATION IN NETWORK DIAGRAM

Network
After performance of a load flow calculation, results are shown on the basis of a View 72.
The next conventions are valid:
- branch: power or current, flowing from the node into the branch,has a positive sign
- load, motor, battery or coil: power or current, consumed by the element, has a positive sign
- external grid, generator, wind turbine, PV or capacitor: power or current, supplied by the element, has a positive sign.

Colour indication after a load flow calculation
Nodes, branches and elements can be coloured when exceeding the limits. Limits have been defined for "normal conditions" and "extreme conditions". The "normal conditions" limits are closer to the rated values than the "extreme conditions" limits. The limits have been defined in th***Options*** , at **Calculation | Limits**. See Limits 131
The limits for nodes can be defined for four fixed voltage levels.
The load limits for branches, transformers and elements can be defined separately.
The corresponding colours can be defined for four levels: **too high**, **much too high**, **too low**, **much too low** and **trigger**. The colours can be defined in th***Options*** , at **Calculation | General**.

Object	**Limit**	**Colour**
Nodes	U < Umin,normal	Too low
Nodes	U > Umax,normal	Too high
Nodes (at profiles)	max(U)-min(U) > dUmax,normal	Too high
Nodes	U < Umin,failure	Much too low
Nodes	U > Umax,failure	Much too high
Nodes (at profiles)	max(U)-min(U) > dUmax,failure	Much too high
Branch / Elements	Load rate < Lrlow	Too low
Branch / Elements	Load rate > Lrmax,normaal	Too high
Branch / Elements	Load rate > Lrmax,failure	Much too high
Switches	I > Inom	Too high
Protections	I > Iout	Trigger

All isolated components will be coloured in the "Island" colour, to be defined in th***Options*** , at **Editor | Drawing**.
The colour of a transformer load is determined after a loadflow, based on both the load rate as well as the voltage level.

RESULTS

Each of the menu items at **Calculate | Results** will be explained below.

General
Calculate | Results | Overview is used to give an overview of the calculated P and Q for each object type and the network losses. The results of the selected components are given separately here.
Then the number of objects with exceedance.
Then the ultimate stresses by voltage level and ultimate load rates by object type, without considering exceedance.
Then the maximum exceedances by voltage level and object type.

Details
Calculate | Results | Details is used to give detailed information on the selected nodes and branches.
If several nodes are selected, the arrows in the left lower corner can be used to show the other nodes or branches.
If multiple component types are selected, the results will be grouped per component type by using different tabs in the result form.

As an alternative, the user can explore the results in the network by clicking on the neighbouring components in the results form.

Graph
With **Calculate | Results | Graph** can show voltage and current of selected nodes, branches and elements in a bar graph. The nodes, branches and elements in the graph are sorted as chosen. At the end of the bar the value of voltage of node or current of branch or element is given. The result colour of the object is the same in the diagram. If a bar of the bar chart is clicked, the object will be brought into focus in the editor.
The results can be compared with the results of a previously performed calculation, provided the results have been saved with **Calculate | Results | Save results**. To do this, the checkbox a***Saved*** must be checked.
After performing a calculation in which the calculation setting profile or period was checked, **Calculate | Results | Detailed graph** shows the results of this calculation with profiles for all consecutive values as a time dependent graph.

Save results
With **Calculate | Results | Save results** the results can be saved for comparison with another load flow calculation with the graph function.

Export
Almost all calculated results can be exported to Excel. In fact, the export is a fixed format report of all objects on three sheets: nodes, branches and elements.

Display low voltages for transformer loads at other stages
After a load flow, the calculated low voltages at both sides of a transformer load can be viewed at **Calculate | Results | Details**.

6.2 Unbalanced load flow

The power system is a three-phase system. In the high and medium voltage networks, the majority of the load are three-phase symmetrical loads. In some cases, such as with the supply of the railways, the load is connected between two phases. In low-voltage networks, most of the connections are single phase connections. The aim is to distribute all single-phase loads in such a way that the three phases are loaded as equally as possible. As a result, the voltage in the distribution grid will be mostly three-phase symmetrical. The deviation of the three phase voltages with respect to the three-phase symmetry is indicated by the asymmetry. The asymmetry is visible if in a three-phase system the effective values of the voltages of the three phases are not equal to each other or are not shifted by 120 degrees relative to each other.

Asymmetry is caused by non-symmetrical loads. This is the case, for example, when single-phase loads are not properly distributed over the different phases of a three-phase connection. But also cause by heavy loads between two phases

6.2.1 Unbalanced load flow: General

The asymmetrical load flow is suitable for calculating three-phase symmetrical systems, where the loads of the three phases are not symmetrically distributed. These asymmetrical loads are the source of imbalance between the three phases. This is noticeable because the three phase currents are not equal to each other and no longer have a 120 degrees phase shift. As a result, the voltages in the network will also be in imbalance.

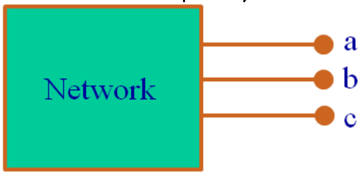
All network parameters are calculated from the parameters that are used by the symmetrical load flow and asymmetrical short-circuit calculations. The calculation uses the symmetrical components method, as used by the IEC 60909 method. The unbalanced load flow data are derived from the normal system impedance (Z1), the inverse-sequence impedance (Z2) and the zero-sequence impedance (Z0). The inverse-sequence impedance is equal to the normal system impedance, but the zero-sequence is usually modelled based on special measurements.
Since the method is based on transmission system modelling, the neutral system and the star-points are not explicitly modelled. The voltage at the star-point and the neutral system can be derived from the zero-sequence

current and impedance of the zero-sequence system. Since there is no unambiguous relation between the neutral system and the zero-sequence impedance in the model, this can only take place outside Vision.

The model and calculation method are based on the TCIM (Three Conductor Injection Method). This method is based on current injections on the phase nodes. The system of equations is solved using a Newton-Raphson solver, with a Jacobian for three phase systems.

Node model

As usual in the transmission-oriented approach, a node is represented by three phase nodes. Neutral nodes are not modelled explicitly.

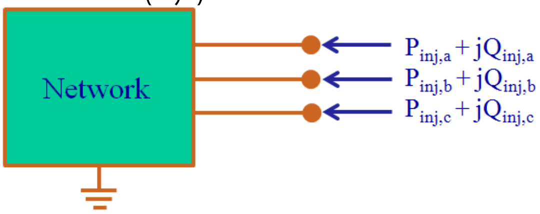


Load model

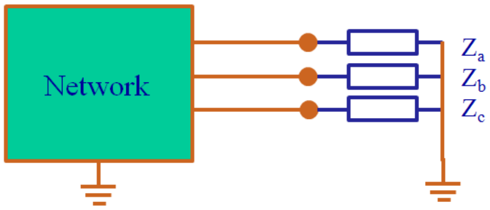
The load can be connected in star (Wye) or delta. In delta connection, no earth connection exists. In star connection, the neutral point may be connected to earth. If an earth connection exists, a return current flows in the zero-sequence system.
The voltage dependency can be defined from percentages of:

- constant power
- constant current
- constant impedance.

Load in star (Wye) connection:

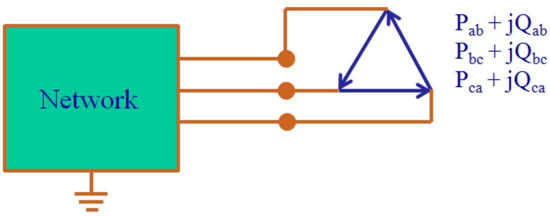


onstant power

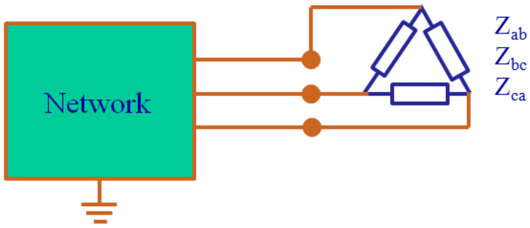


onstant impedance

Load in delta connection:



onstant power



onstant impedance

Cable and connection model

Cables and connections (lines) are modelled as balanced components. The inverse-sequence impedances are equal to the normal system impedances (Rac, X, C). The zero-sequence impedances (R0, X0, C0) should be specified by the user.

Reactance coil model

The inverse-sequence impedance Z2 of a reactance coil may be specified by the user. In case no inverse-sequence impedance is known, the same value as the normal system impedance Z1 can be used.

Transformer model
Transformers are assumed to be balanced components. The unbalanced load flow takes into account the windings configuration and the phase shift. The transformer parameters are the same as for the balanced load flow calculation. The zero-sequence impedance needs to be specified.

Voltage regulator
Based on an MV-system voltage regulator (auto transformer), the special transformer 161 "Auto YNo, asymmetric" has been introduced. This transformer can balance the unequal voltages in the distribution system. The voltage regulator of this transformer can change the tap setting for each of the three phases independently of each other. Also, for this transformer, on the "General" tab, the tap change can be manually adjusted for each or the three phases separately.

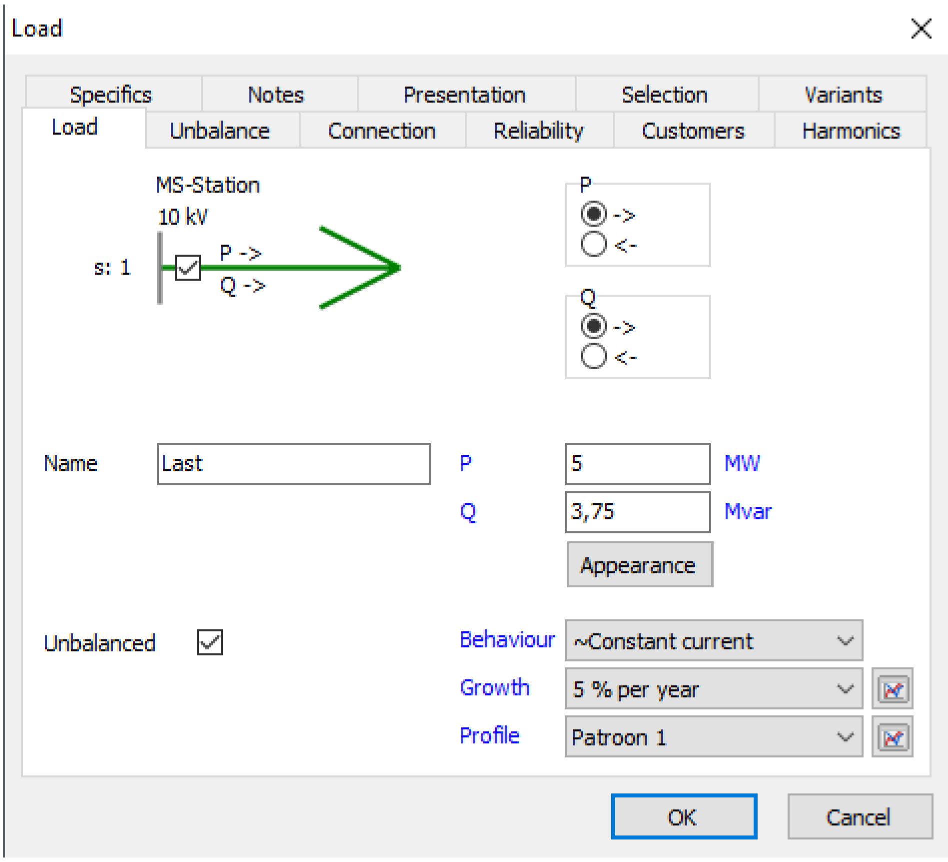
Network source model
The network source is supposed to be balanced. Its parameters are equal to those for the balanced load flow and for the short-circuit calculations.

6.2.2 Unbalanced load flow: Calculation

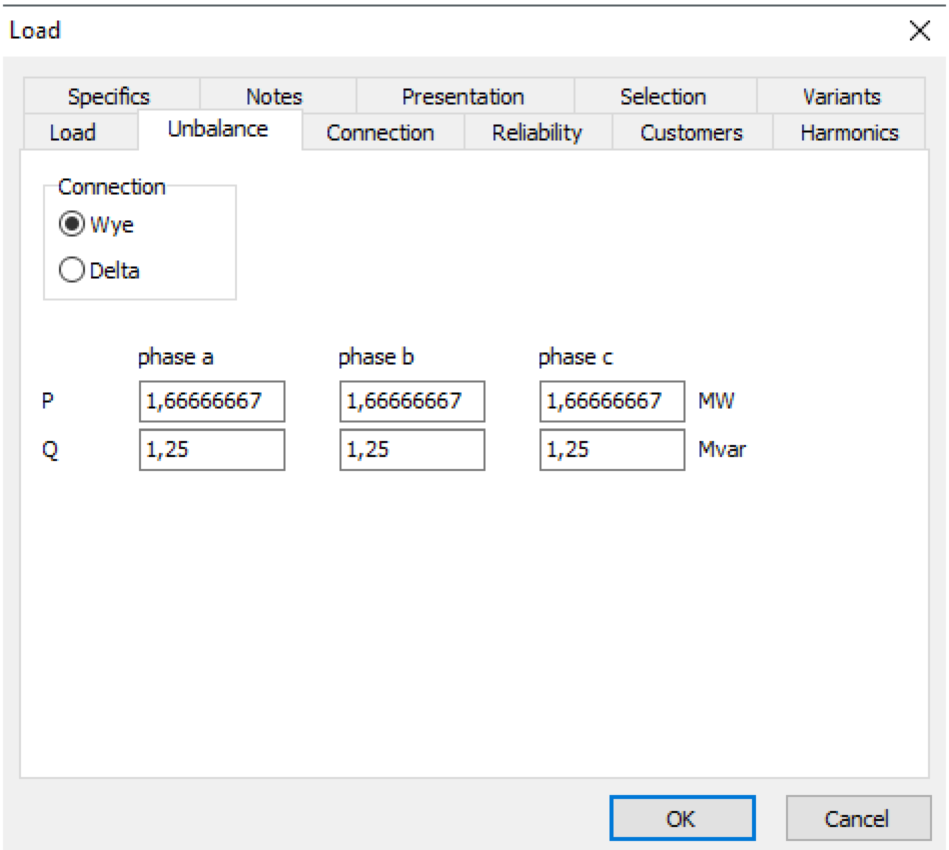
All three phases are modelled for the unbalanced load flow calculation. All parameters are calculated from the input for the balanced load flow and asymmetrical short-circuit calculations. The network is assumed to be balanced. Single-pole switching is not supported.

Because of the zero-sequence return currents, when earth contacts exist, the zero-sequence impedances have to be defined. If one or more objects have missing zero-sequence parameters, a warning will be displayed.

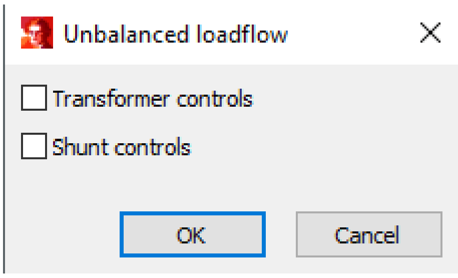
All loads are balanced loads by default. An unbalanced load can be indicated by clicking the "unbalanced" checkbox.



By clicking the "Unbalanced" checkbox, the "Unbalance" tab will appear. On this tab the load may be specified for each phase (star connection) or between two phases (delta connection).



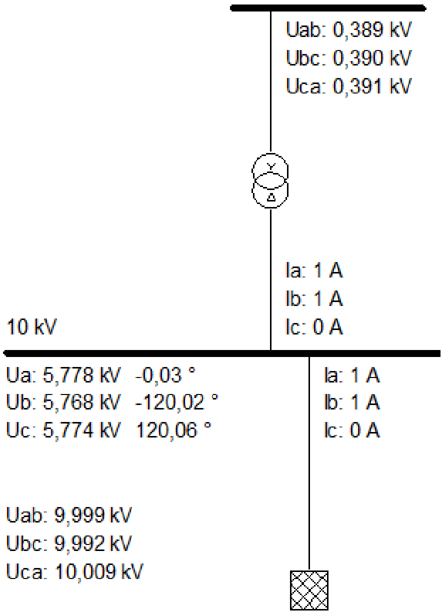
The calculation of the unbalanced loadflow can be started by **Calculate | Extended | Unbalanced loadflow**. In the calculation options form the transformer voltage regulators and the shunt voltage regulators can be enabled.



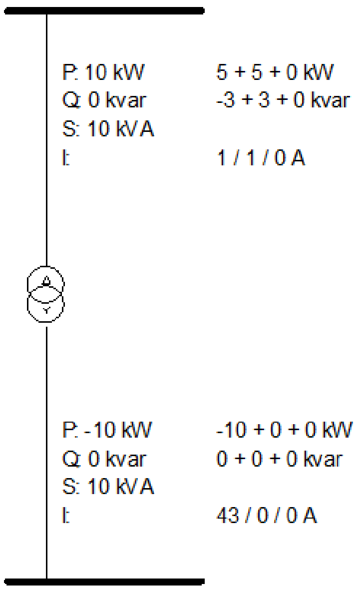
6.2.3 Unbalanced load flow: Result

Results in the network diagram
The results will be displayed in the network diagram according to the view settings. Voltages and currents of the three phases are displayed individually by their absolute values.

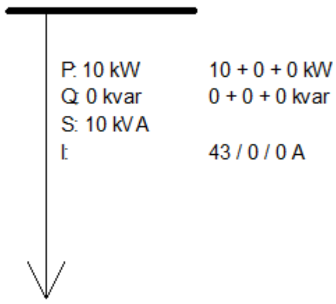
Results in the detail forms
By right-clicking an object, detailed results for the object can be viewed.
For nodes, the phase voltages will be displayed in absolute value and phase angle. By clicking the **Details** button, the voltages will be displayed in their complex notation. Also the voltage unbalance factor a_u (U2/U1) will be displayed in percent.



For branches, their powers and currents will be displayed in absolute value. Powers are displayed as three phase power, followed by the power per phase: <phase a> + <phase b> + <phase c>. Currents are displayed per phase. By clicking the **Details** button, the currents will be displayed in their complex notation and the current unbalance factor a_i (I_2/I_1) will be displayed in percent for both sides.



For elements, their powers and currents will be displayed in absolute value. Powers are displayed as three phase power, followed by the power per phase: <phase a> + <phase b> + <phase c>. Currents are displayed per phase. By clicking the **Details** button, the currents will be displayed in their complex notation and the current unbalance factor a_i (I_2/I_1) will be displayed in percent.



Using **Calculate | Results | Export**, the results can be exported to an Excel-file.

6.3 IEC 60909

6.3.1 General

Calculation of short-circuit currents in accordance with the international standard IEC 60909 is described in the following reports:

IEC 60909-0	International standard Short-circuit currents in three-phase a.c. systems Part 0: Calculation of currents Second edition: 2016-01
IEC TR2 60909-1	Technical report Part 1: Factors for the calculation of short-circuit currents in three-phase a.c. systems according to IEC 60909-0 Second edition: 2002-07
IEC TR 60909-2	Technical report Part 2: Data of electrical equipment for short-circuit current calculations Second edition: 2008-11
IEC 60909-3	Technical report Part 3: Currents during two separate simultaneous line-to-earth short circuit currents and partial short-circuit currents flowing through earth Third edition: 2009-03
IEC TR2 60909-4	Technical report Part 4: Examples for the calculation of short-circuit currents Second edition: 2000-07

Changes compared to IEC 909
The standard IEC 60909 is a modernization of the old standard from 1988. The new standard has been in effect since 2001. The recent edition of IEC 60909 standard from 2016 introduces the method to deal with converter-connected generators. For the time being, both short-circuit methods will coexist in Vision. The most important changes are briefly explained below.

Correction factor c (clause 5.3.1)
In the old standard 909 the correction factor c_{max} was equal to 1.00 for 400V low-voltage systems with a tolerance of +6% and equal 1.05 for other low-voltage systems with a tolerance of +10%. This is now adjustable for low-voltage grids when calculating the maximum I_k''. The choice consists of c_{max} = 1.05 for networks with a voltage tolerance of +6% and c_{max} = 1.10 for networks with a voltage tolerance of +10%. The correction factor is equalized to 0.95 for medium and high voltage systems there is no change.

Current conductor temperature (clause 7.1.2)
The starting point for the short-circuit calculations is always the worst-case scenario. This means that for the calculation of the largest short-circuit current the smallest conductor resistance is used. The standard assumes a conductor temperature of 20°C.

For calculating the smallest short-circuit current the largest conductor resistance is used, which occurs at the conductor end temperature.
The final temperature depends on the cable type and is included in the cable type file.

Impedance mains supply (clause 6.2)
In the old IEC 909, the R/X ratio is a given, both in the normal and the zero-sequence system. The ratio $I_{k"3}/I_{k"1}$ (the quotient of the three-phase and one-phase short-circuit current) is a measure of the zero-sequence impedance Z_0 of the power supply.

In the norm the R/X ratio is not mandatory and is available as an input.
If the ratio is unknown, the standard indicates that the impedance can be regarded as purely reactive in high-voltage networks (Un> 35kV). In other cases, a distribution of 0.0995 resistive and 0.995 reactive can be assumed, so that the R/X ratio is equal to 0.1.

Correction factor net transformers (clause 6.3.3)
A new factor has been introduced for correcting the impedances of transformers. The introduction of the correction factors for transformers has the largest influence on the short-circuit calculation of all changes in the standard. The correction factor is a function of the relative short-circuit voltage. In particular for transformers with a high U_k the correction factor on the impedance becomes small, so that the initial short-circuit current according to the new standard becomes greater than when the old standard is applied.
Incidentally, this factor is not applied to step-up transformers.

Power Station Unit (clause 6.7)
A combination of a synchronous generator and a step-up transformer is seen as an excitation unit. Generator and transformer are then jointly modelled. Vision recognizes this if the transformer is a "step-up" transformer. See: Power Station Unit 270.

Asynchronous engines (clause 6.10 / 6.11)
In the old standard IEC 909 the ratio of R/X was prescribed. The new standard may include a known ratio. If that ratio is not known, the old prescribed values can be used.
Motors that are controlled through static converters can provide a short-circuit contribution and these must also be modelled. They contribute to the symmetrical short-circuit current $I_{k"}$ and to the peak short-circuit current I_p. In the calculation for the contribution, an asynchronous motor with drive is modelled in the same way as an asynchronous motor. However, they do not contribute to the symmetrical breaking current I_b and to the steady-state short-circuit current I_k.

Converter-connected generators (clause 6.9)
Converter-connected generators are introduced in the latest edition of IEC 60909 standard. They are treated as constant current sources in positive sequence circuit. Short-circuit contribution of these generators is mostly limited to the nominal current (only during maximal short-circuit current calculation). During minimal short-circuit current calculation the contribution is neglected. The short-circuit currents of converter-connected generators have to be added using superposition principle to the total subtransient short-circuit current (see, for instance, equation (34) for the three-phase short-circuit), the peak current (equation (61)), the breaking currents (equation (77)) and the steady-state short-circuit current (clause 11.2).

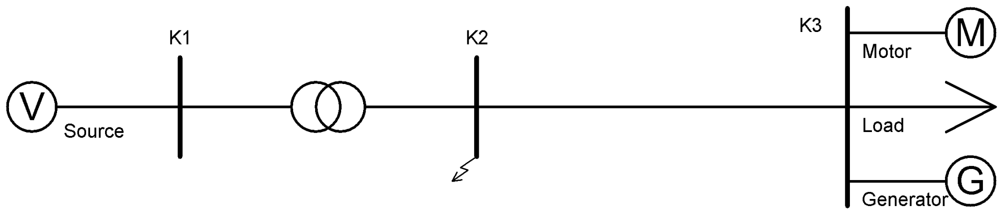
Symbols
The following symbols are used in this section:

Fault	fault type: symmetrical, phase-phase, phase-phase-earth or phase-earth
Situation	indicates whether maximum or minimum short-circuit currents are calculated
$S_{k"}$	sub-transient short-circuit power ($I_{k"}$ * 3 * U_{nom})
$I_{k"}$	sub-transient short-circuit current
$I_{k"a,b,c}$	sub-transient short-circuit current per phase
I_p	peak short-circuit current (kappa * 2 * $I_{k"}$)

I_b	breaking current
$I_{k"e}$	short-circuit current to ground (with fault types phase-phase-earth or phase-earth)
I_r	rated current
Z_i	network impedance at the node
R/X	R/X ratio of the network impedance at the node
$I_{k"1}$	maximum branch currents occurring with a fault close to the "from" node
$I_{k"1a,b,c}$	maximum branch currents occurring per phase with a fault close to the "from" node
$I_{k"2}$	maximum branch currents occurring with a fault close to the "to" node
$I_{k"2a,b,c}$	maximum branch currents occurring per phase with a fault close to the "to" node
$I_{k,1s}$	admissible short-circuit current for 1 second (lines)
$I_{k,2s}$	admissible short-circuit current (LV side) for 2 seconds (transformers)
t_{max}	admissible short-circuit time
I_{max}	maximum through going short-circuit current (with transformers only)
I''	Sub-transient branch or element current that contributes to the short-circuit current
I	Stationary branch or element current that contributes to the short-circuit current
m	rated active power of motors (MW) per pair of poles

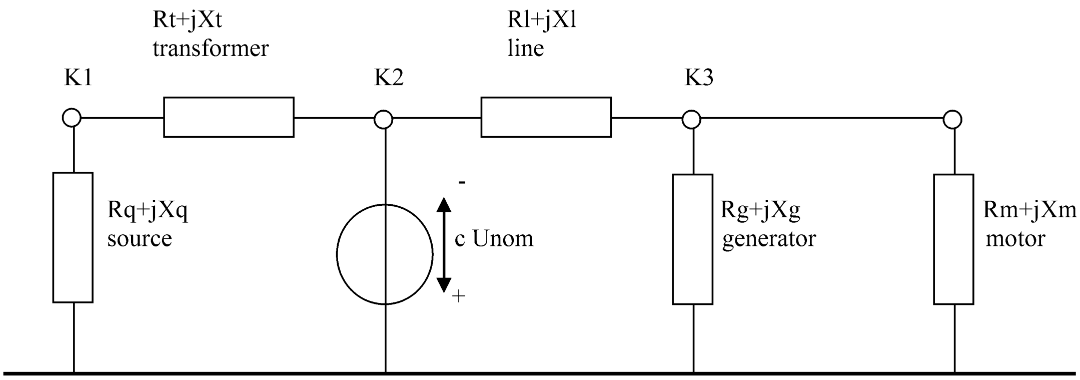
Short-circuit calculations using Vision in accordance with IEC 60909
The method applied by IEC 60909 is based on superposition. The network is represented passively, whereby active elements such as generators and motors are replaced with impedances to earth. A negative voltage source is applied at the fault location. The currents which arise as a result of the voltage source are the fault currents, while the total current which is supplied by the voltage source is the short-circuit current.

The figure below shows a simple Vision network which consists of three nodes. Node K1 is connected to the source, and node K3 contains a load, a generator and a motor. A symmetrical short circuit is assumed at node K2.



Network in Vision with short circuit at node K2

In accordance with IEC 60909, the network can be replaced for the determination of the short-circuit current with the network as shown in the Figure below, whereby loads and shunts are always disregarded. The capacities of lines of the normal (Z_1) and inverse system (Z_2) are also not taken into consideration.



Network in accordance with IEC 60909

All branches and active elements are replaced with impedances comprising R + jX. The method used to determine R and X is described in the component descriptions. A voltage source is applied to node K2 (the fault location), with the following voltage:

$$U_{fault\ location} = -c * U_{nom}$$

The voltage factor c is dependent on the voltage level, and on the choice as to whether minimum short-circuit currents (c_{min}) or maximum short-circuit currents (c_{max}) are to be calculated. The values for c are given in the table below.

Unom		c_{max}	c_{min}
LV	Tolerance +6%	1.05	0.95
	Tolerance +10%	1.10	0.95
MV	1 kV < Unom <= 35 kV	1.10	1.00
HV	35 kV <= Unom <= 230 kV 1)	1.10	1.00

1) This last limit is not present in Vision. Networks with Unom higher than 230 kV are treated in the same way as other HV networks (see also VDE 0102).

IEC 60909 distinguishes between maximum occurring short-circuit currents ($I_k''_{max}$) and minimum occurring short-circuit currents ($I_k''_{min}$) at a fault location. Both calculations can be carried out using Vision.

Calculation of conductor resistance

The conductor resistance is specified for a reference temperature TR. The resistance for the actual temperature T_{act} will be calculated using the correction factor: $(1+0.004(T_{act}-20)) / (1+0.004(TR-20))$.

Maximum short-circuit current calculation Ik"max

In calculating maximum short-circuit currents in a network, a c-factor >= 1 is used. The following are also assumed for the calculation:

- conductors resistance at a temperature of 20 degrees C
- maximum usage of generators
- maximum usage of transformers
- maximum short-circuit power of source
- supply from asynchronous machines (generators and motors)

Minimum short-circuit current calculation Ik"min

In calculating minimum short-circuit currents in a network, a c-factor <= 1 is used. The following are also assumed for the calculation:

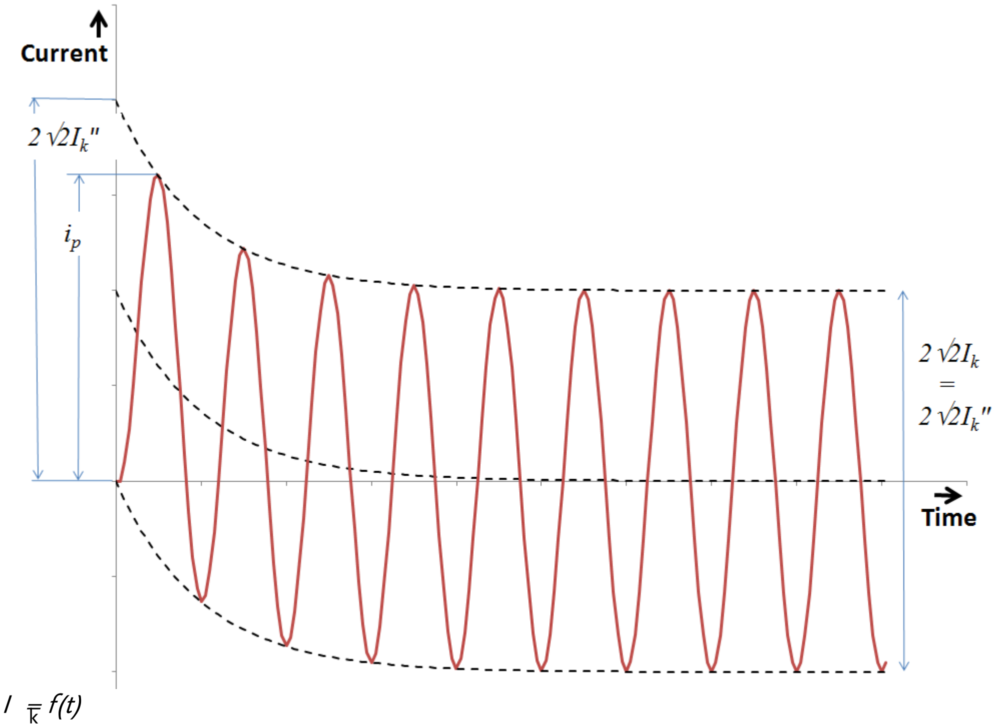
- conductors resistance at a higher temperature (at the end of the short-circuit duration)
- minimum usage of generators
- minimum usage of transformers
- minimum short-circuit power of source. The minimum short-circuit power of the source must be at least 10 % less than the maximum short-circuit power necessary to determine maximum short-circuit currents.

The influence of asynchronous machines (generators and motors) and synchronous motors is not taken into consideration in the calculation of minimum short-circuit currents.

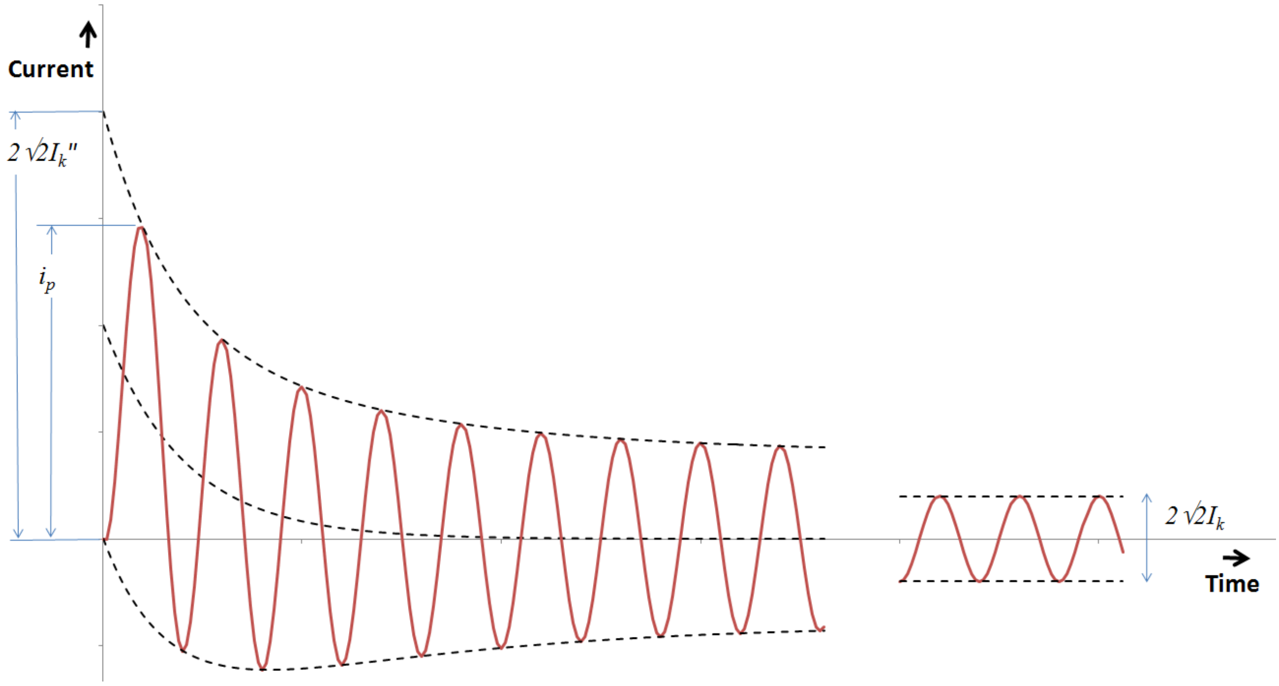
Short-circuit calculations on nodes

The Figure below shows the history of a short-circuit current, whereby the relationship is shown between the peak short-circuit current I_p and the sub-transient short-circuit current I_k''. I_k'' changes into the steady-state short-circuit current I_k.

For faults a considerable distance away from generators, in many cases it can be assumed that I_k is equal to I_k''.



With faults near to generators, I_k is always less than I_k".



In a near-to-generator short circuit, the short-circuit current behaves generally as shown in the figure above. In some special cases it could happen that the decaying short-circuit current reaches zero for the first time, some periods after the short circuit took place. This is possible if the d.c. time constant of a synchronous machine is larger than the subtransient time constant. This phenomenon is not dealt with in detail by the IEC 60909 standard and also not in the IEC module of Vision.

Peak short-circuit current

The peak short-circuit current I_p is determined from I_k" in accordance with the following:

$$I_p = \kappa \cdot \sqrt{2} \cdot I_k''$$

Three methods are given in IEC 60909 for determining the factor kappa (IEC 60909-0, clause 4.3.1.2). Differences between the methods relate to the required accuracy and to the choice of whether to perform calculations on radial or meshed networks. A meshed network is understood to mean the following in accordance with the standard: any network in which the short-circuit current can be supplied from different directions. Thus, for example, a radially-operated 10 kV network incorporating a self-generator or asynchronous machines is a meshed network.

"Method C" given in the standard is used in Vision. This method can be used for both radial and meshed networks. It determines the R/X ratio using an impedance $Z_c = R_c + jX_c$ determined at $f_c = 0.4 * 50\ Hz$ (or $f_c = 0.4 * 60\ Hz$) in accordance with the following:

$$R/X = (Rc / Xc) \cdot (fc / f)$$

where:

R/X	the R/X ratio at the fault location
R_c	the real part of the network impedance Z_c at the fault location at 20 Hz (or 24 Hz)
X_c	the imaginary part of the network impedance Zc at the fault location at 20 Hz (or 24 Hz)
f_c	frequency at which Zc is determined: 20 Hz (or 24 Hz)
f	network frequency: 50 Hz (or 60 Hz)

The following is then determined using the formula:

$$\kappa = 1.02 + 0.98\ exp(-3\ R/X)$$

The peak current is calculated only at the maximum short-circuit current.

Breaking current

Far-from-generator short-circuit

For far-from-generator short-circuits, the short-circuit breaking currents are equal to the initial short-circuit currents. Therefore these breaking currents will not be calculated explicitly.

Near-to-generator short-circuit

The implemented method for calculation of the breaking current follows the method for a three-phase short-circuit in meshed networks, for near-to-generator short-circuits.

The breaking current is calculated at a symmetrical fault on one selected node for 4 steps in time. Hereby the decrease of short-circuit current for every machine is calculated with the following equation.

$$\underline{I}_b = \underline{I}''_k - \sum_i \frac{\Delta \underline{U}''_{Gi}}{cU_n/\sqrt{3}}(1-\mu_i)\underline{I}''_{kGi} - \sum_j \frac{\Delta \underline{U}''_{Mj}}{cU_n/\sqrt{3}}(1-\mu_j q_j)\underline{I}''_{kMj}$$

Where:

$\Delta \underline{U}''_G = jX_d''\ I_k''_G$ for synchronous generators and synchronous motors

$\Delta \underline{U}''_M = jX_d''\ I_k''_M$ for asynchronous motors

The first part of the equation is valid for all synchronous generators and motors. The second part of the equation is only valid for asynchronous motors. For asynchronous generators no decrease is calculated.

The factors q and mu are calculated for the four steps in time with the following equations.

$q = 1.03 + 0.12\ ln(m)$ while $t = 0.02\ s$

$q = 0.79 + 0.12\ ln(m)$ while $t = 0.05\ s$

$q = 0.57 + 0.12\ ln(m)$ while $t = 0.10\ s$

$q = 0.26 + 0.10\ ln(m)$ while $t >= 0.25\ s$

$\mu = 0.84 + 0.26\ exp(-0.26\ I''_k / I_r)$ while $t = 0.02\ s$

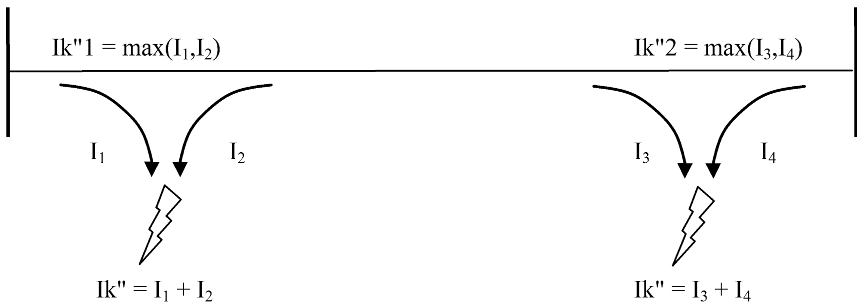
$\mu = 0.71 + 0.51\ exp(-0.30\ I''_k / I_r)$ while $t = 0.05\ s$

$\mu = 0.62 + 0.72\ exp(-0.32\ I''_k / I_r)$ while $t = 0.10\ s$
$\mu = 0.56 + 0.94\ exp(-0.38\ I''_k / I_r)$ while $t >= 0.25\ s$

The breaking current is calculated only for maximum short-circuit currents.

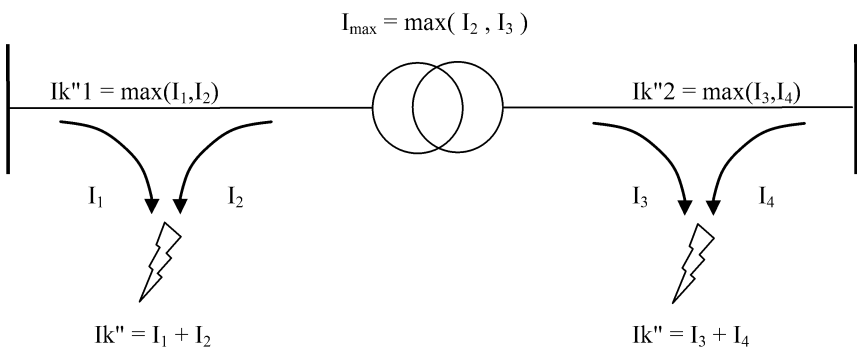
Short-circuit calculations on branches
In short-circuit calculations on branches, the total short-circuit current at the fault location is not shown in Vision, but the greatest current which can occur in a cable, line, reactance coil or transformer. This is illustrated for a line in the Figure shown below. The greatest currents in a line arise with faults close to the "from" node or close to the "to" node. With a fault close to the "from" node K1, the currents I_1 and I_2 occur in the line, giving the short-circuit current I_k'' when added together. As this current is not relevant for the sizing of the line, only the greatest of the currents I_1 and I_2 is represented with $I_k''_1$ in Vision. The same applies to a fault close to the "to" node K2, and the greatest of currents I_3 and I_4 is indicated with $I_k''_2$.

The indices 1 and 2 in I_k'' distinguish between the "from" and "to" nodes.



Determination of I''_{k1} and I''_{k2} for lines

For transformers, the same approach applies as for lines. Once again here, the currents $I_k''_1$ and $I_k''_2$, which may occur in the branch close to the "from" and "to" node respectively, are calculated. These values are significant with regard to transformers, as they are the maximum currents which can occur in the connecting cables of the transformer.
In addition, the current Imax is also calculated. This is the maximum of the currents I_2 and I_3 (LV side) and thus the maximum continuous short-circuit current which can occur in the transformer. The following Figure shows how $I_k''_1$, $I_k''_2$ and I_{max} are determined for transformers.



Determination of I''_{k1}, I''_{k2} and I_{max} for transformers

I_{max} is determined in the same way for three-winding transformers.

Admissible short-circuit time
The maximum admissible short-circuit time t_{max} is calculated using the stated $I_{k,1s}$ or $I_{k,2s}$ for all branches for which an IEC 60909 calculation is carried out.

For lines:

$$t_{max} = 1\ (second) \cdot (I_{k,1s} / I_k'')^2$$

For transformers and reactance coils:

$$t_{max} = 2\ (seconds) \cdot (I_{k,2s} / I_{max})^2$$

where:

t_{max}	Maximum admissible short-circuit time
$I_{k,1s}$	Admissible short-circuit current for 1 second (lines and cables)
$I_{k,2s}$	Admissible short-circuit current (LV side) for 2 seconds (transformers and reactance coils)
I_k''	Maximum occurring short-circuit current in the branch ($\max(I_{k''1}, I_{k''2})$)
I_{max}	Maximum continuous short-circuit current (transformers)

Asymmetrical short-circuit calculations

In addition to symmetrical faults (PPP), the following asymmetrical faults can also be calculated: phase - earth (PE), phase - phase (PP) and phase - phase - earth (PPE).
The symmetrical components method is used for the calculation. This is a methodology for enabling easier calculation of asymmetrical loads in a three-phase system by means of a transformation. Other names for this method include the 0-1-2-components method or the Fortescue transformation.

The aim of this transformation is to obtain three uncoupled single-phase systems from a coupled three-phase system. The three systems are:

- the normal system (index 1); this is a symmetrical three-phase system with normal phase sequence (120° phase shift)
- the inverse system (index 2); this is a symmetrical three-phase system with inverse phase sequence (-120° phase shift)
- the zero sequence system (index 0); in this case, the currents and voltages are the same size and display the same phase relation.

The impedance of the normal system (Z_1) can be measured with a supply consisting of a normal-cycle three-phase system. This impedance corresponds to the normal operational impedance.

The inverse impedance (Z_2) can be measured with a supply consisting of an inverse-cycle three-phase system. For all static network components, this corresponds to the normal impedance. For asynchronous machines and two-pole synchronous machines, however, Z_2 is approximately equal to Z_1. As there is no specification in IEC 60909 with regard to inverse impedance, $Z_2 = Z_1$ is applied in Vision, including all correction factors.

For the calculation of earth to ground faults the following rules apply:

- The zero sequence resistance may not be smaller than the normal operational resistance.
- The zero sequence reactance may not be zero.

For transformers:

- The zero sequence impedance may not be zero.

The zero sequence impedance (Z_0) can be measured with a supply consisting of a zero sequence system. This is difficult to ascertain, particularly for cable connections.

The symmetrical components method is used to calculate all short-circuit and phase currents in Vision.

Provided that $Z_2 = Z_1$ and arg (Z_1) is approximately equal to arg (Z_0), the following apply:

- in the case of the greatest short-circuit currents, the single-phase short-circuit current (PE) is greater than the symmetrical short-circuit current (PPP), if $Z_1 / Z_0 > 1$
- in the case of the smallest short-circuit currents, the single-phase short-circuit current (PE) is smaller than the two-phase short-circuit current without earth contact (PP), if $Z_1 / Z_0 < 0.683$.

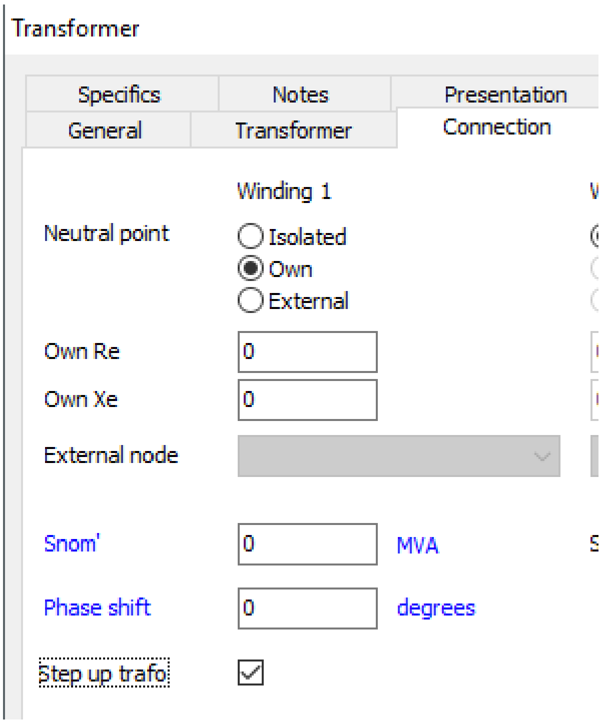
6.3.2 Power Station Unit

The IEC 60909 standard treats a Power Station Unit (PSU) in a different way as a separate generator and transformer. A combination of a synchronous generator and a machine transformer is considered as a single generating unit. In that case the generator and transformer are modelled jointly. Vision recognises this if the transformer is a "step-up" transformer. The calculation follows the method for an on-load tap-changer.

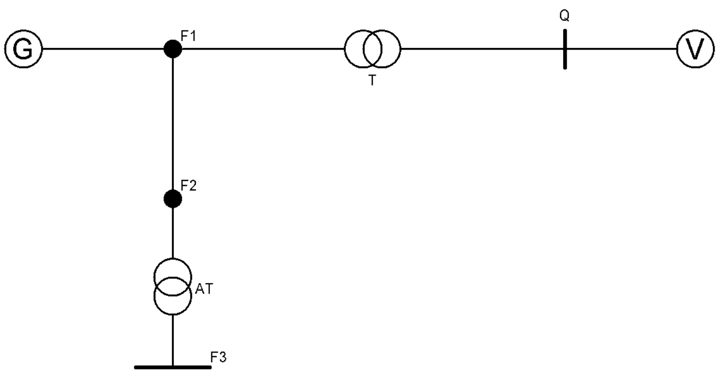
The IEC standard defines correction factors for the generator impedance and the transformer impedance. The definition of these correction factors depends on the short-circuit location:

- at the transformer high-voltage side
- at the transformer low-voltage side and the generator terminals
- at other locations inside the PSU

Vision detects the PSU through the step-up transformer with a generator connected to the low-voltage side. The step-up transformer can be specified using the "Step-up" check-box on the transformer tab "Connection".



The diagram from IEC-clause 4.2.1.3 can be used to further illustrate the method.



In this diagram transformer T is the step-up transformer.

In order to be able to recognise the combination of generator and transformer as part of a PSU, the transformer must be defined as a step-up transformer and the generator must be directly connected to the LV-node of the transformer.

IEC 60909 defines for the PSU:
- short-circuit at the step-up transformer's high-voltage side (Q)
- short-circuit at the step-up transformer's low-voltage side, also the generator node (F1)
- short-circuit at the step-up transformer's low-voltage side, inside the PSU, but not the generator node (F2 and F3)

Vision detects these situations as follows:
- If the short-circuit is located on the step-up transformer's high-voltage node, then the correction factors will be calculated for short-circuits on node Q.
- If the short-circuit is located on the step-up transformers's low-voltage node and the generator is connected to this node, then the correction factors will be calculated for short-circuits on node F1.
- If the short-circuit is located on a node with a rated voltage less than or equal to the voltage of the step-up low-voltage node of the transformer, then it will be concluded that the short-circuit is located inside the PSU and the correction factors will be calculated for short-circuits on nodes F2 or F3.
- If the short-circuit is located on a node with a rated voltage larger than the voltage of the step-up transformer's low-voltage node, then it will be concluded that the short-circuit is located outside the PSU and the correction factors will be calculated for short-circuits on node Q.

6.3.3 Calculation

An IEC 60909 calculation is performed for the selected nodes and branches. The calculation can be performed in two different ways:
- With only one selected node
- With multiple selected objects.

In an IEC 60909 calculation, a distinction is made in the presentation of results between a calculation in which only one node is selected (single-node calculation) or multiple objects. In the case where only one node is selected, all branch and element flows which contribute to the short-circuit current at the selected node (the partial short-circuit currents) in the network are calculated and displayed.
Prior to a single-node calculation, Vision checks whether the clock numbers are correct for parallel transformers in the network. In the event of an incorrect parallel connection, Vision gives a message and the calculation is not performed.

An IEC 60909 calculation takes place as follows:
- choose **Calculate | Basic | IEC 60909**
- indicate fault type
- indicate options
- exit form via [**Ok**]

The following are calculated for each node per fault type:

symmetrical	S_k" I_k", I_p, I_b, Z_i, R/X,Tdc and t_{max}
phase-phase	I_k"$_{a,b,c}$, I_p and tmax
phase-phase-earth	I_k"$_{a,b,c}$, I_k"$_e$ and tmax
phase-earth	Ik"a,b,c, Ik"e, Ip, Z0i, R/Xa and tmax

The following are calculated for each branch per fault type:

symmetrical	$t_{k\,max}$, I_{max}, I_k", S_k"
phase-phase	$t_{k\,max}$, I_{max}, I_k"$_{a,b,c}$
phase-phase-earth	$t_{k\,max}$, I_{max}, I_k"$_{a,b,c}$

phase-earth $t_{k\ max}$, I_{max}, $I_k"_{a,b,c}$

An accelerated choice can be made for a short-circuit calculation with the previously indicated settings, by using the speed button. Also with the help of **F9** the last calculation is repeated.

6.3.4 Result

Network
After performance of an IEC 60909 calculation, results are shown on the basis of a View.
Only if an IEC 60909 calculation is carried out for one selected node can all supply branch and element currents be stated in the network.
The functionalities available with the menu item **Results** will be explained successively below.

General
With **Calculate | Results | Survey** an overview of the results for all nodes and branches for which an IEC 60909 calculation has been carried out will be displayed. The results are shown for nodes and branches in two lists.

Nodes

node	Name of node
Unom	Nominal voltage of the node
Sk"	Subtransient short-circuit power (Ik" * √3 * Unom)
Ik"	Subtransient short-circuit current
Ip	Peak short-circuit current (kappa * √2 * Ik")
Ri and Xi	network impedance at the node
R/X	R/X ratio at the node

Branches

name	Name
from	Name of node
to	Name of node
type	Indicates whether the branch is a transformer
tk max	Maximum admissible short-circuit time
Ik">	Maximum occurring short-circuit current in the branch with a fault close to the "From" node
Imax	Maximum continuous short-circuit current, LV side (only stated with transformers)
Ik"<	Maximum occurring short-circuit current in the branch with a fault close to the "To" node

Details
Calculate | Results | Details is used to give detailed information on selected nodes and branches in a form.
If several nodes and/or branches are selected, **Previous** and **Next** can be used to show the other nodes and branches.

If no IEC 60909 calculation is carried out for the node, the fault symbol is absent, and only Unom is given for the node.

If an IEC 60909 calculation is carried out for a single node, all element and branch currents are given.

If no IEC 60909 calculation is carried out for the branch, the fault symbol is absent.

If an IEC 60909 calculation is carried out for only one node, the branch current is given in A.

With transformers, the greatest continuous short-circuit current Imax (LV-side) is also given. Imax may be less than Ik"> or Ik"<. The latter currents relate to the connecting cables of the transformer.

Graph node
Results | Graph | General can be used to display I_k" and I_p for the selected nodes and branches in a bar chart.

The nodes and branches in the graph are sorted as indicated.
At the end of the bar, the short-circuit current of the node or branch is listed when **Marks** is checked. The colour is taken from the current drawing colour.
If a bar of the bar chart is clicked, the object is selected and the screen focuses on the object.

Export
Almost all calculated results can be exported to Excel. In fact, the export is a fixed format report of all objects on two sheets: nodes and branches.

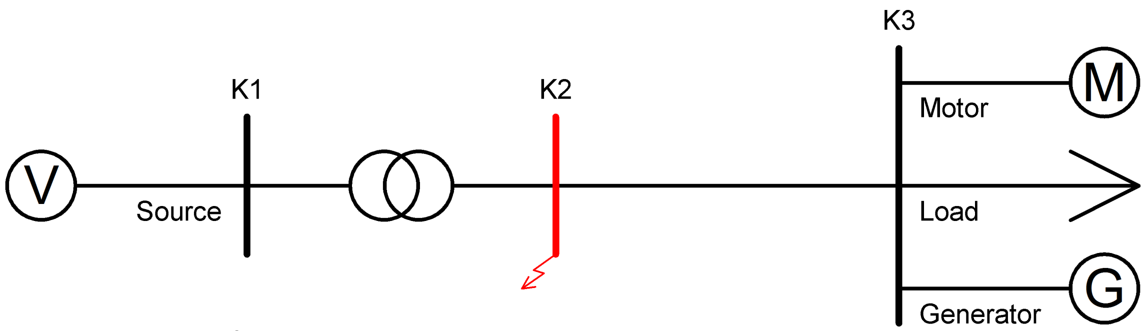
6.4 Fault Analysis

6.4.1 General

The sequential fault analysis feature enables the calculation and analyse of particular fault situations. Multiple sequential faults (in the form of fault impedances) can be applied to nodes, cables, overhead lines and elements. This makes it possible to analyse multiple or "cross country" faults. All currents and voltages in the network are calculated for each sequence. Next to simulating a fault, also the opening of a switch can be performed during the fault analysis.

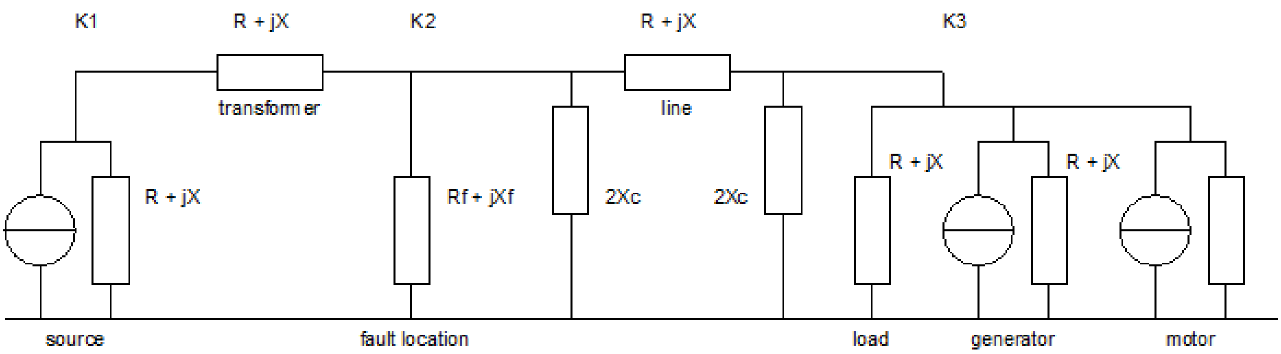
In Vision, sequential fault analyses are performed using the compensation method. In contrast to IEC 60909, the network is represented actively and loads, overhead line capacities and shunts are included in the network.

The following illustration shows a simple Vision network consisting of three nodes. Node K1 is connected to the source and node K3 contains a load, a generator and a motor. There is a symmetrical fault with a fault impedance of $R_f + jX_f$ on node K2.



Vision network with a fault on node K1

For sequential fault analysis, Vision replaces the network illustrated above with the one illustrated below.



Network modelling for sequential fault analysis

The source, generator and motor are replaced by a Norton equivalent, assuming a "pre-fault" voltage determined by the loadflow. R and X are determined for the components, using the method indicated in the component description.
The symmetrical fault has been attached to node K2 in the form of an impedance of $R_f + jX_f$.

When a sequential fault analysis is performed, the subtransient short-circuit current I_k" at each identified fault location is calculated. All voltages, branch currents and element currents are calculated as well. Currents and voltages can be displayed in complex form or as absolute values per phase (a, b, c) or per system (zero sequence, normal, inverse).
The voltages are represented as phase voltages.

6.4.2 Calculation

Fault analysis

Calculate | Basic | Fault analysis is used to perform a sequential fault analysis. Note:
- A sequential fault analysis is always started using **Calculate | Basic | Fault analysis | Start**
- A sequence may consist of:
  - a fault at a node;
  - a fault to a cable or overhead line
  - a fault at an element
  - opening a switch connected to a branch or an element.

After each sequence, all node voltages, branch currents and element currents are recalculated.

The features of the **Calculate | Basic | Fault analysis** menu item are described below.

Start
When **Calculate | Basic | Fault analysis | Start** is selected, the "pre-fault" voltages in the nodes are calculated as a starting point for the fault analysis. These voltages are determined by performing a load flow calculation. The load flow is performed with 100% load and generation. Transformer regulation is switched off and shunt regulations are on.
When starting the calculation, a check is performed to determine whether the clock numbers of the transformers are not in conflict with each other.
After starting, the program enters sequencing mode.

Fault impedance
With **Calculate | Basic | Fault analysis | Fault** a fault can be made at a node, in a branch or in an element. An fault impedance can be indicated as well as the fault distance for cables/connections. The impedance at the fault consists of an impedance between the phases (Zpp) and an impedance between phase and earth (Zpe). The impedances are:
- phase-earth: Zpe between a phase and earth
- phase-phase earth: Zpp between two phases and Zpe between two phases and earth
- phase phase: Zpp between the phases
- symmetrical: Zpp between the three phases
- symmetrical-earth: Zpp between the three phases and Zpe between the three phases and earth

In case of an fault in an element, it is actually made before the element. This allows the current through the connection cable and protection to be viewed. In the protection calculation this current is applied for the element protection.
In case of a fault in a transformer, it is actually made in the connection cable. Only 0 and 100% are possible as fault distances.

A fault is applied as follows:
- select the node, branch or element in which the fault should be applied

- choose **Calculate | Basic | Fault analysis | Fault**
- select the desired closure and if necessary indicate an fault impedance and, in the case of a fault in a branch, also the fault distance

Open switch
With **Calculate | Basic | Fault analysis | Open switch** a switch in a branch or element can be opened. The phases to be opened can be selected here.
The opening of a switch takes place as follows:
- select the branch or element whose switch is to be selected
- choose **Calculate | Basic | Fault analysis | Open switch**
- choose the desired side, in the case of a branch
- choose the phase (s) to open

A sequential failure analysis always starts with: **Calculate | Start | Fault analysis | Start**
The start of a new fault analysis calculation can also be performed, by using the speed button or by pressing F9, if the last calculation was also a fault analysis calculation.

6.4.3 Result

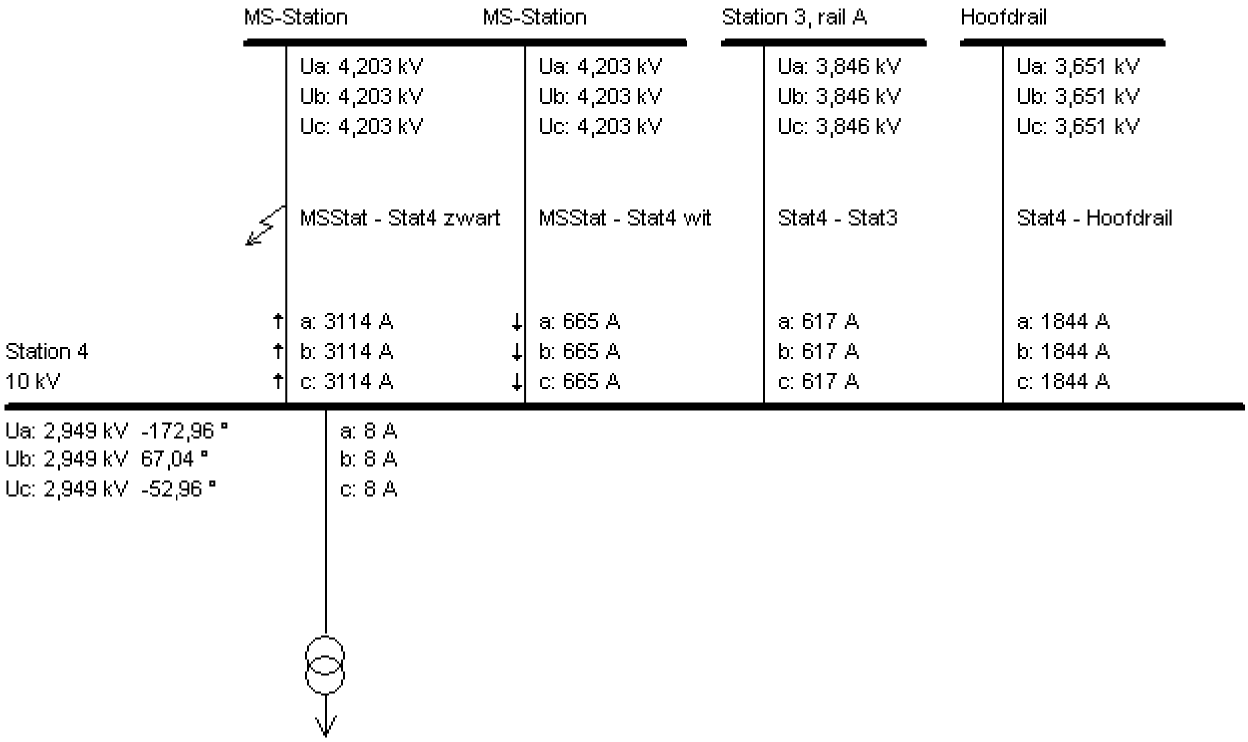
The results for sequence 0 are the same as the results of the loadflow calculation.
All voltages are represented as phase voltages.
The results for sequence 1 and any subsequent sequences are displayed as described below.

Network
Following each sequence in a sequential fault analysis, the results are displayed in a view 69.
The features of the **Results** menu item are described below.

General
Calculate | Results | Overview is used to display a summary of the calculated sequences.

Details
Calculate | Results | Details is used to display detailed information regarding selected nodes, branches and elements on a form.
A vector diagram is can be displayed with the **Graph** button.
With **Appearance** the notation of the voltages and currents can be changed:
- polar notation of the three phases
- polar notation in the symmetrical component system
- complex notation of the three phases
- complex notation in the symmetric component system

With the branches and elements, an arrow indicating the direction of flow is shown next to the current values. This direction is defined in a similar way as the directional sensitivity at the current protection 205 and distance protection 214. The arrows indicate only the direction of the current where there is a direction-sensitive current protection. In the example below two directional safety devices are present.



Graph
With **Calculate | Results | Graph** can show the minimum of U_{mod} a, b, c and the maximum flows in a bar chart of selected nodes, branches and elements. The nodes, branches and elements in the graph are sorted as indicated by the user. If a bar of the bar chart is clicked, the object is jumped directly to the editor.
The results can be compared with the results of a previously performed calculation, provided the results were saved with **Calculate | Results Save results**. To do this, the **Saved** item must be ticked.

Save results
With **Calculate | Results | Save results**, the results of a calculation can be saved for comparison with the future calculations.

Export
Almost all calculated results can be exported to Excel. In fact, the export is a fixed format report of all objects on three sheets: nodes, branches and elements.

6.4.4 Zero sequence test

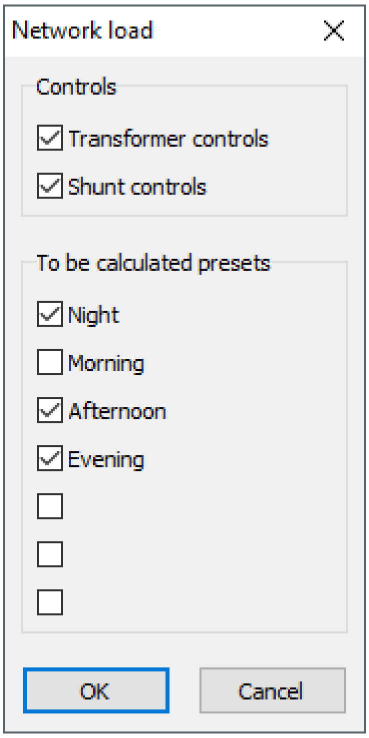
Zero sequence test is equivalent to **Calculate | Basic | Fault analysis | Start** calculation, but all network sources are modeled as zero sequence voltage sources. Positive and negative sequences are neglected in this calculation.

The goal of the calculation is to test the zero sequence impedance of a transformer or a cable. Voltages and currents in the network correspond to those that can be measured during actual zero sequence test. The equivalent zero sequence of the network (seen from the point to which the network source is connected) can be determined via dividing the zero sequence voltage by the zero sequence current of the network source.

6.5 Network load

With a network load calculation a number of load flows are performed, for different load/generation situations. Generally, extreme situations are chosen: maximum load + minimum generation and minimum load + maximum generation.
Generation settings in Vision can differ for generators, PV and wind, the network load calculation uses the presets defined in the options. These presets contain four percentages: generation, load, PV and wind.
Of the maximum seven presets, a number can be selected prior to the network load calculation.

Calculation
A network load calculation can be started as follows:
- choose **Calculate | Extended | Network load**
- choose the presets to be calculated
- leave the form with **OK**.



With **F9** the last calculation performed is repeated. The previously selected settings remain in effect.

Results
There are four ways to view the results:
- in the one-line diagram
- in **Calculate | Results | Overview**
- in **Calculate | Results | Details**
- in **Calculate | Results | Graph**

The results are similar to the load flow results.
See therefore Result 256

6.6 Harmonics

6.6.1 Harmonics: General

Harmonics occur in all electricity networks as a result of non-linear loads or sources, such as rectifiers and converters. Analysis of the network at higher frequencies enables the study of the distortion of the currents and voltages as a result of these sources and how these distortions propagate through the network.

The harmonics module has been based on a symmetrical and balanced three-phase system with balanced harmonic sources. In such network only frequencies of odd harmonic numbers occur. The harmonic multiples of 3 only exist in the zero-sequence system.

All network components like cables, loads, motors, capacitors and coils should be modelled for higher frequencies. Non-linear sources have been modelled as current injections at the loads. Shunt capacitors are modelled as part of a R-L-C filter, for which the characteristics should be specified.

The harmonics module provides insight into the behaviour of the currents and voltages at higher frequencies in the grid. Three functions are available for this: harmonic loadflow, impedance spectrum and ripple control.
- With harmonic loadflow, the behaviour of the injected harmonic currents in the grid and the consequences for harmonic voltages and harmonic distortion can be studied.
- With impedance spectrum it can be analysed which resonances in the network are to be expected.
- With ripple control, the persistence of an injected high frequency signal can be analysed on a network.

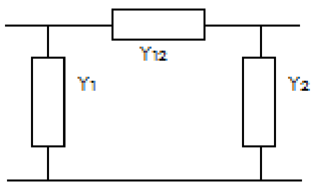
6.6.2 Harmonics: Model

The harmonics modelling for higher frequencies affects the network models of cables, lines, transformers and all elements. The harmonic current injection has been modelled as part of a network load.

The harmonic calculation follows two consecutive steps:
- initial load flow calculation, determining the complex voltages for the base frequency
- calculation on the linearised system for all harmonic frequencies.

The next components harmonic behaviour will be described briefly:
- cable and line
- transformer
- three windings transformer
- network source
- load
- capacitor
- filter
- coil
- synchronous generator and motor
- asynchronous generator and motor

Cable and line
The cable and overhead line have been modelled using a long line (distributed parameter) model.



$$Y_1 = Y_2 = \frac{tanh(\frac{\theta}{2})}{Z_c}$$

$$Y_{12} = \frac{1}{Z_c \cdot sinh(\theta)}$$

In these equations Zc represents the characteristic impedance and θ represents the characteristic angle:

$$Z_c = \sqrt{\frac{R + jh\omega L}{G + jh\omega C}}$$

$$\theta = l \cdot \sqrt{(R + jh\omega L)(G + jh\omega C)}$$

With:
R : resistance in Ohm/km
L : inductance in H/km
G : shunt resistance in S/km
C : capacity in F/km
l : length in km
h : harmonic order number
ω : base frequency in rad/s

If $C = 0$ then the impedance will be calculated as: $Z(h) = R + jhX$.

The admittance matrix elements follow from:

$y_1 = y_2 = Y_1 / Y_{base} = Y_1 \cdot Z_{base}$ [pu]
$y_{12} = Y_{12} / Y_{base} = Y_{12} \cdot Z_{base}$ [pu]

The admittance matrix elements for reactance coils are:

$$y_{12} = \left(\frac{1}{R + jhX}\right) \cdot Z_{base} \quad [pu]$$

$$y_1 = y_2 = \left(\frac{G + jhB}{2}\right) \cdot Z_{base} \quad [pu]$$

Transformer
The winding configuration and an optional phase shift are included in the complex turns ratio. The clock number is an integer number from 0 to 11, representing the winding configuration effect. The phase shift has been specified in degrees. The next equations apply for a transformer with a tap changer on the primary side.

$$n = \frac{U_{nom,sec}/U_{b,sec}}{\left(U_{nom,prim} + U_{trapstand}\right)/U_{b,prim}}$$

$$normale\ systeem: \ cov = n \cdot e^{-j\left(\frac{fasedraiing \cdot 2\pi}{360} + \frac{klokgetal \cdot 2\pi}{12}\right)}$$

$$inverse\ systeem: \ cov = n \cdot e^{+j\left(\frac{fasedraiing \cdot 2\pi}{360} + \frac{klokgetal \cdot 2\pi}{12}\right)}$$

The normal system impedance follows from:

$$z = \left(\frac{u_k}{100} \cdot \frac{U_{nom,sec}^2}{S_{nom}}\right) / Z_{base,sec} \quad [pu]$$

$$r = \left(\frac{{}^{P_k}/_{1000}}{S_{nom}} \cdot \frac{U_{nom,sec}^2}{S_{nom}}\right) / Z_{base,sec} \quad [pu]$$

$$x = h \cdot \sqrt{z^2 - r^2} \quad [pu]$$

$$z(h) = \sqrt{h} \cdot r + j\ h \cdot x \quad [pu]$$

Three windings transformer
The model is similar to the normal transformer model.

Network source
The network source has been modelled as a constant voltage source behind a short-circuit impedance. The reactance is a function of normal reactance and frequency.

$$z_{netvoeding}(h) = r_{netvoeding} + j\ h \cdot x_{netvoeding} \quad [pu]$$

Load
The load is a combination of a harmonic source and a harmonic impedance. There are many ways to model the harmonic load. The chosen model reflects a typical domestic load.

$Z_{load}(h) = R_{50} + jhX_{50}$
$Y_{load}(h) = 1 / Z_{load}(h)$

Where:

$$Y_{50} = \frac{|P|}{U_{nom}^2} - j\frac{|Q|}{U_{nom}^2} \quad [S]$$

$$R_{50} = re(\frac{1}{Y_{50}}) \quad [\Omega]$$

$$X_{50} = im(\frac{1}{Y_{50}}) \quad [\Omega]$$

The load has been taken as absolute values, always resulting in a positive impedance.
In the per-unit method:

$$z = \frac{1}{p - jq} \quad [pu]$$

$$z(h) = re(z_{50}) + jh \cdot im(z_{50}) \quad [pu]$$

$$y(h) = \frac{1}{z(h)} \quad [pu]$$

The harmonic impedance can be included or excluded into the calculations. Excluding the impedance gives a "worst case" result.

Capacitor
The capacitor is a shunt element. Its admittance is calculated from the capacity.

$$y_{cond}(h) = \frac{jh \cdot Q_{cond}}{U_{nom}^2} \cdot Z_{base} \quad [pu]$$

Passive filter

The capacitor bank can be integrated in an R-L-C filter. In order to do so, the filter frequency and the filter quality factor have to be specified. The capacitor size is already specified in Mvar or in µF. The induction and the resistance follow from the filter frequency and the quality factor.

From the capacitor reactive power at nominal frequency (Q_c) the reactance at base frequency will be calculated:

$$X_c = \frac{U_{nom}^2}{Q_c} \cdot \frac{h_f^2}{h_f^2 - 1} \qquad [\Omega]$$

With h_f the quotient of filter frequency and rated system frequency.

The coil reactance at nominal frequency is:

$$X_L = \frac{X_c}{h_f^2} \qquad [\Omega]$$

The resistance will be calculated from the quality factor q (mostly between 20 and 30).

$$R = \frac{h_f \cdot X_L}{q} \qquad [\Omega]$$

The filter admittance for a harmonic frequency of order number h is:

$$y_{filter}(h) = \frac{1}{R + j(h \cdot X_L - X_C/h)} \cdot Z_{base} \qquad [pu]$$

Active filter

An active filter is used for compensation of harmonic currents in certain branch, element or three winding transformer. Active filter can be specified in Vision inside. Before adding the capacitor a measurement point has to be selected first. Further, the measurement point has to be specified from the list. It indicates where the compensation of harmonic currents is desired.
Percentage of compensation can be specified for each harmonic separately. 100% means that the current via the measuring point for this harmonic is fully compensated by the filter.
Active filter is used in Vision only for harmonic loadflow calculation. First, the harmonic loadflow without active filter is executed. In this manner the harmonic currents via measurement point without the compensation are calculated. After that, necessary current injections of the filter are determined and the harmonic loadflow is executed for the second time. The results are the harmonic voltages and currents in the network with the compensation using active filter.

Coil

The coil is a shunt element. Its admittance is calculated from its induction. The admittance is:

$$y_{spoel}(h) = \frac{jh \cdot Q_{spoel}}{U_{nom}^2} \cdot Z_{base} \qquad [pu]$$

Synchronous generator and motor

The synchronous machine is a load for harmonic frequencies. The model is:

$$z_{gen}(h) = \sqrt{h} \cdot r_{gen,50} + jhx_{gen,50} \qquad [pu]$$

Where $r_{gen,50}$ equals the fictive generator resistance, used in short-circuit calculations. The reactance $x_{gen,50}$ is not the same as the saturated sub-transient reactance ($x_d''_{sat}$), used by the short-circuit calculations, but the normal sub-transient reactance x_d''.

Asynchronous generator and motor
The asynchronous machine model follows from:

$$R_s = a \cdot R_M$$

$$R_y = b \cdot R_M$$

Where:
R_M : total motor resistance with the rotor locked
a : 0.45
b : 0.55

The machine impedance for harmonic frequencies follows from:

Positive systeem: $r(h) = r \cdot \left[a \cdot \sqrt{h} + (h \cdot b \cdot \sqrt{h-1}/(h-1))\right] \quad [pu]$

Negative systeem: $r(h) = r \cdot \left[a \cdot \sqrt{h} + (-h \cdot b \cdot \sqrt{h-1}/(-h-1))\right] \quad [pu]$

And the reactance: $x(h) = jh \cdot x \quad [pu]$

6.6.3 Harmonics: Calculation

The harmonics module gives insight in the behaviour of the flows and voltages at higher frequencies in the network. Two functions have been made available: the harmonics load flow and the calculation of the impedance spectrum.

- With the harmonics load flow the consequences of injected harmonic currents on the harmonic voltages and the harmonic distortion can be studied.
- With the impedance spectrum the possible resonances in the network can be analysed.

For both harmonic load flow and impedance spectrum calculations the load impedances can be specified to be included or not, by checking "*Include load impedances*".

Harmonic load flow
The harmonic calculation follows two consecutive steps:

- initial load flow calculation, determining the complex voltages for the base frequency
- calculation on the linearised system for all harmonic frequencies.

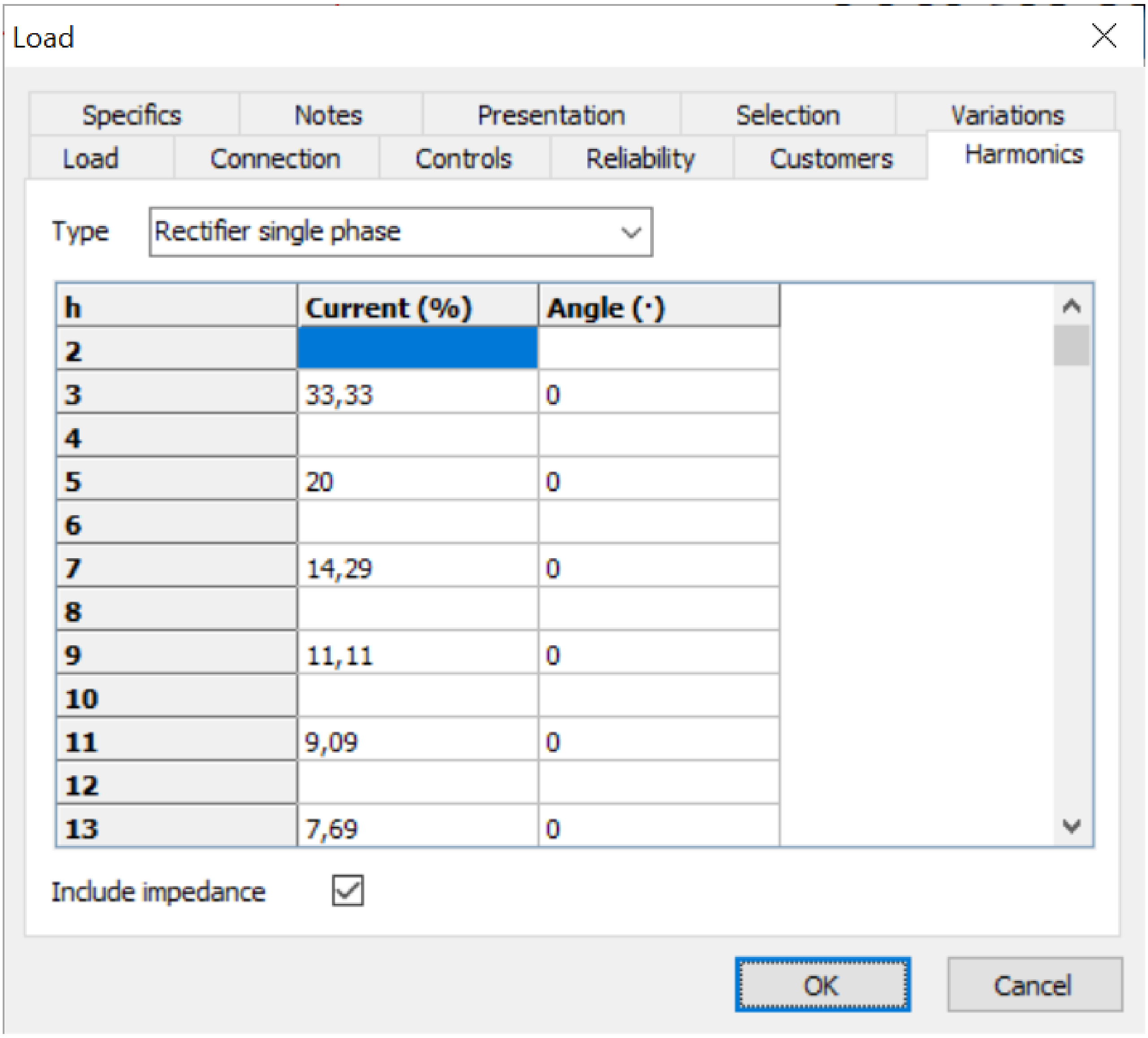
Starting the calculation, the user may specify that the results should be verified to a norm for maximum values of the harmonic voltages. These norms are defined in *Types.xls*.

Non-linear components are harmonic sources for the network. The harmonic load flow will be calculated only if harmonic sources have been specified. The non-linear sources have been modelled as current injections, specified with the loads.

Next diagram shows the harmonic currents for a rectifier. The harmonic currents are a function of the harmonic order number.

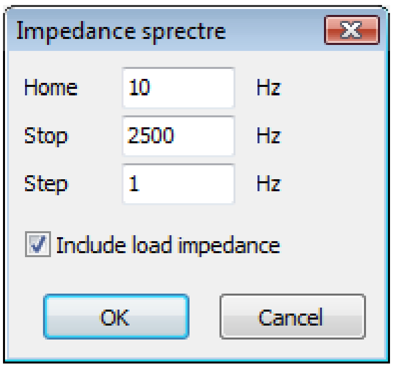
$$I(h) = I_{50Hz} / h$$

The harmonic currents have been specified as percentages of the rated load current at rated frequency and rated voltage.



All injection currents are injected with reference to the basic (50/60 Hz) load flow voltage angle. The harmonic load flow is evaluated for all specified frequencies.

Impedance spectrum
With the impedance spectrum the possible resonances in the network can be analysed. The impedance spectrum calculates the nodal impedance as function of the frequency. The complex impedance will be calculated for all frequencies between the start and stop frequencies.

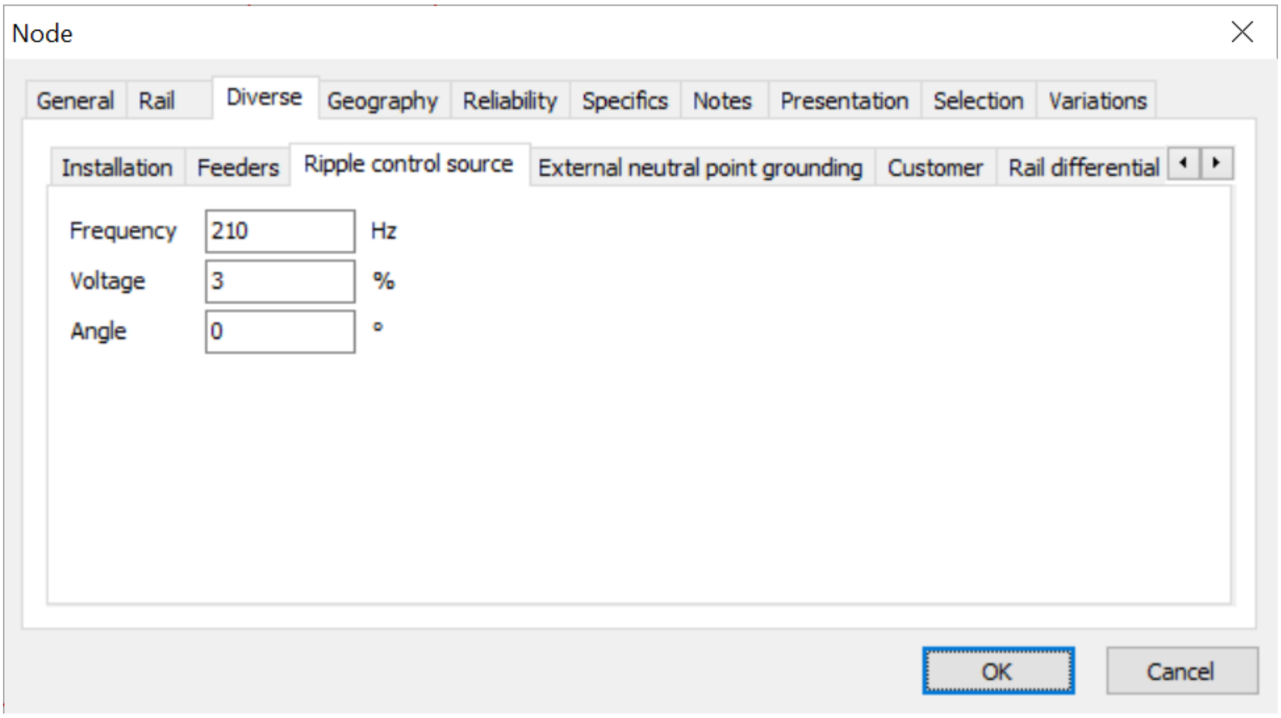


The impedance spectrum will be calculated for all selected nodes.

Ripple control

The ripple control calculation evaluates the control signals propagation in the network. One or more ripple control sources of different frequencies can be modelled. A ripple control voltage source can be defined on the tab 'Specials' of a node input form. The attributes are:

- Frequency: ripple control source signal frequency (Hz)
- U: ripple control voltage, relative to the rated voltage (%)
- Angle: ripple control voltage angle, relative to the actual voltage (degrees)



The calculation uses the normal sequence network and calculates the ripple control voltages throughout the whole network. The results are presented graphically and in tables.

The calculation either uses the standard load model or a frequency-independent load model.

- In the standard load model the reactance is linearly dependent of the frequency:

  $Z_{load}(h) = R_{50} + jhX_{50}$

  with:

  R_{50}, X_{50}: load impedance at rated frequency.

- In the frequency-independent load model the impedance is as follows:

  $Z_{TF} = U^2 / (KN \cdot S)$

  $Z_{load}(h) = Z_{TF} \cdot (\cos(FN) + j \sin(FN))$

  with:

  KN: load factor, considers the simultaneous change (reduction or increase) of the power (real and reactive) of all loads in the network

  FN: load angle, in degrees (0 degrees is pure real impedance, 90 degrees is pure inductive load)

  U: load flow voltage (kV)

  S: apparent power (MVA).

6.6.4 Harmonics: Result

Harmonic load flow

The harmonic load flow result can be evaluated in three ways:
- in the one-line diagram
- in the detail forms
- in a bar chart

Harmonic sources result in harmonic voltages and currents in the network, which will be calculated for each relevant frequency. The RMS-values of voltages and currents are calculated as follows:

$$U_{rms} = \sqrt{\sum_{m=1}^{\infty} |V_m|^2}$$

With: V_m : effective value of the harmonic voltage.

$$I_{rms} = \sqrt{\sum_{m=1}^{\infty} |I_m|^2}$$

With: I_m : effective value of the harmonic current.

The Total Harmonic Distortion (THD) is calculated as follows:

$$THD_V = \frac{\sqrt{\sum_{m=2}^{\infty} |V_m|^2}}{|V_1|} \cdot 100$$

$$THD_I = \frac{\sqrt{\sum_{n=2}^{\infty} |I_n|^2}}{|I_1|} \cdot 100$$

One-line diagram

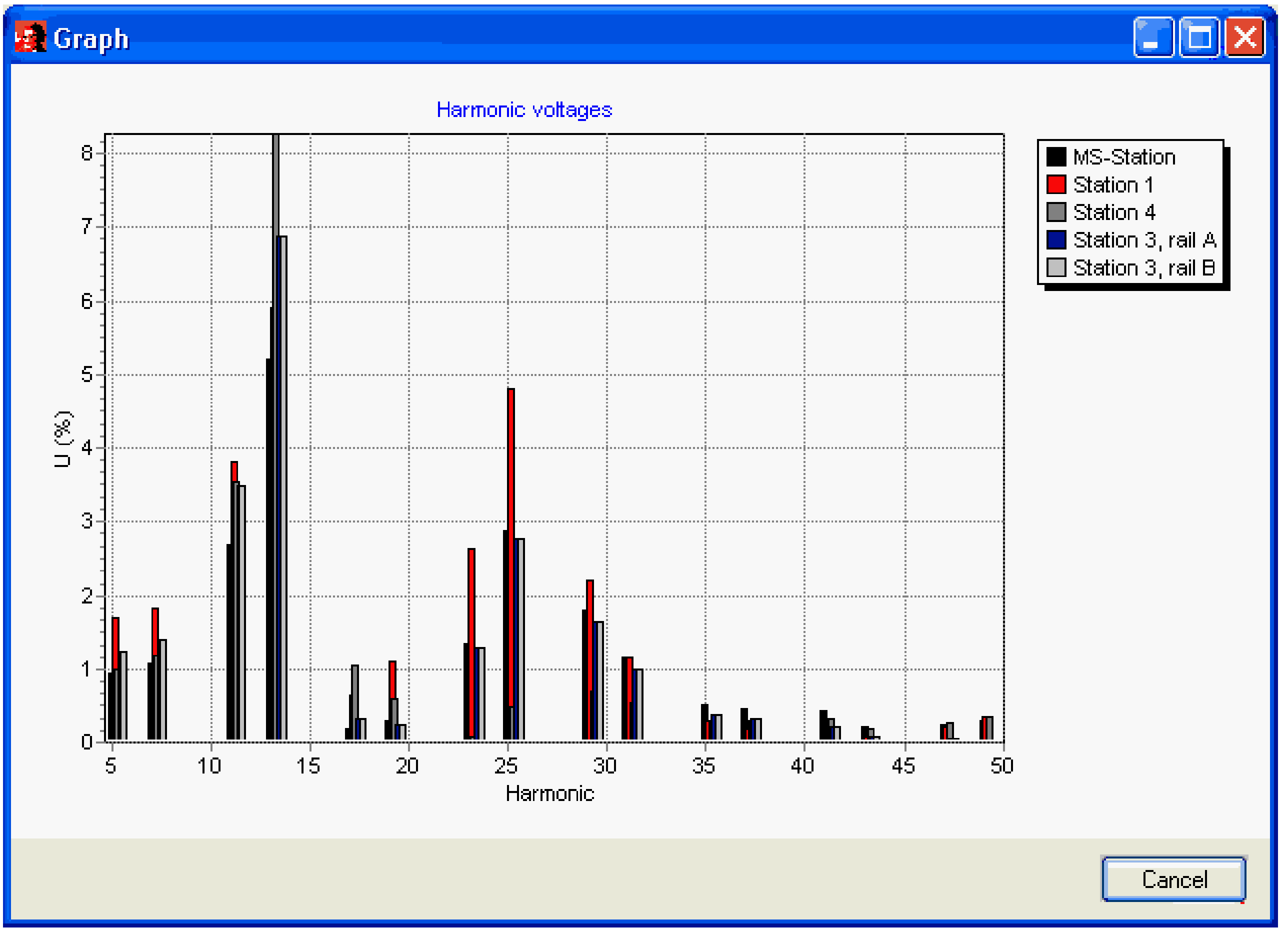
After a successful calculation the RMS-values of voltages and the Total Harmonic Distortion (THD) on the nodes are presented in the view. For all branches the RMS-values of the currents and the THD are presented in the view.

Results, Details

In the details-form of components is presented:
- Nodes: RMS-value and THD; after clicking on the Details-button:
  - Harmonic voltages in V and as percentage of the nominal voltage
- Branches: RMS-value and THD; after clicking on the Details-button:
  - Harmonic currents in A
- Elements: RMS-value and average power (Pav); after clicking on the Details-button:
  - Harmonic currents in A; for loads is the harmonic source current injection included

Bar chart

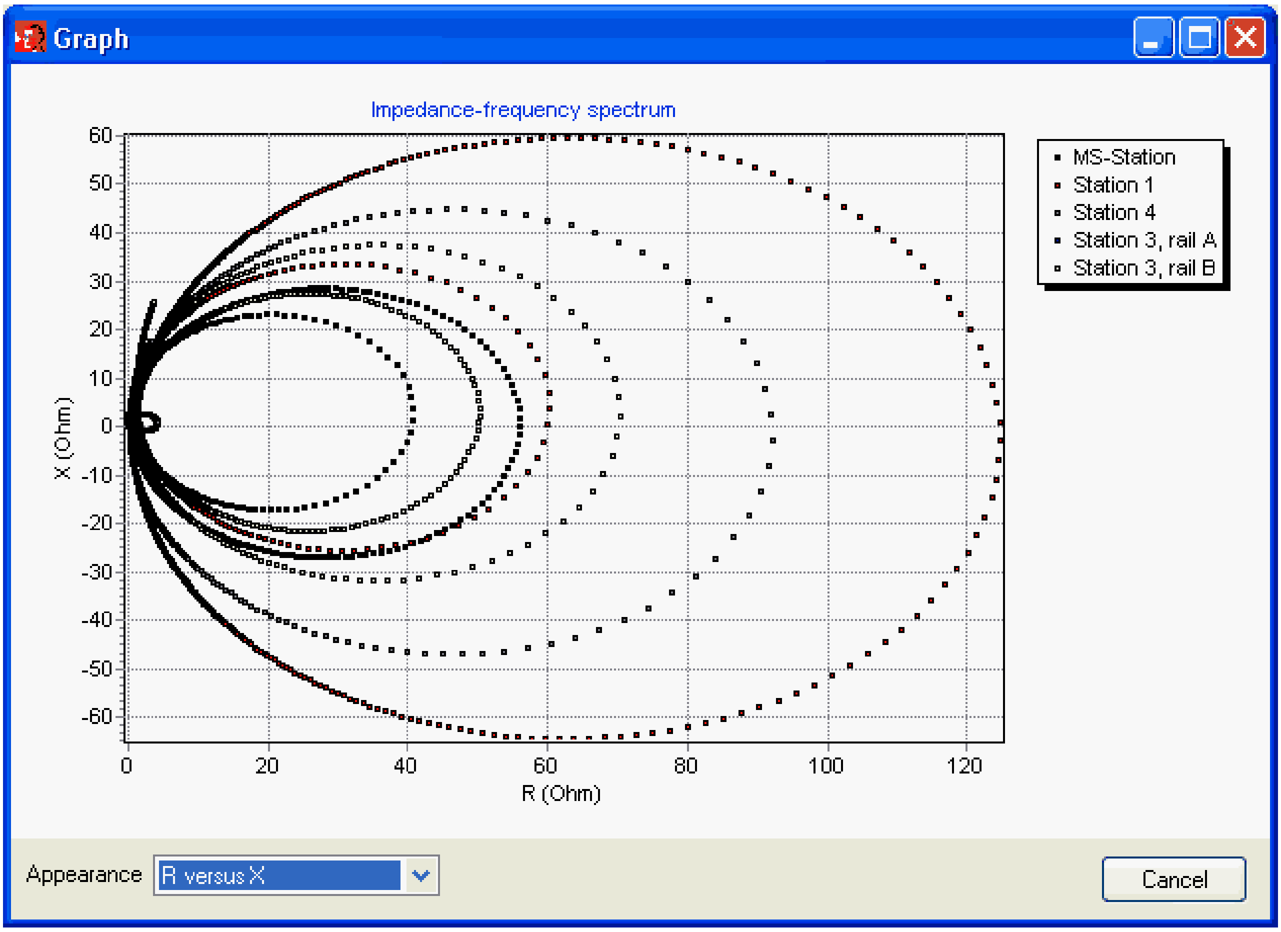
For all selected nodes their harmonic voltages can be presented in a bar chart, using **Results | Detailed graph**. If the user specified that the results should be verified to a norm, the normative maximum values will be plotted as triangular symbols in the bar chart.
For all selected branches and elements the currents are plotted.



Impedance spectrum

For all selected nodes their impedance spectrum can be presented. This can only be presented graphically, using **Results | Detailed graph**.

- R: resistance as function of frequency
- X: reactance as function of frequency
- Z: absolute value of impedance as function of frequency
- R&X: resistance and reactance as function of frequency
- R/X: resistance and reactance as complex vector diagram



Export
Almost all calculated results can be exported to Excel. In fact, the export is a fixed format report of all objects on three sheets: nodes, branches and elements.

6.7 Costs

6.7.1 General

It is not easy to determine network costs or to make economic comparisons of network variants. Network cost calculations are often based on estimated parameters. Nevertheless, it is possible to calculate anticipated operational costs with a reasonable degree of accuracy. In Vision, a cost calculation involves costing the network losses.

Network losses
Network losses are energy losses (kWh). The future cost of network losses can be calculated back to the date of investment (cash value). The valuation of network losses over a given period is explained below.
In the formulae below.

The following parameters are used in the formula's:

P_l	powerloss at maximum load (kW) exclusive transformers and cables magnetizing loss
P_{null}	transformers en cables magnetizing loss (kW)
T_b	duration of maximum load (h/year)
T_l	duration of the loss (h/year)
lf	loss factor for the calculation of Tl (0.2 according to Berry, 0.15 <= lf <= 0.3 according to Epri)
D_e	kWh price (Valuta/kWh)

i real interest (market interest – inflation) (%/year)
y year (y=0 in the first year)

Energy loss costs
The energy cost of losses in the first year is:

$$E_{costs} = P_l * T_l * D_e + P_{null} * 8760 * D_e$$

In Vision, T_l is calculated from T_b as follows:

$$T_l = lf * T_b + (1 - lf) * T_b{}^2/8760$$

so that the energy loss cost can also be represented as:

$$E_{costs} = P_l * (lf * T_b + (1 - lf) * T_b{}^2/8760) * D_e + P_{null} * 8760 * D_e$$

The energy loss cost in another year can be calculated as:

$$E_{costs,y} = E_{costs,0}/(1 + i/100)^y$$

Load growth is taken into account.

6.7.2 Calculation

First, fill in the ***Options*** under **Calculation | Costs**.
Since the calculation is performed by summation of the results of the four daypart presets of load situations (night, morning, afternoon and evening), most of the options can also be entered in quadruplicate.
A daypart year is 2190 hours.

A cost calculation is performed as follows:
- Set the end year for the calculation, using: **Start | Time | Year**
- Select **Calculations | Costs**

No further settings are required.

In the daypart oriented calculation, T_l is determined from T_b according to:

$$T_{l,daypart} = lf_{daypart} * T_{b,daypart} + (1 - lf_{daypart}) * T_{b,daypart}{}^2/2190$$

6.7.3 Result

The features of the **Results** menu item are explained below.

Calculation
Results | Calculation is used to display a summary of the results.

Details
Results | Details is used to display detailed information about selected branches on a form. If several branches are selected, Previous and Next can be used to bring up details of other selected items.

Graph
Results | Graph is used to display the cost of losses in those branches over the entire period.

Export
Calculate | Results | Export allows the results to be exported to Excel.

6.8 Reliabilty

6.8.1 General

Reliability calculations are not easy to carry out. Virtually all the available software is based on high voltage networks and is not or is hardly suitable for calculating MV networks. The available software can only be used by specialists. The execution of the calculations is labour-intensive because of the large quantity of data that have to be input. The reliability module calculates the reliability indices of meshed and radially operated MV network configurations. With this module it is possible in a relatively simple and user-friendly way to calculate the reliability of MV networks.

The reliability module calculates the failure effects of:
- single mode failure
- single mode failure plus protection failure
- common cause failure
- maintenance plus single mode failure.

The reliability module is developed on the following specifications:
- The users have a thorough basic knowledge of reliability analysis.
- The module does not compute short circuit currents. Each fault leads to tripping of a protecting device. There is no distinction between one phase and three phase faults.
- Circuit breaker faults and protection malfunction are modelled in a simple way.
- The process is modelled for a MV distribution network.
- For each component a failure rate is specified.
- The module calculates the ENS (Energy Not Served), P (Outage Probability), F (Outage Frequency) and D (Outage Duration) for each component.
- The presence of only one trouble-shooting team is modelled. Calling in two or more trouble-shooting teams is not modelled.
- Common cause failures are modelled. No common cause failures are modelled during maintenance or repair.
- Maintenance in meshed networks is modelled.
- Anticipated outage is not modelled.
- The module calculates with mean values only.
- There is no partial recovery.

Despite the low user threshold, the reliability analysis still is a difficult matter. Therefore we recommend that only specialists should interpret the results.

6.8.2 Concept

For reliability calculations a number of fixed definitions and relevant symbols are used internationally. For the sake of completeness a few commonly used definitions are set out briefly.

Input data
The reliability input data for all components are:
- Failure frequency: the mean number of occurrences that the component fails.
- Repair duration: the mean duration in minutes that component repair or replacement takes.
- Maintenance frequency: the mean number of occurrences that the component is in maintenance.
- Maintenance duration: the mean duration in minutes that component maintenance takes.
- Maintenance cut-off duration: the mean duration in minutes that it takes to abort component maintenance in case of an emergency.

- No operation probability: Probability that a protection device refuses to trip or a circuit breaker refuses to switch off the fault.

Results
After a calculation the following results are available:
- F, Outage Frequency: the mean number of component outages per year due to a failure in the network
- D, Outage Duration: the mean outage duration of the component per outage due to a failure in the network
- P, Outage Duration per year: the mean outage duration of the component per year due to a failure in the network
- P, Outage Probability: the outage probability of the component per year due to a failure in the network (converted from outage duration)
- ENS, Energy Not Served: the mean amount of energy per year that an element can not consume due to a failure in the network
- P*BC: large customers outage duration: product of P and the number of large customers
- P*SC: small customers outage duration: product of P and the number of small customers

Non-availability
The term non-availability is defined as the time a component is not scheduled out of service. The scheduled out of service duration is not taken into account. The maintenance time is taken into account in combinantion with failures during maintenance.

Group
A group is a set of components that is protected by one protection device or limited by network openings. Failure of one component in the group always leads to outage of all other components in the whole group. See also: Group 73.

Single mode failure
Each failure is regarded as one event. During the repair time no other failures may occur in the model (exception common cause failures and protection refusing). A component failure usually leads to a group outage by an always selective protection.

Protection failures
There are two modes of protection failures:
- failure in a circuit breaker (short circuit)
- a power switch does not switch off a fault on a network component (stuck breaker).

If a power switch fails to open, its function is taken over by another power switch or fuse. In that case there is no selective tripping.

Common cause failure
A common-cause-fault, a double fault with a common cause, results in the simultaneous failure of two or more network components. A common-cause-fault is regarded as one event that is characterised by a failure frequency where the two or more components fail simultaneously. No new fault occurs until the failed components have been repaired.

Preventive maintenance
If case of maintenance the whole group is out of service. All switching devices will be taken into maintenance during this outage. Therefore it is not necessary to specify maintenance data for switching components.

6.8.3 Input

The input data are divided into three parts: general data, component data and common cause data.

General data
The data input procedure is as follows:
- Choose **Application menu | Options**.
- Select the **Calculation** tab and the **Reliability** tab.

- ***Signal fault*** : time needed to signal the fault. ***Short*** : time to signal when remote signalling is present. ***Long*** : time in any other case.
- ***Activate trouble shooting team*** : time needed for the repair crew to be in the fault locating starting position.
- ***Locate fault*** : mean time to locate the fault. ***Short*** : time when all nodes are equipped with short circuit indicator. ***Long*** : time in any other case.
- ***Sequential search*** : mean time to locate the fault when the repair crew follows the cable path.
- ***Binary search*** : mean time to locate the fault when the repair crew follows the binary search method (starting half way).
- ***Isolate fault*** : mean time to isolate the fault, when found. ***Short*** : time when alle switches are remote controlled. ***Long*** : in any other case.
- ***Switch in/over*** : mean time to switch on the outaged components or to change net openings. ***Short*** : time when alle switches are remote controlled. ***Long*** : in any other case.
- ***Emergency power supply*** : mean time to install an emergency generator. The maximum power is specified.
- Choose **OK**.

When locating the fault it is also possible to indicate a search strategy. Each strategy has its own long times. The times are based on a number of stations. The times for the strategy chosen must be filled in.

When sequentially searching the stations are gone over one by one to search for the fault, for this an average time must be indicated and the number of stations for which this average applies. If an average time of 60 minutes is indicated for five stations (from own experience) then in a group of ten stations the time will vary between 12 minutes (fault at first station) and 120 minutes (fault at last station).

In a binary search first the middle station of the string is looked at, then in the middle of half of the string, and so on. In this way the search process is reduced until the fault is found. The time required to find the fault is then logarithmically dependent here on the number of stations. Here too it is necessary to indicate the average time for a number of stations (from own experience).

Component-related input data

For all components in the network the reliability data for the switches must be specified. These parameters are on the **'Field'** and **'Reliability'** tab forms. The **'Reliability'** tab form contains failure, repair and maintenance data. Some component tab forms contain extra data, such as:

- cable: number of sleeves and their failure frequency
- node: presence of short circuit indicator and remote indication.

The tab forms **'Field'** contain information about the switch type and its failure data (not for a node).

To collectively input general reliability data for a large number of components, use **Start | Edit | Collective**.

Common cause failures

For two or more of components the failure data for common cause failures must be specified separately. The procedure is as follows:

- Select the two or more components for which the common cause failure rate will be entered.
- Choose **Insert | Selection**.
- Enter the name for this selection as:

  ```
  common <failure frequency> <repair duration> [<name>]
  ```

  where the ***name*** is optional. So, for example for a selection of components with a common cause failure frequency of 0.0001 and a repair duraition of 480 minutes, the name for this selection becomes:

  ```
  common 0.0001 480
  ```

- Select **OK** to save the data.

6.8.4 Modelling

The reliability evaluation process is divided in to two parts: the failure process and the recovery process. These two part will be discussed separately.

Failure process
The reliability module does not execute any short circuit calculations. All component failures are simulated by opening the protection deviced around the concerning group. Next the influence on the other groups is evaluated. The term 'group' is explained in Reliability: Concept 289.

The failure process is as follows:
- a component fails
- the relevant group is disconnected
- groups where components are in overload are also disconnected.

The reliability calculations are based on the methods from Billington.

Recovery process
The recovery process calculates the duration that the requested energy can not be served. The procedure is not developed to find out an optimal recovery strategy, but to calculate the expected duration for energy recovery by any topology changes, repair or back up generators. The recovered network can not be presented to the user.

All faults more or less lead to the same recovery process. The ultimate recovery method depends on the configuration. The process is, in general:
- signal a failure
- activate recovery and repair crew
- locate faulted component
- isolate faulted component
- recover energy service.

The duration for the first four activities will be summed up to the non availability duration. The last activity may take place in four different ways, called recovery phases. Each component may be recovered in any of the phases.

1. Switching on: The opened switches may be closed again. There may be no overload in any circuits. As many switches as possible are tried to close. Also double rail systems are treated in this phase by closing the double rail couplings.
   $T_{recovery} := T_{signal} + T_{trouble\text{-}shooting\ team} + T_{locate} + T_{isolate} + T_{switch\ on}$
2. Topology change: All net openings around non available groups are tried to close, without causing any overload. As many net openings as possible are tried to close until the groups are recovered.
   $T_{recovery} := T_{signal} + T_{trouble\text{-}shooting\ team} + T_{locate} + T_{isolate} + T_{topology\ change}$
3. Back up generator: If the back up generator duration is smaller than repair of maintenance cancellation the back up generator will be used for the groups still not recovered. Recovery is only possible if the total group requested power is smaller than the generator power.
   $T_{recovery} := T_{signal} + T_{trouble\text{-}shooting\ team} + T_{locate} + T_{isolate} + T_{back\ up\ generator}$
4. Repair or Maintenance cancellation: All other components will be recovered after repair or cancellation of maintenance. The assumption is that switching on or topology change always takes less time than back up generator, repair or maintenance cancellation.
   $T_{recovery} := T_{signal} + T_{trouble\text{-}shooting\ team} + T_{locate} + T_{isolate} + min(T_{repair}, T_{maint.cancel})$

6.8.5 Calculation

After input of all reliability data, the calculation can be started as follows:
- Choose **Calculation | Reliability**.
- Specify the calculation parameters for:
  Refusing Switches:

If required, indicate whether the refusing of switches must be taken into account. This means that the chance that a switch will not open must be taken into account while a fault has occurred in the network.

Common cause faults:

If required, indicate whether common-cause faults must be taken into account. A common-cause fault is a double fault with a common cause that ensures the simultaneous failure of the two or more components. Selections must be made for this.

Maintenance:

If required, indicate whether maintenance must be taken into account.

Selecting one or more of the above options will cause more calculations and therefore slow down the total procedure. It is recommended to first perform an analysis without the above options to obtain a quick insight about.

- Choose **OK** to start the process.

When the calculation starts, the progress can be followed by the progress bar. If one of the options (failure switches, common-cause faults, maintenance) is taken into account, the calculation time is longer. The same applies for meshed networks. Then too the calculation time may be longer.

6.8.6 Result

The results may be examined as follows:
- in the on-line diagram
- using **Results | Survey**.
- using **Results | Details**.
- using **Results | Graph**.

One-line diagram

For each component the plotted results are (defined in Tools | Views):
- F: .../year Outage rate
- D: ... min Mean outage duration
- P: ... min/year Outage duration per year
- P: ... % Outage probability

For each element the Energy Not Served is plotted:
- ENS: ... kWh/year

For each load or transformer load the customer outage is plotted:
- P*BC: ... min/year (P x number of large customers)
- P*SC: ... min/year (P x number of small customers)

Results | Survey

The mean reliability results are presented per component type for the selected components and the whole network.

Results | Details

For a selected node is presented:
- Name
- Reliability results

After clicking the **'Details'** button a table shows:
- Failing component causing the non availability of the selected component
- Remarks, for example the indication that here this is the effect of a refusing switch
- Outage frequency F
- Outage duration D
- Outage probability P
- Recovery phase, the action that leads to restoration of the supply

- D (Tsig + Tsp + Tlok + Tiso + Tins + Toms + Tnr): individual recovery durations that sum up to D [min]. These are:
  - Tsig : time to signal a fault
  - Tsp : time to activate the fault recovery team
  - Tlok : time to locate the fault
  - Tiso : time to isolate the fault
  - Tins : time to close switches for the recovery
  - Toms: time to re-route for the recovery
  - Tnr : time for emergency generator or for repair
- Summation of outage frequency and outage probability.

With these data the greatest cause of the non-availability frequency or the non-availability duration can easily be found.

Results | Graph
The mean reliability results for frequency, duration and probability are presented in bar charts. The type of reliability result can be selected with the selection box. The components are sorted as indicated.
By clicking on a bar in a results bar chart, the user jumps directly to the concerning object in the one-line editor.
The results may be compared with results of another calculation, is saved with **Results | Save**. Use the check-box "**Saved**".

Results | Save
With **Results | Save** the results of a calculation can be saved to compare with another calculation result in **Results | Graph**.

Export
Almost all calculated results can be exported to Excel. In fact, the export is a fixed format report of all objects on three sheets: nodes, branches and elements.

6.9 Protection

6.9.1 General

The protection calculation module gives insight in the behaviour of the protections in case of short circuits in the network. The protection function can be incorporated with a component, such as the fuse, but can also be combined as a separate function to a switching component, such as the circuit breaker switch. The table below gives an overview of the switching components and their possible protections. The circuit breaker switch can be coupled to four different protections. Several circuit breaker switches can be coupled to a differential protection.

Switching component	**Protection type**	**Action**
Load switch	None	None
Fuse	Current protection	Maximum current/time
Circuit breaker	Current protection	Maximum current/time
	Earth fault	Maximum current/time
	Voltage protection	Min/Max voltage/time
	Distance protection	Impedance
Short circuit indicator	Overcurrent	None
Combination of circuit breakers	Differential	Differential current/time

See also:

- Load switch 201
- Fuse 202
- Circuit breaker 203
- Current protection 205
- Earth fault protection 211
- Voltage protection 212

- Distance protection 214
- Differential protection 213
- Short circuit indicator 221

For analysing the protections and checking the correct protection settings the protection calculation module offers two types of calculations: simulation calculation and selectivity calculation. Using the simulation calculation the course of the switching actions after a single short circuit can be studied. Using the selectivity calculation the selectivity of the protections can be examined at a single glance.
It is also possible to present the protection switching characteristics in one graph. See also: Maximum current protection characteristic 101.

Simulation
Using the simulation calculation the behaviour of the protections can be studied in detail during the switch off sequence of a single short circuit. Firstly on a node a short circuit is applied. Then all flows in the network are calculated. For all the activated protections the possible switch off times are calculated. The protection which first trips opens its corresponding circuit breaker switch. Then the network is calculated again. The now fastest protection trips and the corresponding switch opens. This process is repeated until no more protections trip. The result is a number of sequences of disconnections.
Also in cables short circuits can be simulated. For that purpose Vision applies short circuits on a number of equidistance places in the selected connections (cables/lines). The number of equidistance places can be define in th***Options*** at: **Calculation | Protection**.

Changing short circuit currents in a meshed network
When a switch opens in a meshed network, (or in separately protected parallel feeding cables) several protections are activated. In that case it can happen that after the first switching action the other protections are getting to see another flow. This new flow causes new switch off times. The behaviour of the protections on this point are modeled in a way that approaches the reality. This model has been outlined below.

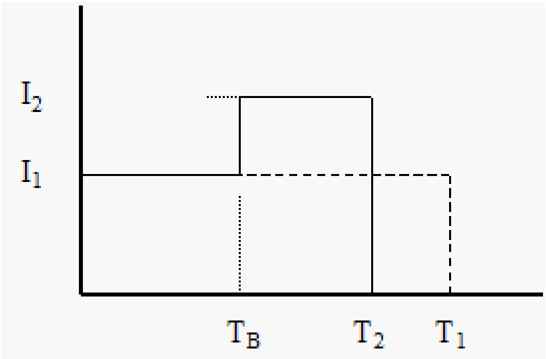
Suppose that two feeders are feeding into the short circuit. At time T_o = 0 s the protections see currents I_A and I_B. If these currents are large enough, both protections are activated and the switch off times are determined according to the protection characteristics. If the current through protection A is $I_A = I_1$, the characteristic switch off time will be t1 and the ultimate switch off time will be:

$$T_A = T_1 = T_0 + t_1 \ s$$

If, however, in this example, protection B switches earlier ($T_B = T_o + t_u$) than protection A, the current through protection A changes from I_1 to I_2. This new short circuit current can be larger or smaller than I_1. As a consequence, the switch off time for protection A has to be calculated again. The procedure follows the table below.

IA	T1	t2	T2	Action
-	-	infinite	infinite	Protection does not trip
I2 < I1	-	t2 = t1	T2 = T1	Protection was activated and trips at the original time
I2 < I1	-	t2 > t1	T2 = TB + t2	Protection was activated and trips later
I2 = I1	-	t2 = t1	T2 = T1	No change
I2 > I1	infinite	t2 < t1	T2 = TB + t2	Protection was not activated but now it is
I2 > I1	< infinite	t2 < t1	T2 = min(T1, TB + t2)	Protection was activated and may trip earlier

Remarks on this model:
- The first situation in the table implies that a protection may be reset. This is a consequence of the worst case approach.
- The thirs situation in the table is a worst case approach. When the current has been reduced (slightly), the new characteristic switch off time is added to the actual time.
- The fifth and sixth situations in the table are the most common situations. After a switching action in a parallel path the remaining short circuit current will increase in most cases.



Selectivity
The selectivity calculation module analyses the selectivity of protections of a component or a group of components.

An object or a group of objects is ***selectively*** protected if the consequences of a short-circuit are limited. This is the case if only the protections, located closely to the short-circuit, interrupt the short-circuit. This has been modelled in Vision so that only the fuses or circuit breakers directly surrounding the failed group will open. Switching in isolated objects does not influence the selectivity. Disconnecting an element by switching of a fuse or a circuit breaker influences the selectivity if defined in the Options (at: **Calculation | Protection | Selectivity | Influence element protection**).

One way of determining the selectivity of protections in simple cases is to compare the protections characteristics 101. The protections are selective if their characteristics do not cross and if there is enough margin between them. For more complex cases with parallel paths, network meshes or dispersed generation, the selectivity calculation module will be preferred.

The selectivity calculation module automatically determines the selectivity of protections. It uses the simulation module calculations. The procedure calculates all protection actions for all possible short circuit situations on a selected component.

In the calculation several faults with various resistances are applied on a node or in a branch (cable/line). The range of fault resistances is established automatically.
For each fault all currents in the network are calculated. The protections, for which the current is larger than the threshold value, will be activated. For these protections the switch off times are calculated. These times are saved and can be viewed with **Results | Detailed graph**. Next the tripped circuit breakers will be opened and the switching times of the remaining protections (especially in meshed networks) will be calculated. This action will be repeated until the short circuit has ended.

The result is a curve of possible protection switch off times as a function of the short circuit current. Presented in a graph, these curves give a good insight in the protections selectivity. The curves show:
• ***Intended switches off*** : selectivity curves for the initially activated protections that intend to switch off
• ***Real switches off*** : switch off curves for the actually switching circuit breakers or fuses.

6.9.2 Calculation

The protection analysis examines the correctness of type and parameter specifications. Vision checks the thermal load of branches and the protection selectivity. For this Vision automatically creates short circuits on user specified nodes, by using the fault analysis 273 method. The calculations may be verified in detail by executing a fault analysis study.
Also faults in cables and connections can be simulated. In that case, in the ***Options*** the ***Cable calculation steps*** must be non-zero. It defines the number of equidistant short-circuit places in each cable or connection. An option has been added to simulate short-circuits close to the from and to nodes (1% and 99% of distance).

Also the consequences of a protection or circuit breaker operating failure can be analysed. If this option is switched on, extra calculations will be made and extra results will be visible.

Vision has four types of protection calculations:

Calculation	Fault location	Fault type	Fault impedance	Result
One fault	One selected object	One fault type	One fault impedance	Details of nodes and branches
Simulation	Multiple selected objects	Multiple fault types	One fault impedance	Details of nodes and summary of branches
Selectivity	Multiple selected objects	Multiple fault types	A range of fault resistances	Selectivity of nodes and branches
Analysis	Multiple selected objects	A range of fault types	Three fault resistances (fixed)	Undesired events

Fault location : the user selects one or multiple fault locations
Fault type : short-circuit between phase and ground, between two phases, between two phases and ground of between three phases; a range of fault types is specified in the ***Options*** , at: **Calculation | Network analysis | Voltage dip analysis and protection analysis**.
Fault impedance : resistance and reactance on the fault location; to be specified by the user; a range of fault resistances is specified in the ***Options*** , at: **Calculation | Protection**; the three fault resistances for the protection analysis are fixed

One fault (Simulation)
The protection sequence can be evaluated for a fault on a single object/location. This is principally the same calculation as the **Simulation** calculation, but always executed for one fault on one specific object/location only. With this calculation, many detailed voltage and current results are available during the sequences of the protection actions.
The results are:
- Protection switching sequence details
- Short-circuit location short-circuit currents during the protection switching sequence (maximum value for the 3 phases)
- Node voltages during the protection switching sequence (minimum value for the 3 phases)
- Branch and element currents during the protection switching sequence (maximum value for the 3 phases)
- Branch I^2t
- Faulted node I^2t

The colour indications are as follows:
- Nodes, branches and elements that are thermally overloaded: too high colour
- Short-circuit indicators that tripped: attention colour
- Protection devices that have picked up: attention colour
- Protection devices that have tripped: trip colour
- Circuit breakers and fuses that have switched off: out colour

This analysis is input by the user as follows:
- select the object for wich the protection has to be evaluated
- choose **Calculation | Calculation | Protection | One fault**
- choose fault type
- specify fault impedance, like in Fault analysis 274
- leave the form with **OK**.

Simulation
Executing a simulation analysis the next steps are carried out:
- a specified fault is created on a specified node or in a branch
- hereafter all network currents are calculated
- next all protection switch off times are determined

- the first tripping protection opens the switch
- the network currents are determined again
- if necessary and available the next switch opens
- the process is repeated until the fault is isolated.

This analysis is input by the user as follows:
- select the nodes for wich the protection have to be evaluated
- choose **Calculation | Calculation | Protection**
- choose the fault types
- specify fault impedance, like in Fault analysis 274
- specify the option to include protection or circuit breaker operating failure
- leave the form with **OK**.

Selectivity
Executing a selectivity analysis the next steps are carried out:
- for a specified fault type several faults, each having a different fault impedance (see ***Options***), are created on the specified nodes
- for each fault all network currents are calculated
- for all protection devices all switch off times are calculated and saved
- the tripped switches are opened
- then all changed network currents and changed switch off timed are calculated
- the tripped switches are opened and the previous step us repeated until the short circuit has been switched off

Result are current and time curves generated by various fault impedances. Presented in graphs, these curves provide insight in the protection selectivity.

This analysis is input by the user as follows:
- select the nodes for wich the protection have to be evaluated
- choose **Calculation | Calculation | Protection**
- choose the fault types
- leave the form with **OK**.

Analysis
The protection analysis function analyses the protection settings, in combination with the possibility that they refuse to operate. See: Protection analysis 304.

User settings
Cable calculation steps
The number of equidistant places within the cable/line where short circuits are to be simulated, can be specified with the number of cable calculation steps. An option has been added to simulate short-circuits close to the from and to nodes (1% and 99% of distance).

6.9.3 Result

Network

After a protection calculation the results are presented on the screen. The results are presented as follows:
- Simulation calculation:
  - Nodes: switch off sequences (short circuit current and switch off times)
  - Branches: I^2 t as percentage of $I(max)^2$ t (branches that are overloaded are coloured with the "high" colour).
  - Branches: I^2 t as percentage of $I(max)^2$ t when protections and switches fail to operate (refuse).
- Selectivity calculation:
  - Nodes: yes/not selective
  - Branches: yes/not selective

The options from the menu-item Results are described below.

Calculation
The menu option **Results | Survey** gives a global presentation about overload and selectivity.

Simulation calculation :

- number of overloaded branches (I^2 t)

Selectivity calculation :

- number of components that are yes/not selectively protected

Details
The menu item **Results | Details** presents the detaild results for nodes, branches and elements. If more than one component is selected, the range can be viewed using **Next** and **Previous**. Also by mouse clicking on neighbouring components the user can walk through the network by viewing detailed results information. For a simulation analysis the following results are available per node:

- Simulation calculation:
  - fault type, node name, fault impedance
  - range of sequences; per sequence the following:
    - Ik": short circuit current on the faulted node (3 phases)
    - switch:
      - t: absolute switching time
      - phase(s): switched phases
      - name: switch name
    - protection:
      - name: protection name
      - sort: current/earth fault/voltage/distance/differential
      - trigger(s): measured value per phase
      - zones: stage/zone in the protection per phase ***)**
      - t: absolute trip time
- Selectivity calculation on nodes:
  - fault type and node name
  - fault range; per fault:
    - Rff or Rfa: fault resistance phase to phase or phase to ground
    - Ik": short circuit current (3 phases)
    - all activated protections; per protection:
      - type
      - protection name
      - switch name
      - t: initial switch off time per phase
- Selectivity calculation on branches:
  - the same results as on nodes, but for all cable calculation steps.

***)** The stage/zone is related to the protection characteristic. The next code has been used.

- Fuse: the largest current-time point in the characteristic which is smaller than the actual current
- Current protection with curve: the largest current-time point in the characteristic which is smaller than the actual current
- Current protection with fixed time: the largest current-time point which is smaller than the actual current (1, 2 or 3)
- Current protection with inverse characteristic: actual current in the curve:1; current larger than I>>: 2; current larger than I>>>: 3
- Current protection with special characteristic: actual current in the curve:1; current larger than I>>: 2; current larger than I>>>: 3
- Current protection with specific characteristic: current larger than I>: 1
- Voltage protection: voltage larger than U>: 1; voltage larger than U>>: 2; voltage smaller than U<: -1; voltage smaller than U<<: -2

- Distance protection: according to the defined 3 zones; directional end time: 4; backwards: -1
- Differential protection: 1

Graph

The menu item **Results | Graph** graphically shows the results for selected nodes and branches.
After a simulation calculation this is per node the course of short-circuit current and time.
After a selectivity calculation this is per node the current through the different protections as a function of the short-circuit current at the fault node, or the switch-off time of the different protections as a function of the short-circuit current.
After a simulation calculation for selected branches the branch load I²t / I²tmax can be shown in a bar chart.
The components in the graph are sorted as indicated. The axes are scaled automatically or in a given range.
By clicking on a bar in a results bar chart, the user jumps directly to the concerning object in the one-line editor.
The results may be compared with results of another calculation, is saved with **Results | Save**. Use the check-box "Saved".

Simulation calculation

After a simulation calculation for all components, where a short circuit is simulated, the course of the short-circuit current as a function of time is presented. For all branches that feed into the short circuit, the branch load I²t / I²t(max) can be shown in a bar chart.

Results / Graph

- Presents for all selected branches that feed into the short circuit, the maximum I²t / I²t(max) as percentage in a bar chart. Appearance: without or with refusing protections/switches.
- Presents no results for nodes

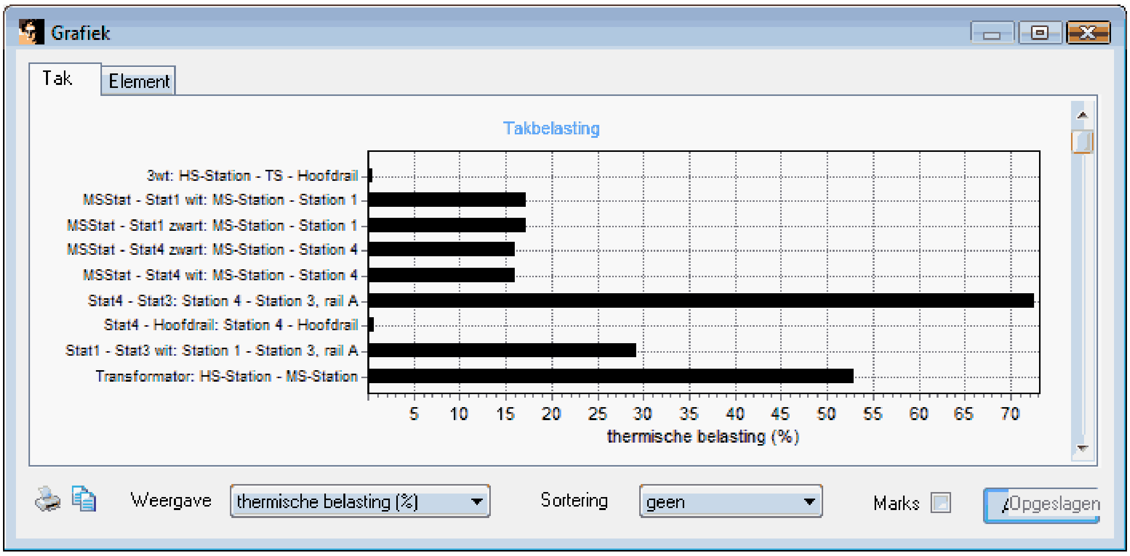


Figure: branch load after a simulation calculation

Results / Detailed graph

- Presents for all short circuited objects (nodes/cables/elements) the simulated course of the short circuit current (I_k") on the fault location as function of elapsed time. This graphic presentation corresponds with the results of the short circuited objects, presented with **Results | Details | Details**.
- Presents no results for currents in branches that feed into the short circuit.

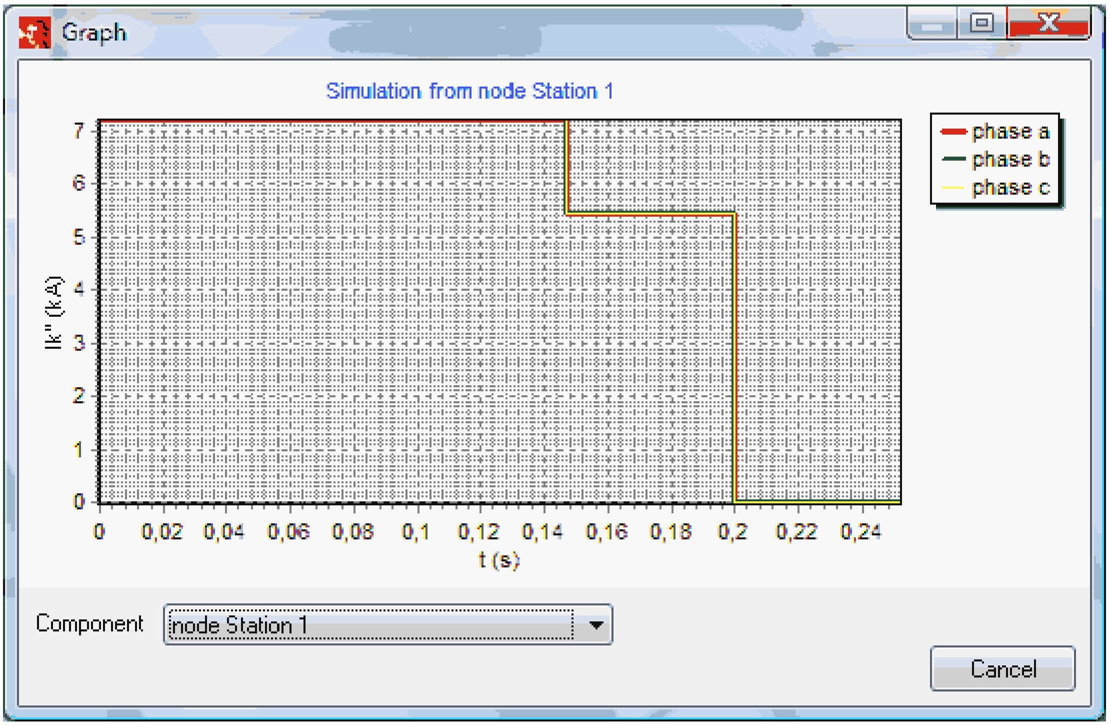
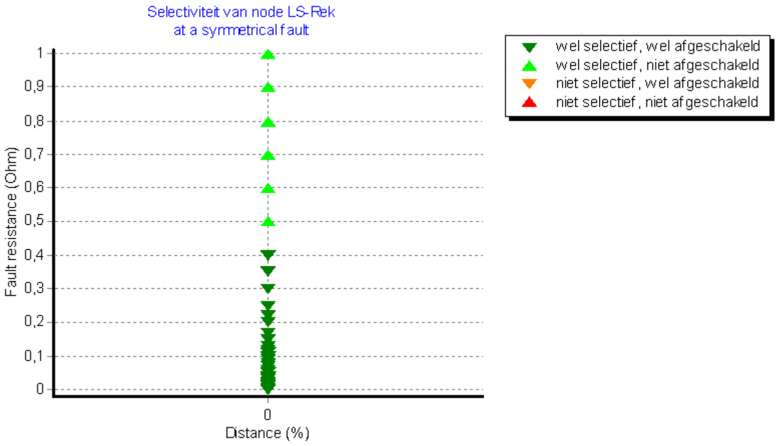


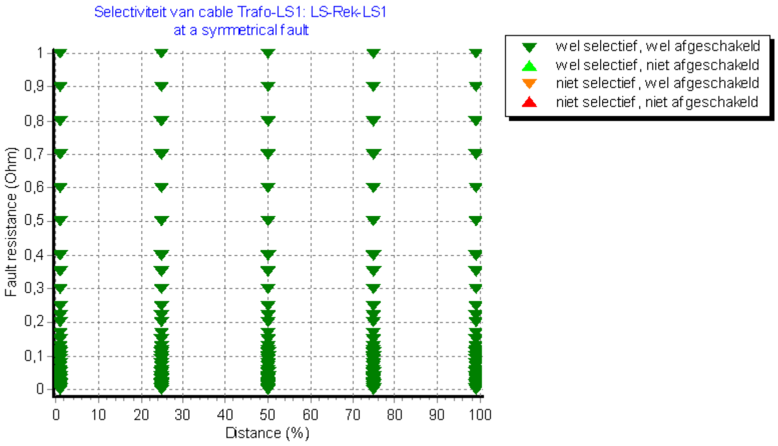
Figure: short circuit current as a function of elapsed time after a simulation calculation

Selectivity calculation
The selectivity calculation is performed for a range of short circuit currents, obtained by varying the fault impedance. The fault impedance range can be defined in th***Options*** , at: **Calculation | Protection**. After a selectivity calculation, for all short circuited objects (node/cable/line) the switch off times as function of the short-circuit currents on the fault location are presented.

Nodes and branches are presented in the too high colour if the protection is not selective.
Fuses and circuit breakers are presented in th***Attention*** colour if they switch off unwanted for any combination of fault location and fault resistance.
The colours can be defined in th***Options*** , at **Calculation | General**.

Detailed results | graph
The protection selectivity of an object can be presented in a graph, summarising selectivity and whether a fault will be switched off or not. If in th***Options*** has been specified to calculate the selectivity over a range of fault resistances, this function allows the user to see up to what fault resistance an object is properly protected (selectively and correctly switched off). In the next example, the node is selectively protected, but a short-circuit with a fault impedance larger than 0.4 Ohm will not be switched off. All short-circuits in the cable will be switched off.





Results | Graph

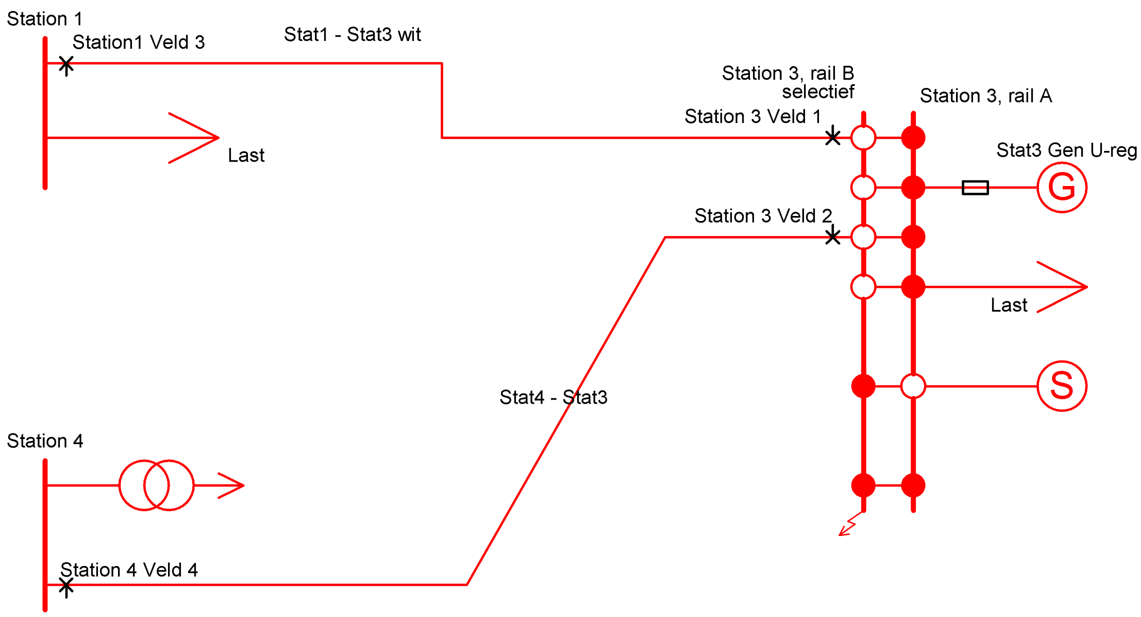
- Presents no information after a selectivity calculation

Details | Graph

Presents per short circuited object the results for the intended or real switch off sequences:

- ***intended switch off*** : intended switch off times for all breakers whose protections have triggered
- ***real switch off*** : switch off times of actually opened switches or blown fuses. The times for the largest short circuit current in this graph match with the result of a simulation calculation, presented with **Results | Details | Details**.

The following figures illustrate the differences between presentation of the intended and real switch off times in a meshed network. As example the demonstration network "demo.vnf" has been used to examine the selectivity for a fault on node "Station 3, rail B". In the ***Options*** , at **Calculation | Protection**, the fault impedance has been defined in the range from 0 to 10 Ohm.The selectivity will be examined for each fault impedance. According to the graph below, the protection of fault will be selective if only the switches in the lines "Stat1-Stat3 wit" and "Stat4-Stat3" will be opened. Eventually the generator may be switched off.



The first figure (*intended switch off*) shows that many protections have detected the short circuit and will pick up. The curves of the protections that might selectively switch off the short-circuit current have a square symbol marker. The curves of the protections that will not selectively switch off the short-circuit current have a triangle symbol marker.

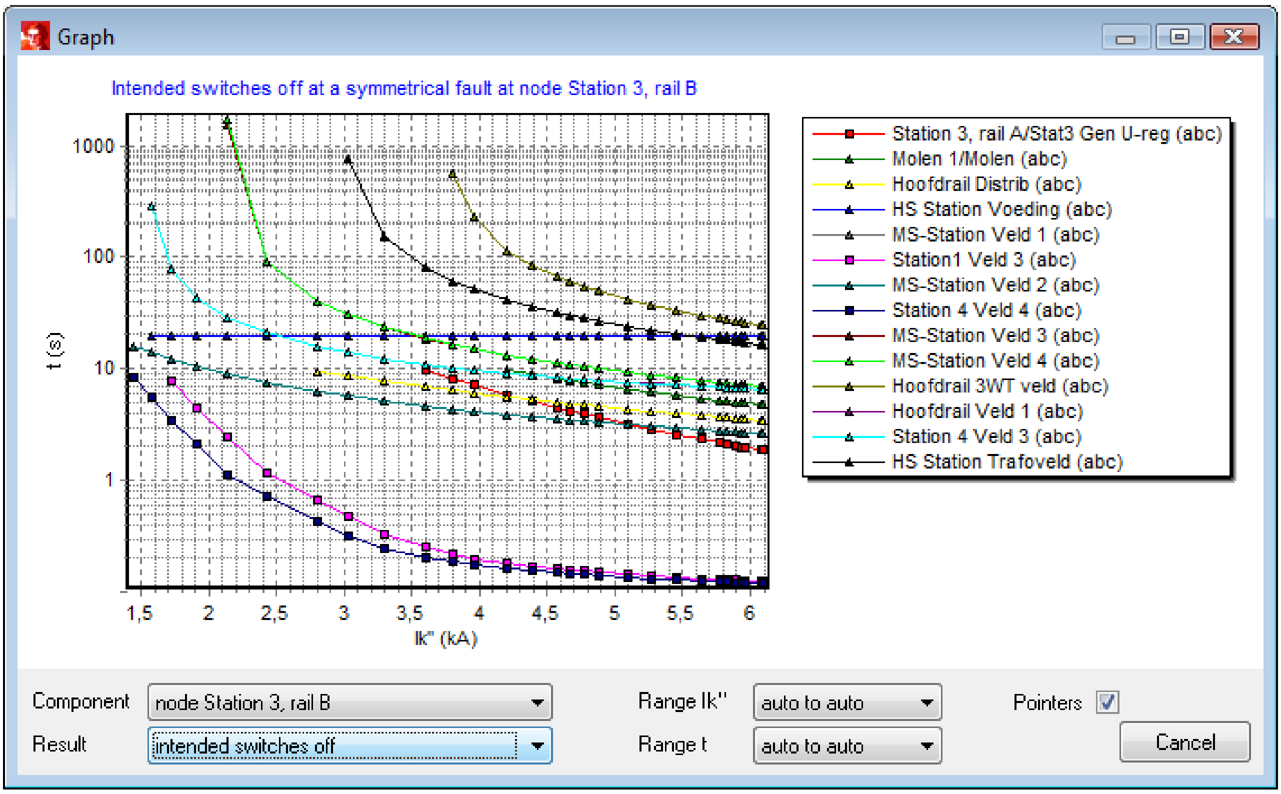


Figure: selectivity graduation of switch off times before a switch opening

The second figure (*real switch off*) shows that the short-circuit on the selected node for the defined range of fault impedances is protected selectively. Only the switches in the mentioned lines and the generator protection will switch off.

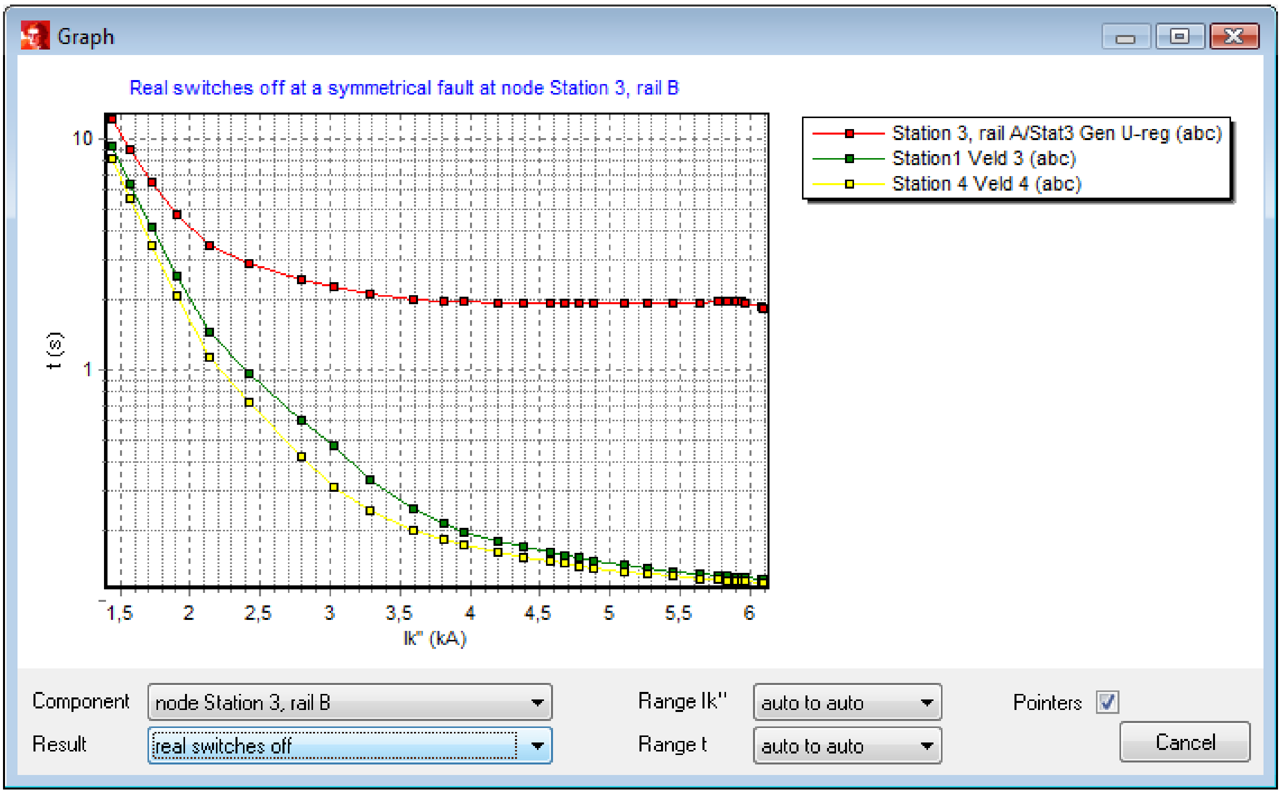


Figure: switch off times

Save
With **Results | Save** the results of a calculation can be saved to compare with another calculation result in **Results | Graph**..

Export
Almost all calculated results can be exported to Excel. In fact, the export is a fixed format report of all objects on three sheets: nodes, branches and elements.

6.9.4 Protection analysis

This function analyses the protection settings, in combination with the possible refusal of operation. The function simulates many short-circuits, of different type and arc resistance, on several locations in the network.
The failure frequency is used to establish the rates of failing objects.
The analysis aims on the primary results for each fault.
During the sequence of events the module analyses:

- switching protections (location and time)
- thermic load of branches (I^2t)
- branch currents after the simulation

The module reports unwanted events, like:

- incorrectly switching protections
- failing protections
- protections switching too late
- sustaining short circuit current after events
- non-available nodes after events
- thermic overload before, during and after the events
- branch overload after the events

6.9.4.1 General

To perform a Security Analysis, the grid must meet a number of preconditions:

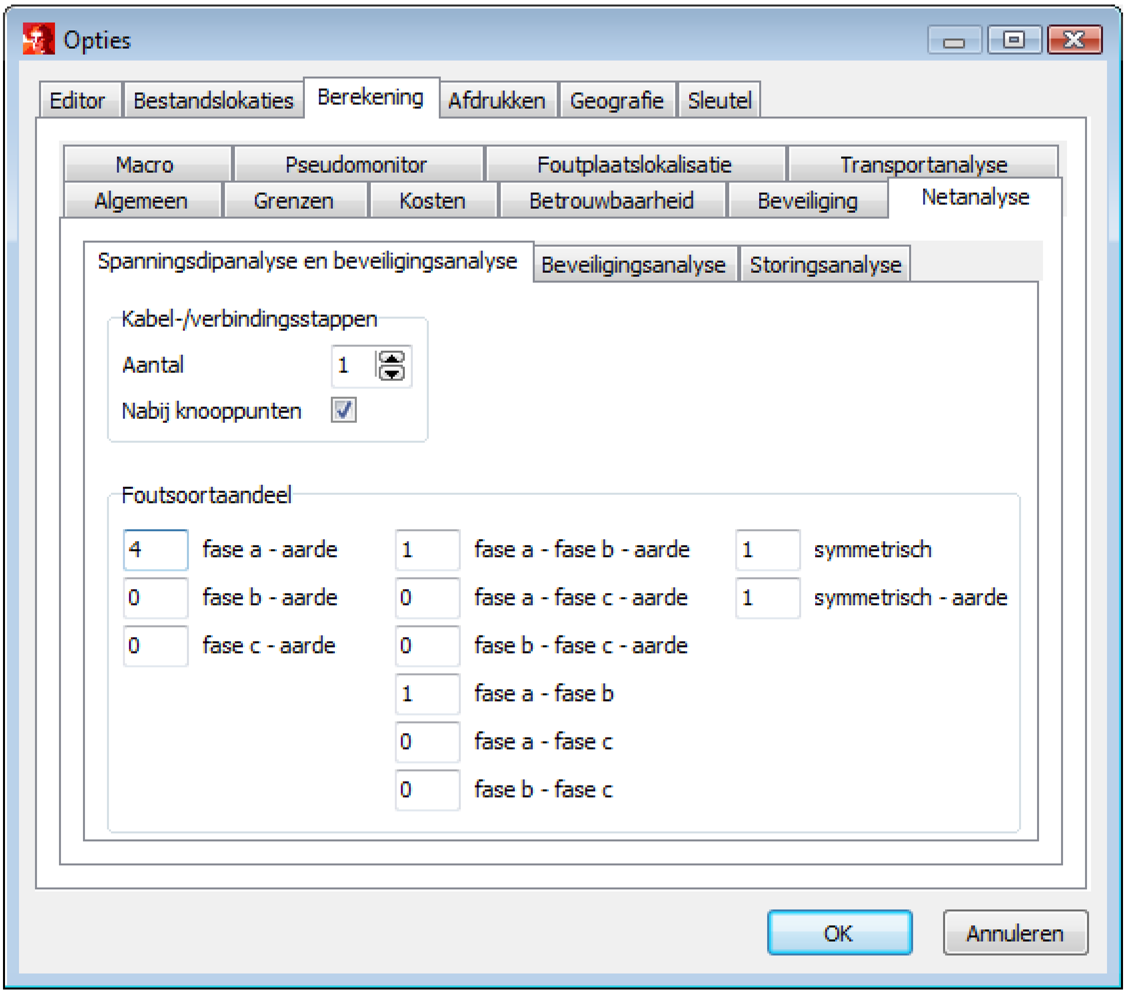
- the grid must have a correct load flow
- the grid must be protected
- all protection devices must be specified
- circuit breakers must be equipped with the probability of refusal, if applicable
- nodes, cables and connections should preferably feature the failure frequency.

Short circuits are simulated on all selected nodes, cables and connections. The failure frequency of those objects determines how often they occur on an annual basis. The function simulates short-circuits of different kinds and with different arc resistance.

The calculation can take a while. A timeline shows the progress.
The calculation is started with: **Calculate | Protection | Analysis**.
The calculation is performed for all selected nodes, cables and connections.

Options
In the *Options* (**Calculation | Network Analysis | General**), it must be defined at how many points in the cables and connections a short circuit is to be simulated. By default, the *Number of cable/connection calculation steps* is zero. The maximum is 9. An option is included to also simulate a short circuit in the cable or connection near the nodes, at 1% and 99% of the length respectively.

The *Error Rate* should also be specified. This is a series of numbers that the user uses to indicate the weighting for the fault type against all possible short-circuits, summed in the failure frequencies. The example below shows that a single-phase earth fault is twice as common as a two-phase earth fault and a symmetrical fault. This means that for a user-specified failure rate of 0.02 /km/year for a cable, the failure rate for a single-phase earth fault equals 0.01 /km/year and for a two-phase earth fault and a symmetrical fault equals 0.005 /km/year.



An option, on the **Security Analysis** tab, concerns values for the resistance at the fault location. Optionally, 0 Ohm and two additional resistance values.
The second additional value is not used with cables. This second additional value is doubled in the calculation of single-phase faults.

An option, on the **Protection Analysis** tab, concerns the level of sequentially refusing protections (0, 1 or 2):

- refusal level 0: analysis of refusing switches is not performed
- Refuse level 1: analysis is performed for only one refusing switch
- refusal level 2: analysis is performed for two sequentially refusing switches

6.9.4.2 Calculation

The function simulates many short circuits, for different locations, types and with different arc resistance. A number of parameters can be specified in the ***Options*** , via **Calculation | Grid Analysis** on the ***Voltage Dip Analysis and Protection Analysis*** and ***Protection Analysis*** tabs . The parameters are:

- Location: at selected nodes and in selected cables/connections (to be set via ***Number of cable/connection steps***)
- Type: single-phase, two-phase, three-phase (to be set via Number of ***faults***)
- Bow resistance: 0 Ohm and two additional (second additional not for cables)
- Sequential reject: 1 or 2 levels (set via ***Reject level***)

The analysis focuses on the primary results per fault. During the shutdown sequence it looks at:

- Which protections switch off at what time

- Thermal load of branches (I^2t)
- Current of branches after completion

The function simulates short-circuits on ***Fault Objects*** , such as nodes, connections and cables and reports on undesired events, such as:
- Wrongly tripping protections
- Not tripping protections
- Late tripping protections
- Remaining (persistent) fault current after switching off
- Unavailable nodes after switching off
- Thermal overload before, during and after switching off
- Current overload after switching off

Reported by fault over:
- Causes: undesirable events in the grid (unavailable nodes, thermal overload, current overload, unjustified, not or late tripping of protective devices or residual fault current), related to short-circuits on the ***Fault object***
- Consequences: undesired events on the ***Consequence object*** (unavailable nodes, thermal overload or current overload), due to short circuits on nodes or cables/connections in the grid.

If the results are viewed by right-clicking on an object, that object is the ***Fault object*** in the lists of Items and Causes and the object is the ***Consequence object*** in the list of Consequences.

6.9.4.3 Result

The results are presented in tabular form via the ***Details*** " button in the detail results form of nodes and cables/connections.
The results can also be exported to Excel.

The security analysis reports on ***undesired events*** , such as:
- Wrongly disabling protections
- Not disabling protections
- Late disabling protections
- Remaining (persistent) fault current after disabling
- Unavailable nodes after tripping
- Thermal overload during and after switching off
- Current overload after switching off

Reported by fault over:
- ***Causes*** : undesirable events on the grid (unavailable nodes, thermal overload, current overload, unjustified, not or late tripping of protective devices or residual fault current), related to short circuits on the ***Fault Object***
- ***Consequences*** : undesired events on the ***Consequence Object*** (unavailable nodes, thermal overload or current overload), due to short circuits on nodes or cables/connections in the grid.

If the results are viewed by right-clicking on an object, that object is the ***Fault object*** in the Causes list and the object is the ***Consequence object*** in the Consequences list.

Details of all causes and consequences are reported on:
- Frequency (per year)
- Consequence (causes, effects): undesired event
- Fault object: the disturbed object causing the unwanted event
- Distance (%): simulated fault distance in the Fault Object (if cable or connection)
- Type: simulated short circuit
- R (Ohm): fault resistance of the simulated short circuit
- n: number of rejected protections
- Refusal1: first instance refusing protection

- Refusal2: second instance refusal protection

Colour indication
Nodes, branches and connections are displayed with the colour ***High*** if the number of causes or effects is greater than zero.
The colours can be defined in the ***Options***, under **Calculation | General**.

6.9.5 Protection for Stedin

The function analyses the settings of the fuses, combined with the possible rejection of the fuses. For this function to work properly, all circuit breakers including their protections and fuses must be modelled.

6.9.5.1 General

Short circuits are simulated on all nodes, cables and connections. The function simulates short circuits of different nature and arc resistance.

The calculation is started with: **Calculate | Protection | Stedin | Analysis**.
The calculation is performed for all nodes, cables and connections.

Options
In the ***Options*** (**Calculation | Network Analysis | General**), it must be defined at how many points in cables and connections a short circuit is to be simulated. By default, the ***Number of cable/connection steps*** is zero. The maximum is 9. An option is included to also simulate a short circuit in the cable or connection near the nodes, at 1% and 99% of the length respectively.

The ***Error Rate*** should also be specified. This is a set of numbers that the user uses to specify which fault types are to be calculated. The value of the shares is not important.

One option, on the **Security Analysis** tab, concerns values for the resistance at the fault location. Optionally, 0 Ohm and two additional resistance values.
The second additional value is not used with cables. This second additional value is doubled in the calculation of single-phase faults.

An option, on the **Protection Analysis** tab, concerns the level of sequentially refusing protections (0 or 1):
- refusal level 0: analysis of refusing switches is not performed
- refusal level 1: analysis is performed for one refusing switch

6.9.5.2 Calculation

The function simulates many short circuits, for different locations, types and with different arc resistance. A number of parameters can be specified in ***Options***, via **Calculation | Grid Analysis** on the ***Voltage Dip Analysis and Protection Analysis*** and ***Protection Analysis*** tabs . The parameters are:
- Location: at all nodes and in all cables/connections (to be set via ***Number of cable/connection steps***)
- Type: single-phase, two-phase, three-phase (to be set via Number of ***faults***)
- Bow resistance: 0 Ohm and two additional (second additional not for cables)
- Sequential reject: possibly 1 level (set via ***Reject level***)

The analysis focuses on the primary results per fault. During the shutdown sequence it looks at:
- Which protections switch off at what time
- Thermal load of branches (I^2t)
- Flow of branches after completion

The analysis reports on problems:
- Short circuit not tripped

- Small margin of protection
- No selectivity
- Overload

6.9.5.3 Result

The results are aggregated by object and presented in detail in tabular form via the ***Details*** " button in the detail results form of nodes and cables/connections.
The results can also be exported to Excel.

The calculation reports on seven problems:
- Not switched off
- Margin too small
- Not selective
- Overloaded
- Not switched off, on rejection
- Not selective, on rejection
- Overloaded, on rejection

Details of all short-circuits are reported on:
- Fault distance: simulated fault distance (%) in the fault object (if cable or connection)
- Fault type: simulated short circuit
- Fault resistance: fault resistance (Ohm) of the simulated short circuit
- Refusing: possibly refusing protection
- Not disconnected: whether the short circuit is not completely disconnected
- Margin too small: whether the current through any tripping protection only barely (less than 20 %) exceeds the minimum set current
- Not selective: whether the short circuit is not selectively tripped
- Overloaded: whether any branch is thermally overloaded or current overloaded during or after the short circuit

Colour indication
Nodes, cables and connections are displayed with the colou ***High*** if there is a problem.
The colours can be defined in th ***Options*** , under **Calculation | General**.

6.9.6 Protection for Enexis

This module consists of five components and replaces Enexis' "Setup Plan" programme.

Its main objectives are:
- check the setting of the safeguards
- analyse the operation of the safeguards.

The secondary objectives are:
- test the transmission grid for n-1 reliability
- creating pdf diagrams
- filling adjustment forms.

For proper operation, the network must be modelled with all circuit breakers, including their protections.

6.9.6.1 General

Prior to analysis, loadflows can be performed. A normal load flow and load flows with failure of one transport cable at a time.

Protection settings can be checked against items from the prescribed tactics.

Analysis consists of making short-circuits. Short circuits are simulated at all nodes and in all cables and connections. The function simulates blunt short circuits of various kinds.

Pdf diagrams of the transmission network and distribution directions can be generated.

Setup forms can be generated.

Options

In the **Options (Calculation | Limits)**, normal limits and fault limits must be specified.

In the Options (Calculation | **Grid Analysis | Enexis Security)**, the default number of parallel transmission cables p, the stagger time and the location of the adjustment forms must be specified.

Terminology

Transport

Transport nodes and cables are determined automatically.
A transport cable is a mesh cable.
A transport node is a node that has at least one mesh cable attached to it or an unsecured link to such a node.

Itoe

The$_{Itoe}$ ($_{It\ Allowable}$) is a quantity that Enexis assigns to cables. It is a kind of extended$_{Inom}$.

The$_{Itoe}$ of a distribution cable is the minimum of:

- The$_{Inom}$' of the cable * 1.3
- The$_{Inom}$ of the current measuring transformer * 1.2
- The$_{Inom}$ of the load switch
- The trip current of the fuse / 1.5
- The$_{Inom}$ of the circuit breaker
- The trip current of the current protection device / 1.5 or 1.3 (1.5 for mechanical; 1.3 for electronic)
- The I> of the distancing protection / 1.5 or 1.3 (1.5 for mechanical; 1.3 for electronic)

The$_{Itoe}$ of a transport cable is the minimum of:

- The smallest$_{Inom}$' * pf of the cable sections * 1.45 * 1.07
- The$_{Inom}$ of the current measuring transformer * 1.2
- The$_{Inom}$ of the load switch
- The trip current of the fuse / 1.5
- The$_{Inom}$ of the circuit breaker
- The trip current of the current protection device / 1.5 or 1.3 (1.5 for mechanical; 1.3 for electronic)
- The I> of the distancing protection / 1.5 or 1.3 (1.5 for mechanical; 1.3 for electronic)

pf is a factor based on p from the options and the cable type (GPLK or XLPLE (actually non-GPLK)).
For GLPK, pf(p) is 1.00; 0.80; 0.66; 0.62; 0.58; 0.55; 0.54; 0.52; 0.51; 0.49.
For XPLE, pf(p) is 1.00; 0.84; 0.74; 0.69; 0.65; 0.61; 0.59; 0.57; 0.55; 0.53.

A mechanical relay is a relay with one of the following texts in its type name or short type name:
SD14, SD34, LI41, ISM, MU1, BMA311, WIpx, HK, HB, MWD, BMA, RACID, RACIF, R3A or OT87.

6.9.6.2 Loadflow

The calculation is started with: **Calculate | Security | Enexis | Loadflow**.
In the calculation settings form, the scaling percentages for load and generation can be specified.

First, a normal loadflow is performed. The voltages of nodes and currents of branches and switches are tested at normal limits. Already tripped protections are signalled.

Successively, one by one, all transport cables (mains cables) are switched off and a load flow is performed. Voltages and currents are tested for fault limits. Already tripped protection devices are signalled.

The load flow calculates:

- in normal situation: voltages and currents and tripped protective devices
- in fault conditions: voltages and currents and tripping protections

RESULTS

Network
After running the load flows, results are displayed as text in the diagram.

For nodes, the results are:

- The normal voltage
- The minimum and maximum voltage, across all n-1 situations

For branches, the results are:

- The $_{Itoe}$ (for cable only)
- The normal current and associated load degrees in relation to $_{Inom}$ and $_{Itoe}$
- The maximum current over all n-1 situations and the corresponding load degrees in relation to $_{Inom}$ and $_{Itoe}$

Colour indication
Nodes, branches and switches are displayed in colour when voltage and load limits are exceeded. A distinction is made between limits for a "normal situation" and limits for a "fault situation". Limits for a normal situation are closer to nominal values than limits for a fault situation. Limits **are defined** in the ***Options*** , under **Calculation | Limits**.
Load limits for connections and transformers can be defined separately.

The corresponding colour indications can be defined in the four levels ***higher, high, low*** and ***lower*** . Colour selection takes place in the ***Options*** , at **Calculation | General**.

Object	**Boundary**	**Situation**	**Colour indication**
Junction	U > Umax	N-1 situation	High
Node	U > Umax	Normal situation	Higher
Node	U < Umin	Normal situation	Lower
Node	U < Umin	N-1 situation	Low
Node	In island at n-1	N-1 situation	Warning
Branch	Load degree > Bmax	N-1 situation	High
Branch	Load factor > Bmax	Normal situation	Higher
Switch and protection	Load degree > 100	Normal situation	Higher
Switch and protection	Load rating > 100	N-1 situation	High
Protection	Switches off	Normal situation	Higher
Security	Switching off	N-1 situation	High

General
Calculate | Results | Overview displays a list of problem objects:
- Node with over- or undervoltage
- Node becoming de-energised
- Branch with overload
- Switch with overload
- Circuit breaker already tripped

Details
Calculate | Results | Details (or right-click on an object in result mode) displays detailed information of selected nodes, branches and protections in a form.

The results displayed for a node are:
- The normal voltage
- How many times the node is de-energised, across all n-1 situations
- The maximum voltage and at which n-1 situation
- The minimum voltage and at which n-1 situation

The results shown for a branch are:
- $_{Itoe}$ (only for cable)
- The normal current
- The normal load degree in relation to$_{Inom}$
- The normal load degree in relation to$_{Itoe}$
- The maximum current
- The maximum load degree in relation to$_{Inom}$
- The maximum load degree in relation to$_{Itoe}$
- At which n-1 situation

The results shown at a secondary are:
- The normal voltage
- The normal current
- The normal load degree
- Whether the protection already trips normally
- The maximum current
- The maximum load degree
- Whether the protection already trips in any n-1 situation

Graph
With **Calculate | Results | Graph** the results can be viewed as a bar graph.
For nodes the stress band Umin...Umax.
For branches the load degree band normal...max.

Export
The results can be exported to Excel using **Calculate | Results | Export**. The export is a report of all objects, in a fixed format, on three worksheets: Nodes, Branches and Switches and Safeguards.

6.9.6.3 Tactics

The presence and settings of safeguards are checked with: **Calculate | Security | Enexis | Tactics**.

Security settings
Anomalous protection settings are detected first.

Safeguards in transformers, transport cables and descending distribution cables must be set according to the prescribed tactics. If a deviation is detected, the protection is reported, with the current setting and the prescribed setting.
What is tested?

- Fuse protection and first current protection in a transformer or transformer load
- First earth fault protection in a transport cable
- First current protection and first earth fault protection in a distribution cable
- First steam fuses/distribution fuses at either end of a transmission cable

Missing protections
Missing protections are reported second.

- A transformer must include a safeguard
- A transport cable or descending distribution cable must contain a fuse

A protection here is a fuse, current protection, differential protection or distancing protection.

Staffing
Thirdly, staffing faults in the distribution network are detected.
Relative to a sure protection, a preceding protection must be set at various currents with a larger time.
'Miscellaneous' currents run up to a maximum of 40 kA for symmetrical short-circuits and up to a maximum of 3000 A or 1000 A for single-phase short-circuits in an earthed or non-earthed network, respectively.
Fuses, current protections, distance protections and earth fault protections are considered.
If there is a deviation, the fuse and preceding fuse are reported.

Adjustability
Fourth, the adjustability of protective devices is tested.
In case of an error, the guard and its settings are reported, as well as the minimum and maximum adjustable values or the nearby adjustable values.

Intermediate protections
Fifth, intermediate protections are tested.
More than one sequential intermediate protection in a line is reported.

Last protections without I>>
Sixth, last first current protections without I>> are reported.
In such a case, this stage could be set.

Differential protections with different measuring transformers
Seventh, differential protections with anomalous measurement transformers are detected.
This concerns the$_{\text{Inom}}$ of current measurement transformers.
A 7SD610 may have different$_{\text{Inom}}$ and never causes a report.
For an MBCI and a DL91, the primary sides must be the same.
For a DL4, the primary and secondary sides must be equal.
For a 7SD503, a 7SD74 and an RN25b, the primary sides must be equal in principle, but a discrepancy states that this is possible when using an intermediate current transformer.

Available but not set earth fault protections
Eighth, unset but available earth fault protections are reported.
These are non-set first earth fault protection, where the first current protection is set.

The also common check for cables with an$_{\text{Inom}}$ greater than 1500 A and cables with a length less than 10 m are part of the general network check in Vision, to be carried out via Prepare 80.

6.9.6.4 Analysis

If necessary, select a number of objects.
Start the calculation with: **Calculate | Security | Enexis | Analysis**.

In the calculation settings form, the scaling percentages for load and generation can be specified. Also whether the analysis should be performed on the selected objects or on all objects. Fault types and having circuit breakers rejected can also be set here.

The analysis simulates many blunt short circuits, at (selected) nodes and in (selected) cables, with different fault types.
For cables, the short-circuits are basically made every 100 metres. For short cables, however, five locations are tested. For long cables, 40 locations are used.

During the tripping sequence, consideration is given to:
- Which protections switch off at what time
- Thermal load of branches and switches (I^2t)
- Current in branches and switches afterwards

The analysis calculates per short circuit:
- Short circuit not tripped
- Short circuit not selectively tripped
- Power switches tripped
- Contact factors of the protections (I / I>)
- Overloaded branches
- Overloaded switches
- Unavailable transport nodes and number of unavailable distribution nodes

RESULTS

Network
After performing the analysis, results are displayed as text in the diagram.

For nodes and cables, the results are:
- Number of times (or length) not disconnected
- Number of times (or length) not selective
- Number of times overloaded by a short circuit (somewhere else)

Colour indication
Nodes and branches are displayed in colour when problems occur.
Colour selection takes place in th***Options*** , under **Calculation | General**.

Cause object	**Problem**	**Colour indication**
Node or cable	Not selective	High
Node or cable	Not selective	Higher

Impact object	**Problem**	**Colour indication**
Cable or switch	Overloaded	Warning

General
Calculate | Results | Overview provides an overview of nodes and cables that have a protection problem. This is:
- not switched off
- not selective
- causes overloading

Details
With **Calculate | Results | Details** (or right-clicking on an object in result mode), information of selected nodes and cables is displayed in a form.

The "**Details**" button displays the protection items in a table.
One line per short circuit.
The results per short circuit are:

- The fault distance (only for cable)
- The fault type
- Possibly which circuit breaker refuses
- Whether the short circuit is not tripped
- Whether the disconnection is not selective
- The switches that actually disconnect
- The response factors of the circuit breakers that actually trip
- The thermally and/or current-overloaded branches
- The thermally and/or current-overloaded switches
- The unavailable transport nodes
- The number of unavailable distribution nodes

Right-click anywhere to turn on the filter via the popup menu and then set the filter.

Export
The results can be exported to Excel using **Calculate | Results | Export**. The export is a report of all short circuits in objects, in a fixed format, on two worksheets: Nodes and Cables.

6.9.6.5 Scheme

Schedule generation is started with: **Calculate | Security | Enexis | Schematic**.
The presence of a pdf printer is necessary. This is a printer with 'pdf' in its name.
The name of the pdf file to be generated is requested.

The first sheet contains the transport node.
The following sheets contain one transport node or transport station and the distribution network behind it, transformed into a waterfall diagram.
A node behind an open switch may be drawn several times.

For now, the text shown is fixed and based on a view with:

- Node: name, short name and blades
- Branch: name, fields, cable length and$_{\text{Itoe}}$
- Element: type name
- Switch and security: type name and long setting

Some text positions are automatically adjusted:

- branch (fields): on the outside of a vertical rail
- switch: above a horizontal cable
- measurement field: below a horizontal cable

All text sizes (except of a link) are set to 30.

An IEC-60909 calculation is performed automatically beforehand.
This allows single-phase and three-phase short-circuit currents to be put at the ends of routes in the diagram.
Ik,3f in kA. Ik,1f in A.

6.9.6.6 Form

In the **Options**, the folder of the empty adjustment forms and the output folder of the generated forms can be specified.
Select the circuit breakers from which an adjustment form is to be created.
Start the generation with: **Calculate | Security | Enexis | Form**.
Afterwards, a list of the generated adjustment forms is displayed.

The name of a generated setup form is derived from the location and type of security.
It is: node.shortname + _ + field + _XX_ + type.name + _ + node.name + _ + branch.name.
For the different protection types, XX is replaced by:

- M for a fixed-time current protection device (OMT)
- SRR for a forward current protection with fixed time
- DS for a distance protection
- DF for a differential protection

6.10 Voltage dip analysis

Voltage dip analysis is a function for the calculation of voltage dips, caused by short circuits at all possible locations in that network. This function combines reliability analysis, short-circuit calculations and protection calculations. The result is a statistical overview of the voltage quality.

6.10.1 General

Apart from the sudden increase of load currents and transients, voltage drops particularly result from short-circuits in the electricity network. The deepest break-downs are caused by 2- and 3-phase short-circuits, which may cause the line-to-line voltage to drop down to 0 %.

Voltage drops are transferred by the faulted network through the transformers into all following nets. E.g. one short-circuit in the medium voltage network induces voltage dips in all connected low-voltage systems. The lower the voltage level, the more frequently voltage drops occur, since the fault frequency in the network is higher and dips from higher voltage networks are transferred to all connected lower voltage systems.

For the duration of the voltage drops the protection devices are of crucial influence. Voltage dips can lead to malfunctions of connected devices. Thereby, computer systems and electric drives are particularly endangered.

By means of fault statistics and short-circuit current calculation, for every point in the network its statistically expected frequency of voltage dips can be calculated in both dip depth and duration. The fault statistics thereby determines the frequency, the short-circuit calculation the depth and the protection device in the network the theoretical duration of the voltage dips.

The voltage dips are categorised as follows:

- nine voltage categories in steps of 10%
- nine duration categories:
  - < 20 ms
  - 20 ... 100 ms
  - 100 ... 300 ms
  - 300 ... 500 ms
  - 0.5 ... 1 s
  - 1 ... 2 s
  - 2 ... 5 s
  - 5 ... 10 s
  - > 10 s

6.10.2 Calculation

Before a network analysis can be carried out, the distribution network has to comply to a number of conditions:

- the network must have a sound load flow
- the network must be well protected against all possible short-circuits
- all protections must be correctly set
- all nodes (and possibly cables and connections) must be provided with failure frequency data

The procedure simulates short circuits on all selected nodes, cables and connections. Their failure frequency determines the yearly occurrence rate. Following each short-circuit, the voltage dips in the whole network are calculated. The protection action determines the duration of each corresponding voltage dip.

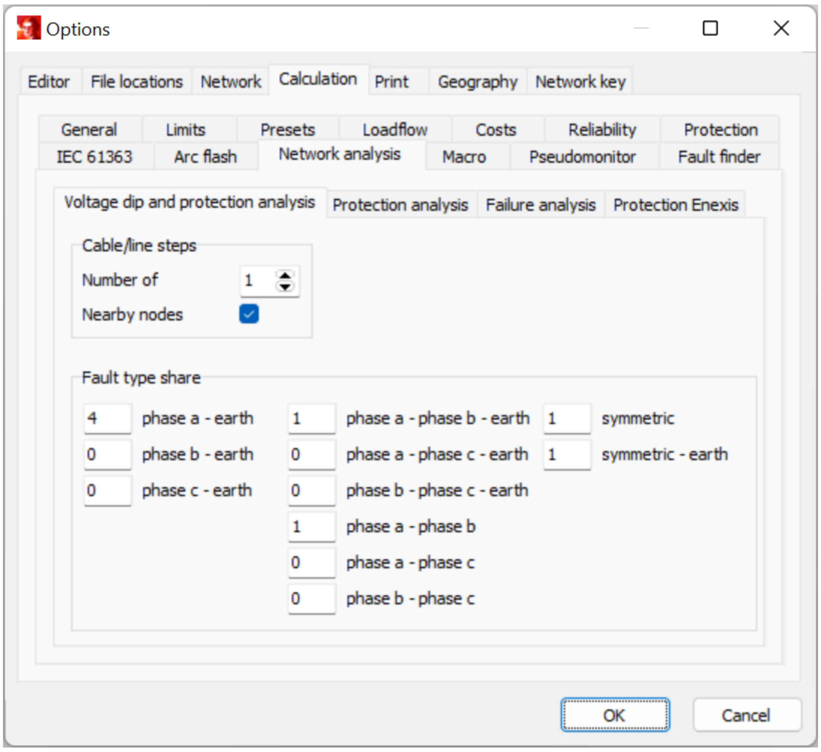
Start the calculation using: **Calculations | Voltage dip analysis**.

The calculation may take some time, depending on the network size and the number of short-circuits in branches.

Options
The network analysis options (**Application menu | Options | Calculation | Network analysis | Voltage dip analysis and protection analysis**) define two options.

Number of cable calculation steps
The number of cable calculation steps determines how many short-circuits have to be simulated in all cables and connections. Default the number of calculation steps is zero. The maximum is 9. An option has been added to simulate short-circuits close to the from and to nodes (1% and 99% of distance).

Fault type share
The fault type share is a range of numbers, defining the weight of all possible fault types in the failure frequency parameter. Next example defines that a single phase to ground fault occurs twice as much as a two phase to ground fault and as a three phase fault. This means that e.g. for a cable failure frequency of 0.02 /km/year, the frequency of a single phase to ground fault is 0.01 /km/year and for the other two fault types 0.005 /km/year.



6.10.3 Result

The results of a network analysis calculation can be viewed in three ways:

- in the node detail output form: the maximum voltage dip and the maximum dip duration
- extended detail for each node: table with voltage dip frequencies, classified in 9 dip depth categories and 9 dip duration categories
- graphically for each node: circles diagram of voltage dip frequencies, classified in 9 dip depth categories and 9 dip duration categories

Extended detail output form

Next table presents an example of the voltage dip frequencies for one node*Substation* ", classified in 9 dip depth categories and 9 dip duration categories.

Details network analysis

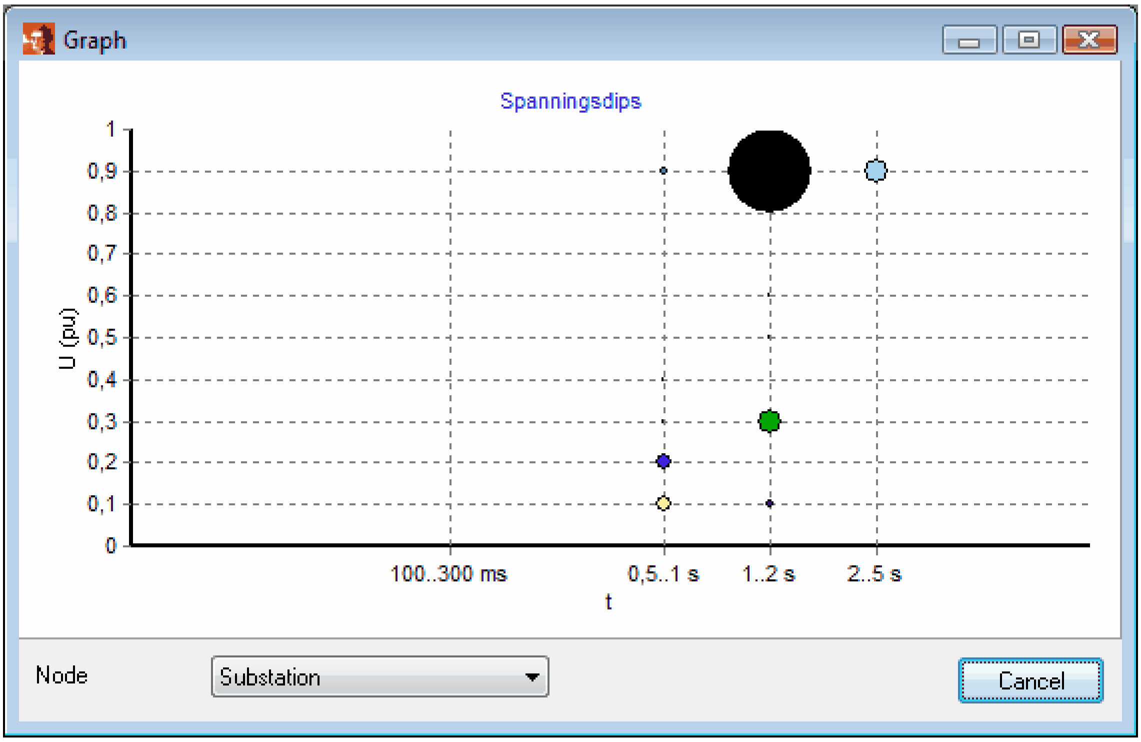
Voltagedip frequency [/year] at node Substation

	< 0,02 s	0,02..0,1 s	0,1..0,3 s	0,3..0,5 s	0,5..1 s	1..2 s	2..5 s	5..10 s	> 10 s
0,8..0,9 pu					0,0756	0,8199	0,2218		
0,7..0,8 pu						0,0007	0,0002		
0,6..0,7 pu									
0,5..0,6 pu						0,0506			
0,4..0,5 pu					0,0089	0,0354			
0,3..0,4 pu					0,0401	0,0082			
0,2..0,3 pu				0,0039	0,0419	0,2363			
0,1..0,2 pu					0,1566	0,0179			
0,01..0,1 pu			0,0010		0,1517	0,0645			

Cancel

Circles diagram

Next graph presents an example of the voltage dip frequencies for one node*Substation* ", classified in 9 dip depth categories and 9 dip duration categories. The circle size represents the frequency.



6.11 Failure analysis

This function analyses the recovery of the delivery of electricity after failures in the network. Requirements concern load of cables, lines and transformers in the new situation after switching. The number of switching actions for protecting, isolating and recovery will be reported. Also the largest cable load and the lowest voltage will be reported. Problems will be reported specifically.

Before the analysis can start, the network should meet the following requirements:
- the network should have a correct load flow
- circuit breakers and fuses should be modelled; no protection data necessary

The module simulates faults on nodes and in branches. The module analyses the events of failing and restoration the delivery of energy. Attention is paid to load, current and voltage.

During the events up to six switching actions for rerouting the electric current will be performed. For the rerouting actions five types of switching points have been defined:
- ***switch-in points*** : open switch in a branch between a faulted and a live network part
- ***coupling points*** : open switch in a branch in the faulted network part
- ***splitting points*** : closed switch in a branch in the live network part
- ***branching point*** : open switch in a branch in the live network, at a short distance from a switch-in point.
- ***junction point*** : closed switch in a branch in the live network, at a short distance from a switch-in point.

6.11.1 General

De functie analyseert het verloop en het herstel van de elektriciteitsvoorziening bij storingen in het net. Daarbij wordt gekeken naar de belastinggraden en spanningen bij het herstel van de levering in de drie fasen: uitschakelen, isoleren+wederinschakelen en omschakelen.

De spannings- en belastinggraadgrenzen kunnen worden gedefinieerd in d***Opties*** , bij **Berekening | Grenzen**.

Alle vermogenschakelaars en smeltveiligheden moeten in het net gemodelleerd zijn. Het is niet nodig beveiligingen van de vermogenschakelaars te specificeren.
De analyse wordt uitgevoerd voor geselecteerde knooppunten en takken. In de analyse worden drie achtereenvolgende fasen onderscheiden:
1. ***Uitschakelen*** : de hele groep wordt uitgeschakeld;
2. ***Isoleren en wederinschakelen*** : alleen het knooppunt wordt uitgeschakeld aan alle kanten of alleen de tak wordt uitgeschakeld aan beide kanten;
3. ***Omschakelen*** : via schakelpunten wordt het niet-beschikbare netdeel weer onder spanning gebracht.

6.11.2 Calculation

Voor het uitvoeren van een Storingsanalyseberekening moet het net aan een twee randvoorwaarden voldoen:
- het net moet een correcte loadflow hebben (zie onder)
- in het net moeten vermogenschakelaars en smeltveiligheden gemodelleerd zijn (beveiligingsgegevens zijn niet nodig)

Aan "losse" knooppunten achter een netdeelgrens wordt tijdens de berekening een onzichtbare netvoeding toegevoegd. Daardoor kan via dit punt vermogen geleverd worden, na omschakelen.
Let op dat het geleverde vermogen onbeperkt is, terwijl dit in werklijkheid niet zo is. De rapportage vermeldt zo'n omschakeling via "geïmporteerd vermogen".

Er worden storingen gesimuleerd in knooppunten en takken. De faalfrequentie van die objecten bepaalt hoe vaak dat op jaarbasis voorkomt. De functie analyseert het verloop en het herstel van de elektriciteitsvoorziening bij storingen in het net. Daarbij wordt onder andere gekeken naar de belastinggraad en de spanning.

Omschakelen

Ten behoeve van het omschakelen worden maximaal zes schakelhandelingen verricht (te definieren in d***Opties***), waarbij ook schakelaars geopend kunnen worden. Hiertoe zijn vijf soorten schakelpunten gedefinieerd:

- ***inschakelpunt*** : open schakelaar in een tak tussen het spanningsloze net en het ongestoorde net;
- ***koppelpunt*** : open schakelaar in een tak in het spanningsloze net;
- ***splitspunt*** : gesloten schakelaar in een tak in het spanningsloze net;
- ***bijkoppelpunt*** : open schakelaar in een tak in het ongestoorde net, op kleine afstand van een inschakelpunt.
- ***bijsplitspunt*** : gesloten schakelaar in een tak in het ongestoorde net, op kleine afstand van een inschakelpunt.

De omschakeling vindt plaats met maximaal zes schakelhandelingen, in de volgende combinaties, zolang nog geen goede oplossing is gevonden:

totaal aantal schakelhandelingen	**aantal inschakelingen**	**aantal koppelingen**	**aantal splitsingen**	**aantal bijkoppelingen**	**aantal bijsplitsingen**
1	1				
2	2				
2	1	1			
2	1		1		
2	1			1	
3	3				
3	2	1			
3	2		1		
3	1	2			
3	1	1	1		
3	1		2		
3	2			1	
3	1	1		1	
3	1		1	1	
3	1			1	1
4	4				
4	3	1			
4	3		1		
4	2	2			
4	2	1	1		
4	2		2		
4	3			1	
4	2	1		1	
4	2		1	1	
4	2			1	1
5	5				
5	4	1			
5	4		1		
5	3	2			
5	3	1	1		
5	3		2		
5	2	2	1		
5	2	1	2		
5	2		3		
5	4			1	
5	3		1	1	
5	3			1	1
5	2	2		1	
5	2	1	1	1	
5	2		2	1	
5	2		1	1	1
6	3		3		

Een combinatie wordt pas berekend als:

- het aantal relevante inschakelpunten kleiner is dan 10 en
- het aantal relevante koppelpunten kleiner is dan 10 en
- het aantal relevante splitspunten kleiner is dan 20.

Het maximale aantal schakelhandelingen kan worden opgegeven in d***Opties*** . In situaties met veel uitval en veel schakelpunten zal de rekentijd kwadratisch toenemen met het maximale aantal schakelhandelingen.

De omschakeloplossing wordt ***goed*** bevonden als:

- het aantal maastakken nul is
- het aantal overbelaste takken nul is en
- het aantal overbelaste schakelaars nul is en
- het aantal eilandknooppunten nul of één (bij storingknooppunt) is en
- het aantal onderspanningen nul is en
- het aantal overspanningen nul is en
- het aantal geschakelde netdeelgrenzen nul is en
- het geïmporteerde vermogen kleiner dan 2 MVA is.

Er is een optie om bij het herstellen tijdens het omschakelen overbelasting toe te staan. Indien aangevinkt, zal overbelasting resulteren in een goede oplossing.
Er is een optie om bij het herstellen tijdens het omschakelen overspanning toe te staan. Indien aangevinkt, zal overspanning resulteren in een goede oplossing.
Er is een optie om bij het herstellen tijdens het omschakelen onderspanning toe te staan. Indien aangevinkt, zal onderspanning resulteren in een goede oplossing.
Er is een optie om bij het herstellen tijdens het omschakelen netdeelgrensschakelen toe te staan. Indien aangevinkt, zal netdeelgrensschakelen resulteren in een goede oplossing.
Er is een optie om bij het herstellen tijdens het behouden van eilandknooppunten niet toe te staan. Indien aangevinkt, wordt het herstellen niet doorgevoerd als er eilandknooppunten overblijven.
Er is een optie om bij het herstellen tijdens het omschakelen de beoordelingsprioriteit van herstel, overbelasting en overspanning/onderspanning te wijzigen. Hiermee kunnen problemen geaccepteerd worden, ten gunst van herstel. Dit resulteert echter niet in een goede oplossing.
Er is een optie om bij het herstellen tijden het omschakelen een maximale rekentijd toe te staan.
Er zijn opties om de criteria voor het kleuren na afloop te kiezen.

Na het omschakelen is er geen extra overbelasting, overspanning en onderspanning gecreëerd, tenzij bovengenoemde opties zijn aangevinkt of beoordelingspriorieit daartoe aanleiding geeft.
Indien nodig zal deelherstel toegepast worden door splitsen.
De volgorde van de schakelhandelingen wordt niet in de berekening meegenomen.
Het ontstaan van mazen wordt wel in de berekening meegenomen. Dit mag niet voorkomen.
Bij het uitschakelen en isoleren en wederinschakelen worden de storingsgrenzen uit de opties gebruikt.
Bij het omschakelen worden optioneel de normale grenzen of de storingsgrenzen uit de opties gebruikt.
Bij de spanningscontrole worden alleen spanningen in aanmerking genomen die meer dan 0,5 % afwijken van de normale spanning.
Bij de takbelastinggraadcontrole worden alleen belastinggraden in aanmerking genomen die meer dan 2 % groter zijn dan de normale belastinggraad en waar de stroom bovendien 5 A groter is dan de normale stroom
Bij de secundairbelastinggraadcontrole worden alleen belastinggraden in aanmerking genomen die meer dan 5 % groter zijn dan de normale belastinggraad en waar de stroom bovendien 10 A groter is dan de normale stroom

Uitvoeren berekening
De berekening wordt gestart met: **Berekenen | Storingsanalyse**.
Zet de percentages voor opwekking en belasting.
De berekening wordt uitgevoerd voor alle geselecteerde knooppunten en takken.

6.11.3 Result

Een samenvatting van de resultaten wordt gepresenteerd in het detail-resultatenform. Een uitgebreide presentatie van de resultaten wordt gepresenteerd via de ***Detail*** -button van het detail-resultatenform.
De resultaten kunnen ook in tabelvorm worden gepresenteerd door de resultaten te exporteren naar Excel met behulp van: **Berekenen | Resultaten | Exporteren**.

De resultaten hebben betrekking op niet-beschikbaarheid, overbelasting en spanning. De meeste resultaten zijn gespecificeerd voor de achtereenvolgende acties ***Uitschakelen***, ***Isoleren en wederinschakelen*** en ***Omschakelen***. De resultaten zijn:

- ***Belastinggraad***: belastinggraad in normale situatie

- ***Spanning*** : spanning in de normale situatie
- ***Frequentie*** : frequentie waarmee een storing optreedt
- ***Groep*** : willekeurig toegewezen groepnummer
- ***# Schakelaars*** : het aantal vermogenschakelaars plus smeltveiligheden dat nodig is om de groep uit te schakelen
- ***# Niet-beschikbare knooppunten*** : het aantal knooppunten dat spanningsloos is
- ***# Niet-beschikbare grootverbruikers*** : het aantal grootverbruikers dat via (transformator)belastingen is aangesloten op niet-beschikbare knooppunten
- ***# Niet-beschikbare royaalverbruikers*** : het aantal royaalverbruikers dat via (transformator)belastingen is aangesloten op niet-beschikbare knooppunten
- ***# Niet-beschikbare kleinverbruikers*** : het aantal kleinverbruikers dat via (transformator)belastingen is aangesloten op niet-beschikbare knooppunten
- ***Niet-beschikbare verbruik*** : het gesommeerde vermogen van (transformator)belastingen die zijn aangesloten op niet-beschikbare knooppunten
- ***# Stijgende takbelastinggraden*** : het aantal takken dat minstens 2 % meer belastinggraad en minstens 5 A meer stroom heeft dan in normale situatie
- ***# Overbelaste takken*** : het aantal takken dat overbelast is (uit de takken met gestegen belastinggraad)
- ***# Stijgende secundairbelastinggraden*** : het aantal schakelaars dat minstens 5 % meer belastinggraad en minstens 10 A meer stroom heeft dan in normale situatie
- ***# Overbelaste secundairen*** : het aantal secundairen dat overbelast is (uit de secundairen met gestegen belastinggraad)
- ***Zwakste tak*** : de tak die het meest belast is (uit de takken met gestegen belastinggraad)
- ***Zwakste-tak-stroom*** : de stroom door de tak die het meest belast is (uit de takken met gestegen belastinggraad)
- ***Zwakste-tak-belastinggraad*** : de belasting van de tak die het meest belast is (uit de takken met gestegen belastinggraad)
- ***# Mogelijke inschakelpunten***
- ***# Mogelijke koppelpunten***
- ***# Mogelijke splitspunten***
- ***# Mogelijke bijkoppelpunten***
- ***# Mogelijke bijsplitspunten***
- ***# Ingeschakelde inschakelpunten***
- ***# Ingeschakelde koppelpunten***
- ***# Uitgeschakelde splitspunten***
- ***# Ingeschakelde bijkoppelpunten***
- ***# Uitgeschakelde bijsplitspunten***
- ***# Waarvan ingeschakelde netdeelgrenzen***
- ***# Maastakken***
- ***Geïmporteerd vermogen:*** het vermogen dat via fictieve netvoedingen achter netdeelgrenzen komt
- ***# Onderspanningsknooppunten***
- ***# Overspanningsknooppunten***
- ***Laagste spanning*** : de laagste spanning op een MS-knooppunt (uit de knooppunten met minstens 0,5 % spanningsdaling)
- ***Hoogste spanning*** : de hoogste spanning op een MS-knooppunt (uit de knooppunten met minstens 0,5 % spanningsstijging)
- ***Geschakelde punten*** : de schakelpunten die gesloten/geopend zijn.

Kleurenindicatie

Een object dat niet goed omgeschakeld kan worden, wordt getekend in de kleu***Eiland*** .
Een object dat onderspanning veroorzaakt, wordt getekend in de kleu***Te laag*** .
Een object dat overbelasting of overspanning veroorzaakt, wordt getekend in de kleu***Te hoog.***
Een tak die normaal al overbelast is of een knooppunt dat normaal al overspanning heeft, wordt na de analyse getekend in de kleu***Veel te hoog*** .

Een knooppunt dat normaal al onderspanning heeft, wordt na de analyse getekend in de kleur ***Veel te laag***.
Een tak die tijdens het omschakelen geschakeld moet worden, wordt na de analyse getekend in de kleur ***Attentie***, als de analyse voor één object is uitgevoerd.
De kleuren worden gedefinieerd in de ***Opties***, bij **Berekening | Algemeen**.
De kleuring kan beïnvloed worden in de storingsanalyse-opties.

6.12 Normal Open Point optimization

6.12.1 General

The normal open point optimization module calculates alternatives for the location of the normal open point in a feeder. The procedure starts from a cable with a Normal Open Point at one side. Alternative locations for the normal open point are evaluated. All the possible branches in the same feeders are evaluated until a node with 4 or more connected branches has been encountered or after six cables have been evaluated.

The objective of the normal open point optimisation is to minimise the power loss.
The constraints on the voltage level and current loading are taken into account.
The optimisation will be performed for all Normal Open Points within the network.

6.12.2 Calculation

No settings are required to perform this calculation.
The calculation is performed for the four predefined load situations: night, morning, afternoon and evening. Because these four take the same length of time, the average loss can be calculated afterwards by averaging over the loss over these four moments.
The calculation starts with calculating the grid loss of the initial situation. Subsequently, all grid openings are examined successively. For each of them it is individually checked, whether an alternative grid opening leads to a lower loss. The current normal open point is closed and the adjacent cables are terminated in both directions, each time a switch is opened the losses are calculated. This process stops at a node with four or more branches on it or after six cables sections have been evaluated.

6.12.3 Results

A cable with a suggested closure of a switch will be presented in the one-line diagram with the ***High***-colour.
A cable with a suggested opening of a switch will be presented in the one-line diagram with the ***Lower***-colour.
Alternatives will be presented with the ***Low***-colour.
The ***High***- and ***Low***-colours are defined in the ***Options***, at **Calculation | General**.

Results | Survey presents the results in a table, containing suggested openings and closures and their resulting power losses reductions.

Results | Graph presents the loss reductions of all suggested alternatives.

If no alternatives are suggested, no results will be presented.

6.13 Pseudomonitor

To make good use of the transport capacity of cables and transformers in MS distribution networks, insight into the actual loading of the grid and voltage management is essential. This requires detailed measurement data which, unfortunately, is not widely available for distribution networks. The pseudomonitor offers solace.

Most of the grid manager's assets are in the extended middle and low-voltage networks. When dimensioning these networks, the grid manager often still assumes the maximum load, taking into account the growth of the individual users. As a result, the medium-voltage grids often have more transport capacity than necessary. Because these networks are, however, limited in size, there is insufficient insight to be able to make good use of the remaining capacity.

One of the possibilities to get more out of the networks against small investments is to use knowledge about the specific behavior of groups of customers. These are temporarily continuously measured for this purpose. Especially asset managers have carried out these measurements to gather knowledge about the typical behavior of users and user groups.

The pseudomonitor makes use of these measurement data. Determining the unequality of loads per unit of time creates a much better insight into the actual grid load and voltage management without having to measure at every point in the grid. For example, an analysis can provide the insight that a new customer sometimes even leads to better stress management. The consequences of decentralized generation, large-scale or small-scale in new-build projects (micro-combined heat and power units) can also be calculated. This makes the pseudomonitor an effective tool.

Focused on the medium-voltage grid, the focus is on combining measurements in a substation with load patterns of grid stations. The maximum flow measurements of grid stations serve as the basic distribution. The tax patterns are constructed from the composition of the customer groups per station and the load patterns of the individual customer groups, such as households, shops and offices. All in all, the pseudomonitor combines load measurements of the downstream directions in the substation, maximum flow measurements at the grid stations, load patterns of the grid stations, composition of the customer groups per network station and load patterns of the individual customer groups. This results in a reliable and detailed insight into the voltage management and grid load in medium-voltage networks.

6.13.1 Pseudomonitor

The purpose of the pseudomonitor is to monitor medium voltage networks based on measurements and load profiles. The monitoring consists of calculating the voltage and power management in a network during a period.

INPUT

The pseudomonitor uses the following input:

- a Vision network of a medium-voltage grid with transformer loads as distribution stations
- a number of Excel files or text files per file pertaining to one or more output fields in the substation, consisting of a number of times with a measurement of power or current.
- possibly a number of Excel files or text files with external profiles.

Measurements
A standard measurements Excel file contains flow or power measurements from one field for a number of times. The first row contains the header. For current measurements this is: A1: Date; B1: Time; C1: Current. This may also be: A1: Date time; C1: Current.
For power measurements this is: A1: Date; B1: Time; C1: P. This may also be: A1: Date time; C1: P. The reactive power may be added to it: D1: Q. The power values are in kW and kvar.
Company-specific measurement files can be supported on request.

Network file
The network file contains profiles. Elements are assigned a time-related profile in the input form.
The tax value of an element is chosen so that it, multiplied by the profile factors, gives a good estimate of the current loads.
A measuring field is applied in the outgoing fields. The name of a measurement field must match the start of a measurement file name. Possibly this combination is company-specific.

CALCULATE

Start the calculation as follows:
- Choose **Calculate | Pseudomonitor | Phase 1**
- Select the measurement files to be processed. Use **<Ctrl>** and/or **<Shift>** to select more files. Choose Excel or text files under **File Type**.

During the calculation, the elements are set at their expected load value for each time (measurement) to be calculated, using the profiles. A load flow is then performed. The calculated apparent power in the outgoing field is compared with the measured power. All elements with a profile unequal to 'default' in that field are corrected. A load flow is then performed. The calculated power now corresponds to the measured power within one percent. All flows and voltages in the network are now known.

RESULTS

After the calculation, the following results are available for each calculated time:
- low voltage of all transformer loads
- load of all transformer loads
- loss of all transformer loads
- load of all cables
- loss of all cables
- total power loss.

Five times have also been detected when an extreme value was reached:
- maximum low voltage of a transformer load
- minimum low voltage of a transformer load
- maximum load of a transformer load
- maximum load on a cable
- maximum total power.

The results can be viewed in different ways.

Schematic
In the schematic network, the stress band and / or the load band are shown for the calculated objects.

General
Choose **Calculate | Results | Overview**. A global overview of the results appears, namely the five extreme situations, the operating time or. duration of the calculated period and total energy loss during the operating time.

Detailed
Select a number of objects and choose **Calculate | Results | Details** or right-click on an object. All calculated bands are shown per object. The **Details** button shows all calculated times with their calculated values.

Graphic
Select a number of objects and choose **Calculate | Results | Chart**. The tapes of the selected objects are shown graphically.
Select a number of objects and choose **Calculate | Results | Detail graph**. The results of the selected objects are shown graphically in four graphs. The fifth graph shows the total power loss of the selected objects.

Network

The current networks belonging to the five extreme situations are automatically stored in network files after the calculation. These network files have the same name as the opened network file, plus the date and time. After opening such a network in Vision, switching and fault situations can be analyzed manually.

PHASE 2

After phase 1 the actual loads at all times are known for the elements. It is now possible to calculate a modified network configuration for the entire period. To do this, choose **Calculate | Pseudomonitor | Phase 2**.
The available results are equal to phase 1, except for the graph with correction factors and the storage of the networks in the five extreme situations.

PHASE 3

After phase 1 the actual loads at all times are known for the elements. It is now possible to calculate a modified network configuration for the entire period and/or add PV automatically to loads and transformer loads based on a percentage to be specified. To do this, choose **Calculate | Pseudomonitor | Phase 3**.
The available results are equal to phase 1, except for the graph with correction factors and the storage of the networks in the five extreme situations.

6.14 Outage simulation

Enter topic text here.

6.14.1 General

The fault simulation is a separately available module, which trains operators in locating and resolving faults. This involves 'unknown' faults in the network. The operator commnunicates with the network by receiving automatic and telephone notifications, remote control and station actions. At a station, the operator can view the protection relays photographically. Time records are kept of the actions performed. Fault consumption minutes are also recorded. This quantitative appreciation of the resolution process gives fault simulation a competitive element.

Fault simulation uses the following inputs:
- a Vision network
- images of protection relays'
- an image information file.

Network file
The network file contains the utilities required for displaying the images:
- The short name of a protection relay must match a name in the image information file
- In a differential protection and short-circuit relay, this name must be added as a value to the 'type' attribute.

In the network file, voltage transformers can be specified in the details of a node: 'voltage transformer=TRUE' or 'voltage measurement transformer=50', where the number defines the sign location at the node.

6.14.2 Calculate

Once in the options, enter the file location for the type images.
The protection relay images should be in this folder.
The protection relay information file ProtectionPictures.ini should also be here.

Start the calculation with **Calculate | Fault simulation**.
The fault simulation form appears. This form remains visible 'on top'. Behind it, you can work with the network in the editor. You can also close the screen at any time and call it up again in the same state via the menu.

The fault simulation form contains an invisible copy of the network. Interaction with this network is mainly in the form of text.

The fault simulation form consists of nine tabs.

Start
A short circuit can be applied at/in any node or cable (proportional to the failure frequencies entered), at a location to be specified or according to a case included in the network. In a case, a protection and/or circuit breaker may fail.
During the short circuit, signals from protection relays' and short-circuit indicators are set and circuit breakers and fuses are switched off.

Statuses
The following data can be viewed of nodes that have been reported far:
- The voltage of the node
- The current in a branch
- The current in an element
- The switching position of a load switch
- The switching position of a circuit breaker

Alarms
Alarms are immediately received from objects that have been reported off:
- From a node with remote notification: a circuit breaker switched off
- From a circuit breaker with inhibit notification: the circuit breaker which has been switched off
- From a short-circuit indicator with remote indication: the short-circuit indicator that is signalling

Fault signals
Fault messages are periodically received from (transformer) loads (consumers).

Remote control
Load switches and power switches with remote control can be switched on or off.

Moving
You can visit a station. The travel time is calculated relative to the previous station with route planning or according to the great circle distance. The time to reach the first station is 30 minutes.

Station action
The following actions are possible in a station:
- Viewing a protection relay
- Viewing a load switch
- Viewing a circuit breaker
- Viewing a fuse
- Viewing a short-circuit indicator
- Measuring the Voltage
- Measuring a cable/trace phase-to-ground
- Measuring a cable/track phase-phase
- Replacing a fuse
- Switching on a load switch
- Switching off a load switch
- Switching on a circuit breaker
- Switching off a circuit breaker
- Securing / blocking a circuit breaker
- Disconnecting / disconnecting a circuit breaker
- Disconnecting the power transformers
- Connecting the power transformers

- Resetting some protection relays
- Resetting a short-circuit relay

When viewing a protection relay or short-circuit indicator, a picture of the device is shown, where present, with the lights and display indicating the status.
Active actions are carried out in the network. A short message of the result is displayed for all actions.
During troubleshooting, the fault limits from the options are applied for the load of branches and elements. After troubleshooting, the normal limits apply.

Stop
After you have performed all actions to solve the fault (as far as possible), you can end the fault simulation.
The summary of the results includes:

- The time duration
- The number of fault consumption minutes
- Unresolved objects
- Faulty operations
- Overloaded objects
- Location of the short circuit

The summary, including details, can be reported to a text file.
'Exit' deletes this session of fault simulation.

Logging
A list of all actions performed (so far) with the result.

TIP

Move quickly
Although the network in the graphical editor and the network in the fault simulation are not linked (a copy is made at the start), you can still move quickly in fault simulation via the editor, because selecting a node schematically is more convenient than choosing from a list. To do this, close the fault simulation form, select one node in the editor and call up the fault simulation form again via the menu.

6.15 Stability analysis

Stability Analysis module determines whether a dynamical system is stable in case of small disturbances ('small signal stability analysis'). Analysis is performed based on computation of eigenvalues.

6.15.1 General

Stability analysis of electrical network is divided in the classical theory in two types. The first type is so-called transient stability analysis, where the dynamic behavior of the network is analyzed during large disturbances (such as, for instance, short-circuits). Typical outcome of the transient stability analysis is the Critical Clearing Times (CCTs). The CCTs are the short-circuit times for which the system still finds itself on the border of stability. Larger short-circuit times result in out of step operation of synchronous machines, transient voltage instability phenomena, etc. CCTs can be determined in Vision using Dynamic Analysis module.

The second type of stability analysis considers behavior of the system during relatively small changes (like, for example, the reference step of the active power of a generator or normal changes of load powers). For this type of stability analysis the dynamic model of the network is linearized first, and after that the eigenvalues of the linearized system are computed. Based on the real parts of the eigenvalues it is concluded whether the system is stable or not. These second type of stability analysis can be performed with Stability Analysis module.

6.15.2 Model and calculation

The model used for the calculation is actually the same as that of Dynamic Analysis module. The dynamic model is in general nonlinear, and therefore it has to be linearized first. This is done using numerical perturbations around the operating point. The operating point is determined by running loadflow and initialization routine of the dynamic module. Results of linearization are state-space matrices A, B, C, D. Eigenvalues of A-matrix determine the stability of the system.

The short summary of the computation steps is as follows:

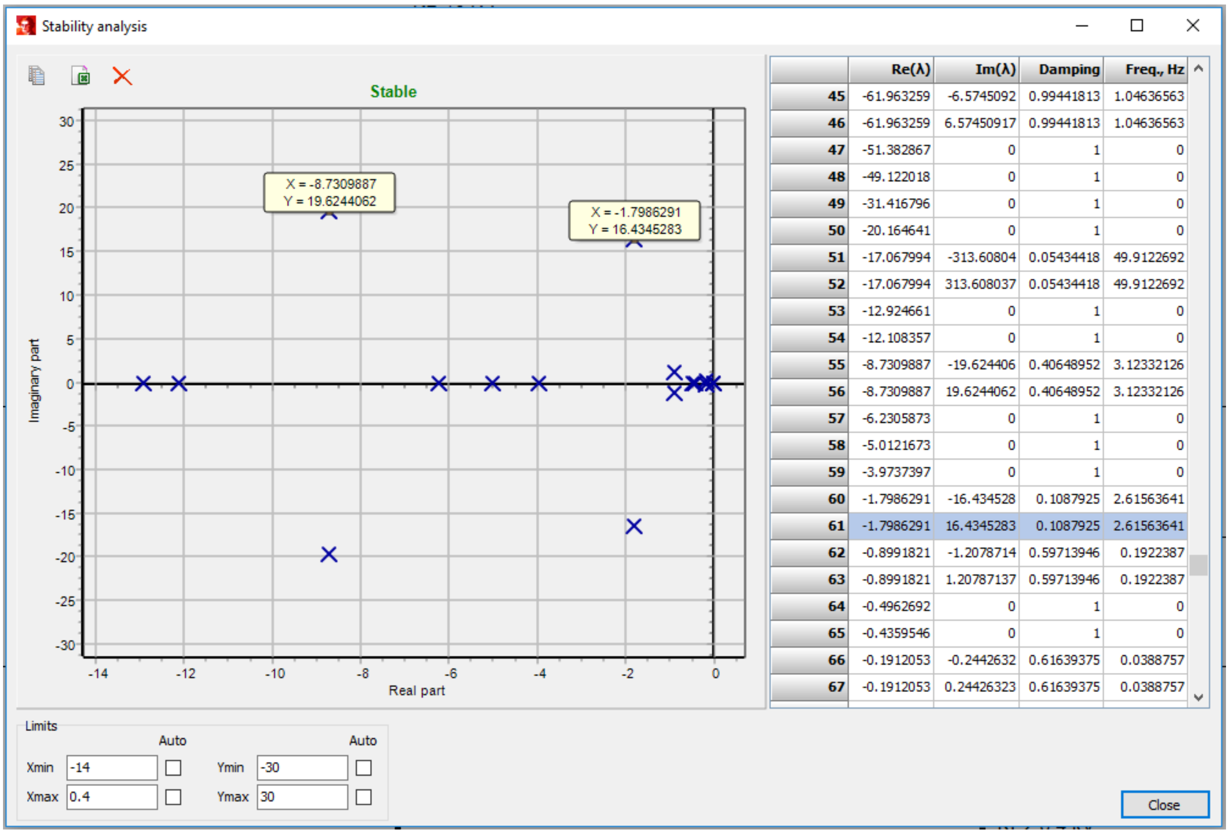
- determining the operating point (using loadflow and initialization of the dynamic model);
- linearization of the dynamic model using numerical perturbations;
- computation of the eigenvalues of A-matrix of the linearized system.

Numerical calculations of eigenvalues are performed using the numerical library for linear algebra LAPACK (http://www.netlib.org/lapack/).

6.15.3 Results

The result of the calculation is the eigenvalues of the A-matrix of the linearized network model. If all eigenvalues are located on the left half-part of the complex plane (with respect to the imaginary axis), then the system is stable. The more to the left the eigenvalues are, the more stable the system is. Imaginary part of an eigenvalue is related with the frequency of oscillation of respective mode.

After performing the computation the following window appears:



	Re(λ)	Im(λ)	Damping	Freq., Hz
45	-61.963259	-6.5745092	0.99441813	1.04636563
46	-61.963259	6.57450917	0.99441813	1.04636563
47	-51.382867	0	1	0
48	-49.122018	0	1	0
49	-31.416796	0	1	0
50	-20.164641	0	1	0
51	-17.067994	-313.60804	0.05434418	49.9122692
52	-17.067994	313.608037	0.05434418	49.9122692
53	-12.924661	0	1	0
54	-12.108357	0	1	0
55	-8.7309887	-19.624406	0.40648952	3.12332126
56	-8.7309887	19.6244062	0.40648952	3.12332126
57	-6.2305873	0	1	0
58	-5.0121673	0	1	0
59	-3.9737397	0	1	0
60	-1.7986291	-16.434528	0.1087925	2.61563641
61	-1.7986291	16.4345283	0.1087925	2.61563641
62	-0.8991821	-1.2078714	0.59713946	0.1922387
63	-0.8991821	1.20787137	0.59713946	0.1922387
64	-0.4962692	0	1	0
65	-0.4359546	0	1	0
66	-0.1912053	-0.2442632	0.61639375	0.0388757
67	-0.1912053	0.24426323	0.61639375	0.0388757

The eigenvalues are shown graphically on the plot. The limits of the plot can be set automatically or adjusted manually. If an eigenvalue in the plot area is clicked, the respective value is selected in the table. A double click on an eigenvalue in the plot area gives a label with values of real and imaginary parts of this eigenvalue on the figure. The labels can be deleted using button ***Delete marks*** (see the upper-left part of the plot). Next to it the button ***Copy plot*** to the clipboard is located, which can be used to copy the plot graphically and paste it, for instance, to Microsoft Word. The button ***Export to Excel*** exports detailed information of stability analysis results. The following information is exported:

- A-matrix of the linearized network model;
- description of the states;
- eigenvalues, respective damping and oscillation frequency;
- right and left eigenvectors;
- participation factors.

Participation factors (visible only in the exported Excel file) contain important information about the behavior of the system. They give indication of which state influences which eigenvalue the most. Participation factors in Vision are normalized and given in per cent such that the sum of all participation factors per column has to be 100%. However, small participation factors (less than 0.01%) are neglected in order to keep the overview more readable. Therefore, small deviations from 100% can be present.

Participation factors can be analyzed in the following manner. First, the eigenvalues can be checked. The number of the eigenvalue with the worst damping (that has its real part the closest to zero) can be noted. The column with the noted number can be located on tab *Participation factors*. Then the state number for the largest participation factor in the column can be determined. Using this state number it can be traced on tab *States* – which component and which variable cause the bad damping.

6.16 Dynamic analysis

Dynamic Analysis module gives insight in the dynamic behavior of the currents, voltages and other variables during transients in the network.

6.16.1 General

Besides static calculations (like, for instance, loadflow or short circuit calculations according to IEC 60909) it is also often interesting to perform dynamic simulations. The results of dynamic simulation give more insight in the dynamic evolvement of voltages and currents in time in case of different events (for example, a short circuit or the start of a motor or a voltage dip). Also the results of static calculations can be validated with the dynamic results.

6.16.2 Model

The network model in the module is suitable for the analysis of electromagnetic transients with duration from hundreds milliseconds till several seconds. The typical examples of these are short-circuits and voltage dips. Electromechanic transients such as the start of a motor or rotor angle / rotor speed oscillations of electrical machines (transient stability) after short circuit can also be studied with this model. Fast electromagnetic transients, for instance, the behavior of the network after a lightning strike or development of the arc after a short circuit, currently cannot be modeled.

In the electromagnetic approach all objects are modeled with differential equations. Each coil/capacitor is modeled by a differential equation. The simulation with this model is very accurate, but costs relatively a lot time. Therefore, the module is more suitable for the analysis of small to medium size networks.

In order to increase the simulation speed the transformation to the synchronously rotating DQ0 reference frame can be used. The biggest advantage of DQ0 reference frame is that the voltages and currents during steady-state situation are constant, while they vary sinusoidal in the usual ABC reference. Together with the use of variable time step solver for the numerical solution of differential equations this results in faster computations than in traditional packages for simulation of electromagnetic transients.

The types of objects modeled for dynamic analysis are as follows:
- cables and cable/line equivalents;
- two- and three-winding transformers;

- zigzag grounding transformers;
- grids (external networks);
- loads;
- shunt capacitors;
- shunt and series reactors;
- induction generators and motors;
- synchronous motors;
- synchronous generators including:
  - o excitation systems;
  - o power system stabilizer;
  - o reactive power and power factor controls;
  - o turbine and governing system.

All models, except that of synchronous and induction machines, use no extra parameters with respect to the parameters of static calculations. For the Y-connected elements it can be chosen on tab Neutral whether the neutral point is isolated, grounded or grounded via impedance.

Cable and cable/line equivalent
All cables and cable/line equivalents are represented by one or multiple π-section models or T-section models. It is possible to neglect the shunt capacitances of cables. This can be done collectively via the calculation options of Dynamic Analysis on tab *Advanced* or by selecting *Neglect cable capacitances* in the tab ***Dynamic*** of the cable options. Neglecting the shunt capacitances (in situations when they are of little influence, for instance, for very short cables) results in a great speedup of the simulation.

Transformer
The transformer is modeled by a set of three mutually coupled coils. Parameters of transformer are determined from the short circuit and no load transformer tests. For a correct dynamic model the no load transformer current is of big importance. From this current the value of mutual inductive coupling between the coils is determined. In case the no load current is unknown, it can be set to a value between 1% and 2% of the nominal current of the transformer. This would guarantee that the mutual couplings in the transformer model are large enough.

Zigzag transformer
The zigzag transformer is modeled by a zero-sequence resistance R0 and reactance X0. In case the neutral point of the grounding transformer is grounded via impedance Re+jXe, it can be specified on tab *Neutral* . The total zero-sequence resistance and reactance of the zigzag transformer is then determined as: R0+3*Ra en X0+3*Xa.

Grid
The grid (external network) is modeled by the three phase voltage source behind the resistor and inductor. There exists the possibility to dynamically define the voltage of the source in each phase (see Case and events 338). In such manner the voltage dip in the network can be simulated.

Load
The load is represented by constant impedance model. For inductive loads the series connection of resistors and inductors is used. For capacitive load the parallel connection of resistors and capacitors is used. Loads are Y-connected and balanced.

Capacitor
The capacitor is represented by capacitances in three phases. Only Y-connection of the phases is currently supported.

Coil
The coil is represented by inductances in three phases. Only Y-connection of phases is supported.

Synchronous generator and motor

The synchronous machine is represented by the detailed electromagnetic model. For description, see for instance the book of Kundur “Power System Stability and Control”.

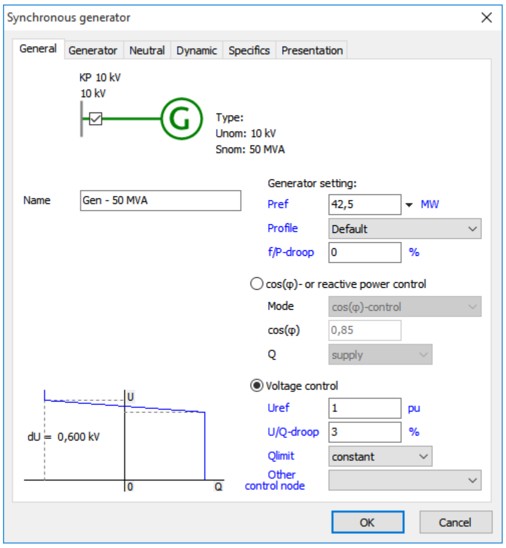
Machines with salient pole rotor are modeled by 8 differential equations:

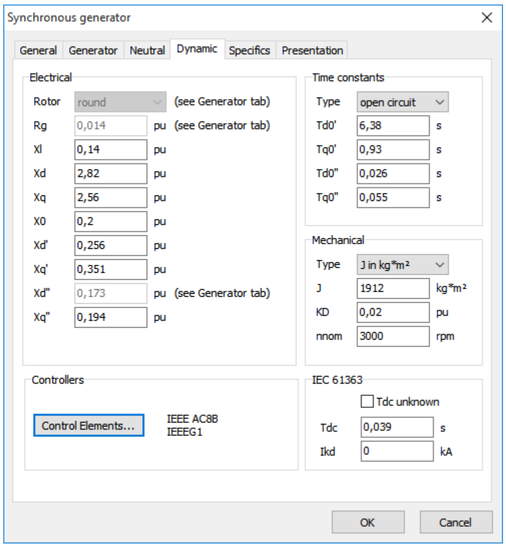
- 3 differential equations for stator fluxes
- 1 differential equations for the field winding
- 2 differential equations for damper windings (1d, 1q)
- 1 differential equations for the rotor speed
- 1 differential equations for the rotor angle.

Machines with round rotor are modeled by 9 differential equations:

- 3 differential equations for stator fluxes
- 1 differential equations for the field winding
- 3 differential equations for damper windings (1d, 1q, 2q)
- 1 differential equations for the rotor speed
- 1 differential equations for the rotor angle.

Parameters of the model are determined from the synchronous, transient and subtransient reactances and time constants. For dynamic modelling of synchronous machine are extra parameters necessary. These parameters are located on the tab *Dynamic* of the input window.





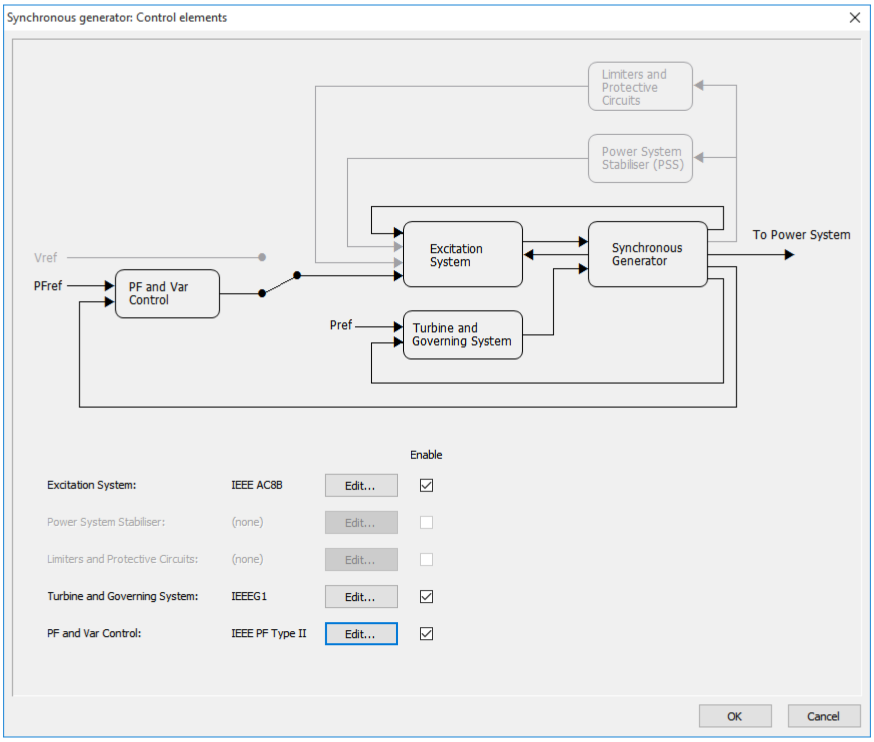
Some parameters are already filled-in in other tabs, for instance, the rotor type, the stator resistance Rg and the subtransient reactance on the d-axis Xd’’. Other parameters that still have to be filled-in are:

Parameter	Unit	Description
Xl	p.u.	leakage reactance
Xd	p.u.	synchronous reactance, d-axis
Xq	p.u.	synchronous reactance, q-axis
Xo	p.u.	zero sequence reactance
Xd'	p.u.	transient reactance, d-axis
Xq'	p.u.	transient reactance, q-axis (n.a. for salient pole rotor machine)
Xd''	p.u.	subtransient reactance, d-axis
Xq’’	p.u.	subtransient reactance, q-axis
Tdo’ or Td’	s	open- or short-circuit transient time constant, d-axis
Tqo’ or Tq’	s	open- or short-circuit transient time constant, q-axis (n.a. for salient pole rotor machine)
Tdo’’ or Td’’	s	open- or short-circuit subtransient time constant, d-axis
Tqo’’ or Tq’’	s	open- or short-circuit subtransient time constant, q-axis
H or J	s or kg·m^2	inertia, rotor and turbine together (H in s based on Snom)
KD	p.u.	damping coefficient of the rotor speed (in case it is not known: use zero)
nnom	r.p.m.	nominal speed

All resistances and reactances are in p.u. based on the nominal data of the machine.

Synchronous generator control elements

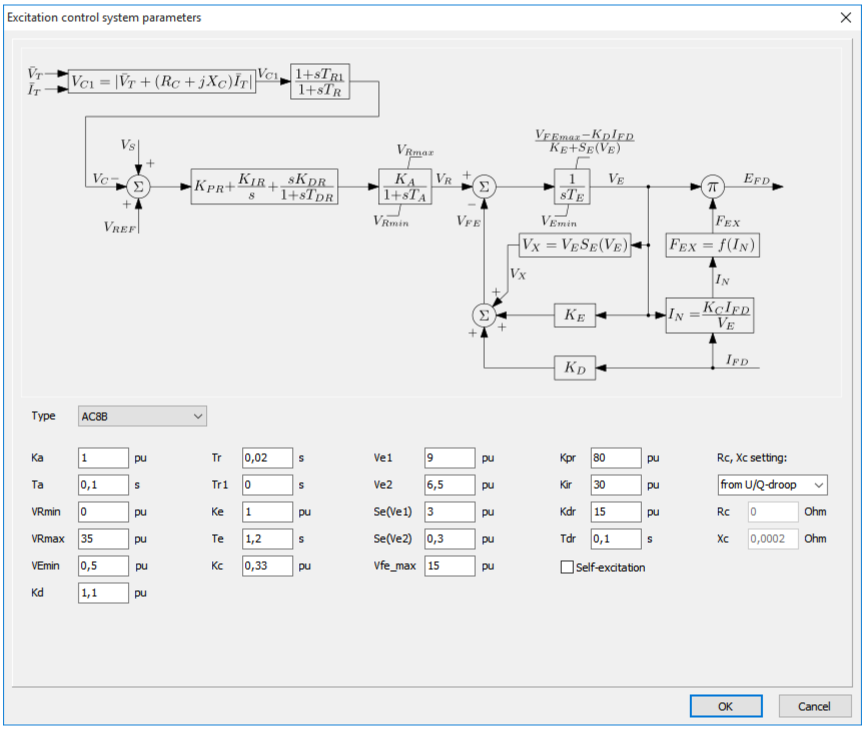
In order to model the influence of synchronous generator controls during dynamic analysis, the control elements and respective parameters have to be specified. This can be done by clicking *Control Elements...* button on tab *Dynamic* in the parameters of the synchronous generator.



This form gives an overview of the chosen control strategy and respective control elements. Using *Edit...* button it is possible to choose the controller type (this will be described in more detail below) and specify the parameters of controller. By checking and unchecking *Enable* checkboxes a control system can be switched on and off. In case a control system is switched off, it is represented by a constant input, the value for which is determined during the initialization (from the results of the loadflow calculation). 'Power System Stabilizer' and 'Over- and Underexcitation Limiters' are currently not modeled.

Excitation system

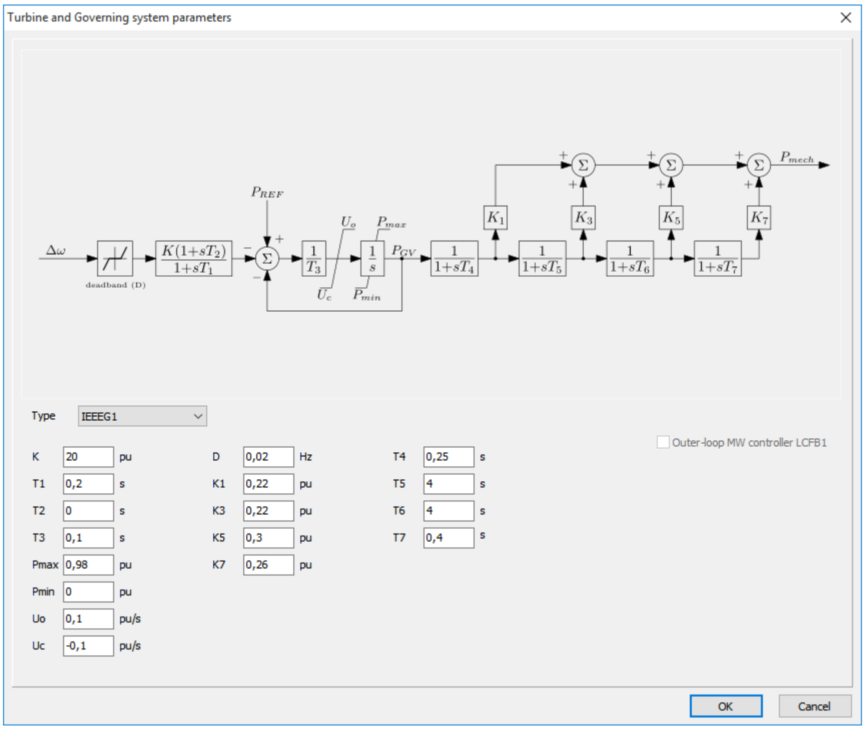
The basic function of an excitation system is to provide a controlled DC current to the field winding of the synchronous generator. Due to variation of this current the magnetic field of the rotor changes and the voltage induced in the stator windings changes as well. On the form shown below it can be chosen between 20 standard IEEE models (IEEE Std. 421.5-2005).



The parameters filled-in by default can be used just as an example. These are neither typical nor representative. For a detailed description of the models and the detailed example, please see:
http://www.phasetophase.nl/pdf/SynchronousMachineExcitationSystems.pdf

Turbine and governing system

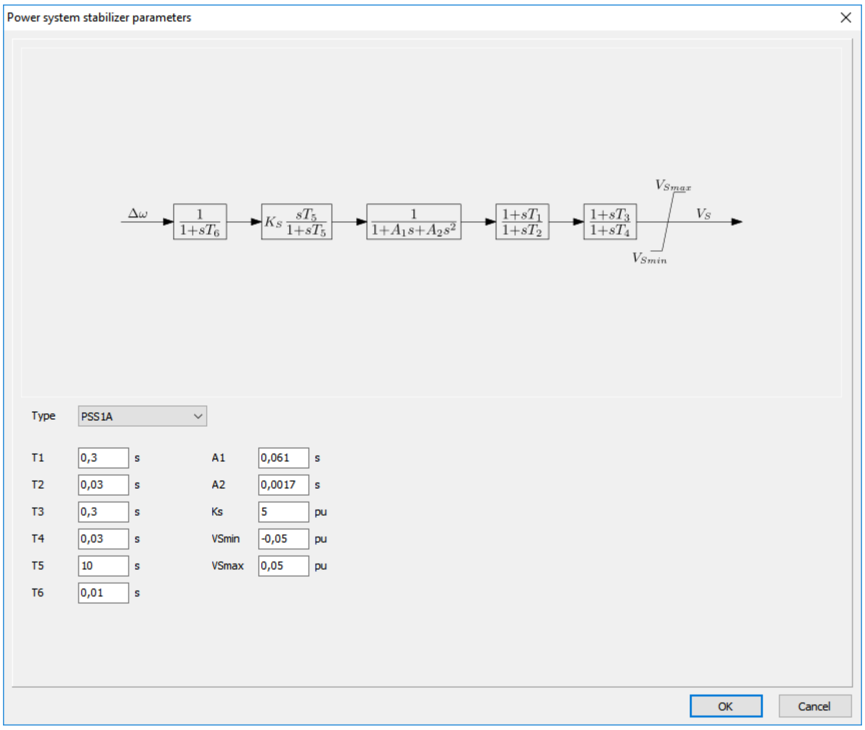
Besides the excitation of the field winding the behavior of a synchronous generator is influenced by a prime mover and its control. Correct modelling of turbine and governing system is especially important for the transient stability studies, where analysis of large disturbances is of concern. Five models proposed by IEEE (PES-TR1) are currently implemented in Vision (see form below).



The parameters filled-in by default can be used just as an example. These are neither typical nor representative. For a detailed description of the models and the detailed example, please see:
http://www.phasetophase.nl/pdf/SynchronousMachineTurbineGoverningSystems.pdf

Power System Stabilizer

The Power System Stabilizer (PSS) is used to enhance damping of power system oscillations through excitation control.A logical signal to be used as an input to the PSS is the speed deviation , other inputs could be the frequency and power. On the form shown below the IEEE PSS1A model is shown together with the input parameters (IEEE Std. 421.5-2005).

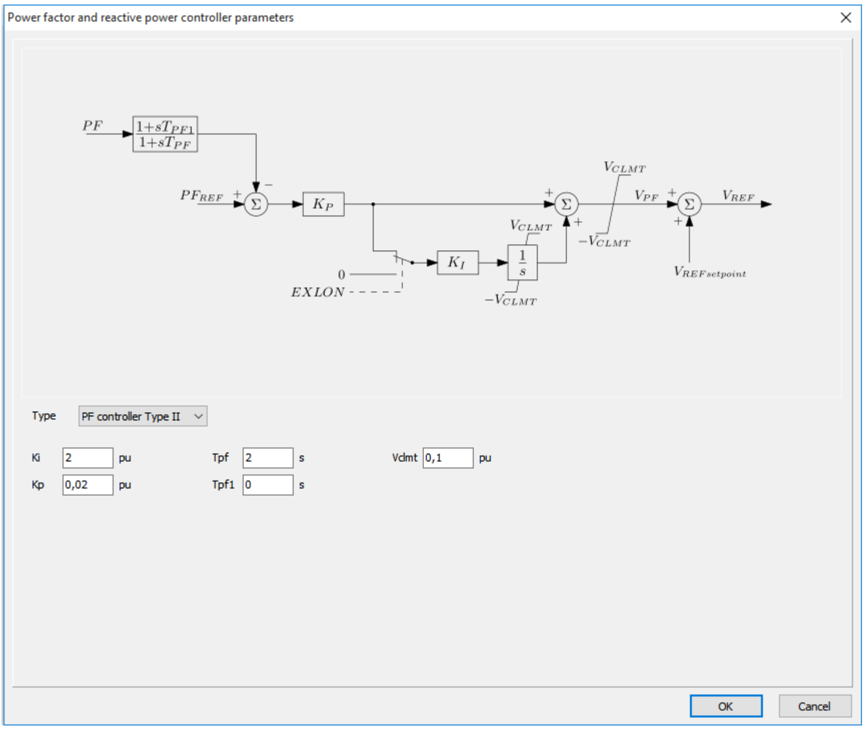


The parameters filled-in by default can be used just as an example. These are neither typical nor representative. For a detailed description of the models and the detailed example, please see:
http://www.phasetophase.nl/pdf/SynchronousMachineExcitationSystems.pdf

Reactive power and power factor control

Excitation systems are sometimes equipped with a reactive power or power factor control. This control is implemented as a slow outer loop controller for the excitation and automatic voltage regulator. The reference voltage V_{REF} is controlled by a PI controller that minimizes the difference between the reference signal and the measured reactive power or power factor.

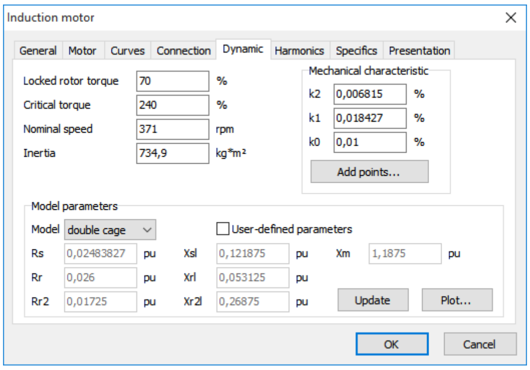
Reactive power/power factor control is used typically for the industrial applications. For such applications the generator is usually connected to the plant distribution bus. The voltage on the terminals of the generator has to follow the value determined by the external network and voltage control of the generator is not desirable in this case. In Vision *PF controller Type II* and *var controller Type II* models from IEEE standard (Std. 421.5-2005) are implemented. The controller type and its parameters can be specified using form shown below.



The parameters filled-in by default can be used just as an example. These are neither typical nor representative. For a detailed description of the models and the detailed example, please see:
http://www.phasetophase.nl/pdf/SynchronousMachineExcitationSystems.pdf

Induction generator and motor

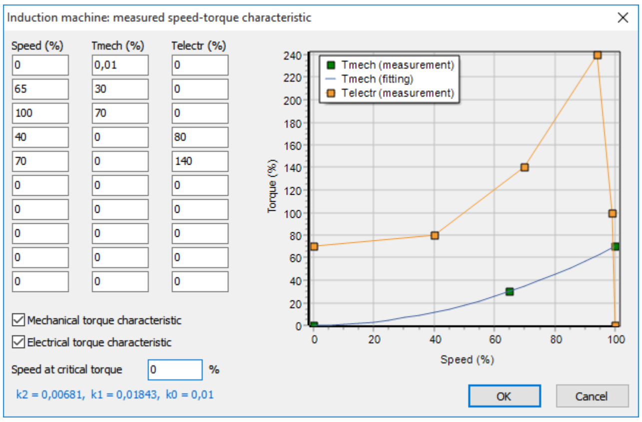
The induction machine is represented by the detailed electromagnetic model. For detailed description of the model see, for instance, the book of Krause “Analysis of Electric Machinery and Drive Systems”. It is possible to choose between single cage and double cage model. Single cage model is the most widely known model, but it is in general not precise enough to model well both the startup and the short circuit behavior of the machine. The double cage model solves this problem. Therefore, it is advised to use by default the double cage model.



Extra parameters of the induction machine are:

- Locked rotor torque, in percent of the nominal torque
- Critical torque, in procent of nominal torque
- Nominal speed, r.p.m.
- Inertia, kg*m² (rotor and drive mechanism summed up)
- k2, k1, ko are the coefficients of the quadratic approximation of the mechanical characteristic of the driven mechanism: $T_m = k_2 \cdot n^2 + k_1 \cdot n + k_0$, where T_m is the mechanical torque in percent of nominal and n is the speed in percent of nominal speed. It is possible to use linear approximation (k2 = 0) or a constant mechanical torque (k2 and k1 = 0).

The easiest way to enter the mechanical characteristic of the machine is via addition of the measured points (button *Add points...*). The following form appears after click on the button:



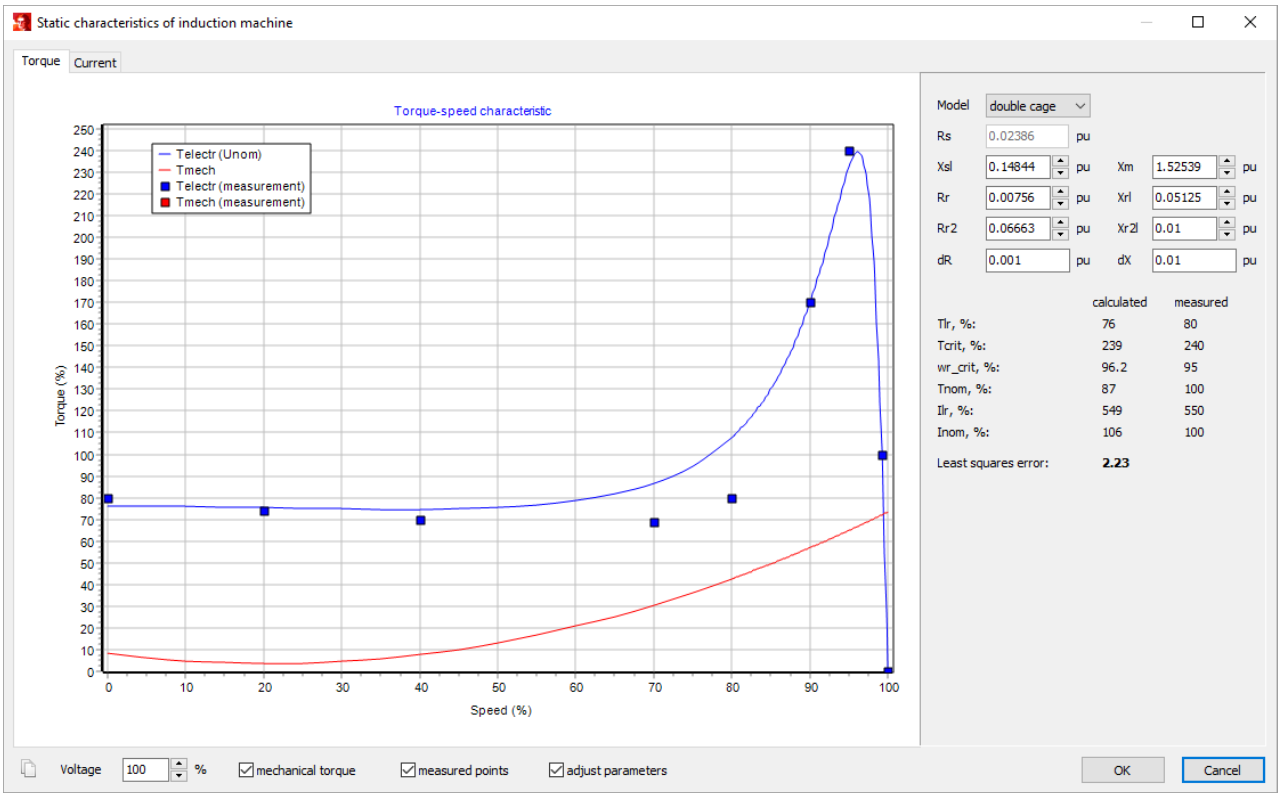
The measured points of the mechanical torque-speed characteristic and/or these of the electrical torque-speed characteristic can be entered here. The points of the mechanical torque characteristic are used for the automatic computation of the best coefficients k2, k1 and k0. If you click on *OK* button, the values of the coefficients are automatically filled-in in the respective fields. The added points of the electrical torque characteristic (if they are known) are used for the better estimation of model parameters. If the speed at critical torque is known, it can be also added. In case it is unknown, you can set zero as a value (internally it will be determined automatically).

Model parameters are used for automatic solution of the following optimization problem: find model parameters that approximate the known points of electrical torque-speed and stator current-speed characteristics as good as possible. If no extra points are available, then only locked rotor current, lock rotor torque, critical torque and the nominal data of the machine are used for the automatic estimation of model parameters. But if more points are specified, the model approximates the reality better.

It is also possible to specify own model parameters by checking *User-defined parameters* .

Update button is used for automatic computation of model parameters via optimization. The automatic calculation is also applied in case if *User-defined parameters* is not checked and one or more parameters have changed (for instance, the locked rotor torque) and you click on *OK* button.

The button *Plot...* shows torque-speed and stator current-speed characteristics for the given model parameters.



The characteristics are plotted normally at the nominal voltage. In case of deviating stator voltages it is also possible to adjust it using *Voltage* input field.

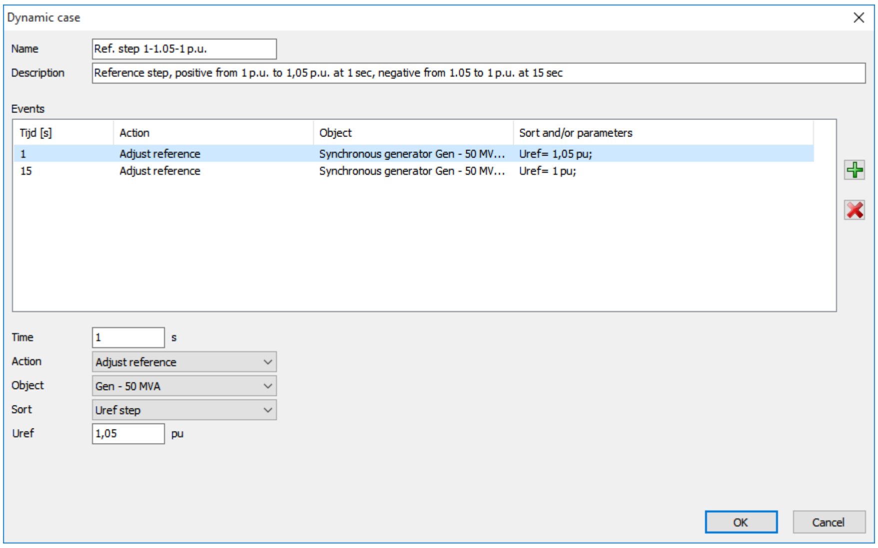
Checkbox *measured points* shows the points specified earlier via Add points...

Checkbox *adjust parameters* lets the user to visualize immediately the influence of model parameters adjustment on the characteristics. This adjustment takes place via direct changing of parameter value or via clicking arrows next to respective input field. In the last case the corresponding parameter is increased/decreased by the value specified in *dR* (for resistance) or *dX* (for reactance) input field. Deviations for important points are summed up in numerical form on the right hand side of the window. Calculated points come from the calculation of characteristics using model parameters. Measured points were specified by the user earlier by entering the induction machine nameplate data. Least squares error gives how close the calculated characteristics approximate the reality (the measured points). The smaller is this number, the better is approximation. If the parameters were changed and OK button is clicked, then the parameters will be automatically entered in the respective input fields of the main window of the induction machine.

6.16.3 Case and events

Dynamic analysis is of specific importance in situations when something is going to change in the network. Therefore, it is possible to define different dynamic events. The sequence of events can be stored in a dynamic study case (further referred simply as a case).

The addition of a case can be done via the menu **Start | Insert | Miscellaneous | Dynamics case**. There appears a form where one or more dynamic events (and their parameters) can be specified.



Using this form it is possible to define the following types of dynamic events (and their parameters):

- Apply short circuit
- Clear short circuit
- Apply voltage dip
- Start motor
- Adjust reference (synchronous generator):
  - o voltage (Uref step);
  - o active power (Pref step);
  - o reactive power (Qref step);
  - o power factor (PFref step).

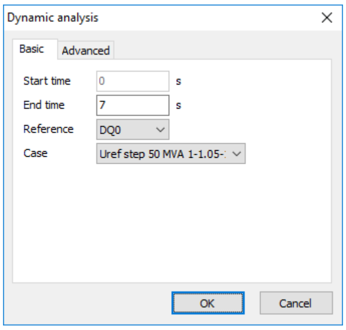
All other sorts of events are stored inside the case. First, the start time of the event has to be specified. After that, the sort of event (Action). Further, the object, on which the action will be applied, has to be chosen. The list of objects is modified in such way that it contains only objects applicable to the chosen action. For instance, the short circuit can be applied only on a bus and a voltage dip only on a source.
The fault type and the resistances of a short circuit can be defined in the Sort combobox, Rff and Rfe input fields.
The action *Clear short circuit* switches off the short circuit on the bus with the same name.

The action *Apply voltage dip* defines the change of voltages of a grid. The input fields Ua, Ub and Uc represent the values of p.u. voltages in phases a, b and c. The voltage dip can be disabled by restoring all voltages to normal level (i.e. by setting all voltages to 1 p.u.). The action *Start motor* simulates the motor start of the specified motor. The action *Adjust reference* changes the reference of the given synchronous generator (this is only possible for the generators with controllers).

After addition of a case, extra tab *Dynamics* appears in the main menu, where dynamic cases can be modified and erased. All cases are saved in the network file.

6.16.4 Calculation

A dynamic calculation can be started using **Calculate | Dynamic analysis**.



In the form the parameters of the dynamic simulation can be specified.
Basic parameters are the start and the end time of the calculation and the dynamic case.

Also it is possible to choose between DQ0 and ABC reference. DQ0 reference is in general faster than ABC (especially in case the end time of the simulation is large), but less suitable for unbalanced events. DQ0 reference is a good choice for the modelling of the following dynamic events:

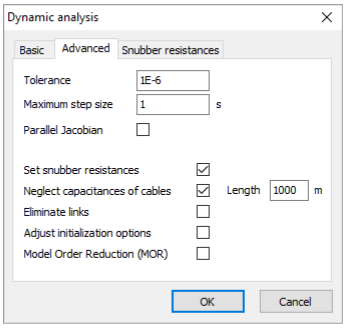
- start of an induction motor;
- reference step of a control system of synchronous generator;
- three phase (balanced) voltage dip;
- three phase (balanced) short-circuit.

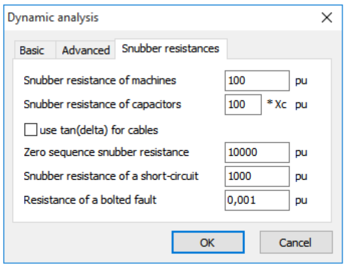
ABC reference is advisable for:

- unbalanced voltage dip;
- unbalanced short-circuit.

For both references it is valid that both ABC and DQ0 variables can be seen after the calculation. For instance, after DQ0-calculation it is possible to plot ABC voltages and currents. The difference is in the model of the network used during the simulation.

The tolerance and maximum step size of the numerical solver can be specified on tab Advanced. There it is also possible to specify values of the snubber resistances and neglect cable capacitances during dynamic analysis.





Tolerance

This is the coefficient that is used for weighting of the vector of local errors of system of differential equations. The value set by default is 1E-6. The decrease of tolerances leads to more accurate numeric solution, but, on the other hand, this slows the computation significantly. The increase of tolerances results in faster solution, but can lead to numeric instability.

Maximum time step

This parameter gives the limit of the values of time steps that are used inside the numeric solver. The time step inside the solver is automatically changed, based on the value of local errors. Therefore, in most situations the explicit change of maximum and minimum time steps is not necessary.

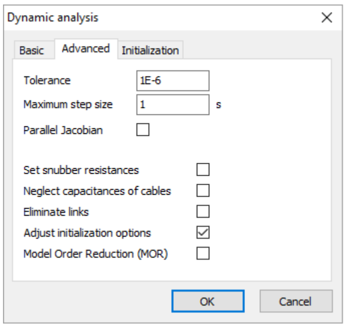
Parallel Jacobian
This calculation option switches on and off the use of multiple processor cores. The use of all processor cores can speed up the calculation significantly in case of large networks. For small network this option is not necessary and can even lead to somewhat slower solution in some situations.

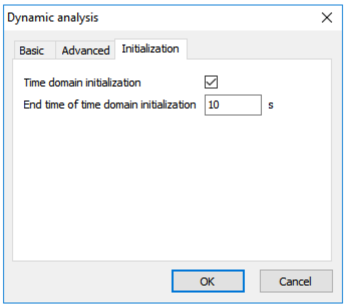
Neglect capacitances of cables
This option specifies whether the shunt capacitances of cables have to be neglected. Neglecting cable capacitances (in situations when they are not of importance) increases the computation significantly. This is especially important in case of short cables. Therefore it is possible to set the minimal length of cable with shunt capacitances. Cables having length longer or equal to the given length are modelled with shunt capacitances. For shorter cables there are no capacitances present in the model.

Eliminate links
Links are modelled in Vision as small resistances. The magnitude of this resistance is to be set via Vision Options (F11): Options | Calculation | General. These rather small resistances can cause bad numerical effects during dynamic simulation. If there are many links present in the network, the calculation may become significantly slower. Therefore, it is possible to eliminate links during dynamic simulation. In this case two nodes connected by a link are considered as a single node. The disadvantage of this is that the currents through links cannot be plotted anymore.

Set snubber resistances
Here the values of different snubber resistances that are used internally, can be adjusted. After checking this option tab *Snubber resistances* will appear.
The snubber resistances that can be modified are as follows:
- Snubber resistance of machines: internally the resistor is set at each terminal of each machine (due to the reasons related with numerical solution of differential equations). This resistance is specified in p.u. based on the nominal data of the machine. The default value of 100 p.u. means that the error in the calculation for 1 p.u. stator current will be in order of 1%).
- Snubber resistance of capacitors: there are no pure capacitances present in the module for dynamic analysis. The large resistance is connected internally to each capacitor. This prevents problems with numerical stability. The value of the resistance is given relatively to the reactance of the capacitor. The default value of 100 means that one hundred times larger resistor is set on each capacitor.
- Zero sequence snubber resistance is used to build-up the voltage in ungrounded parts of a network. P.u. value is based on global p.u. system (defined by nominal voltage of a bus and Sbase in general options of Vision).
- Snubber resistance of a short circuit is related with the internal model of a short circuit in DQ0 reference frame. P.u. value is based on global p.u. system.
- Resistance of a bolted fault: if the short circuit has zero resistance, then the small value of resistance is actually used. P.u. value is based on global p.u. system.

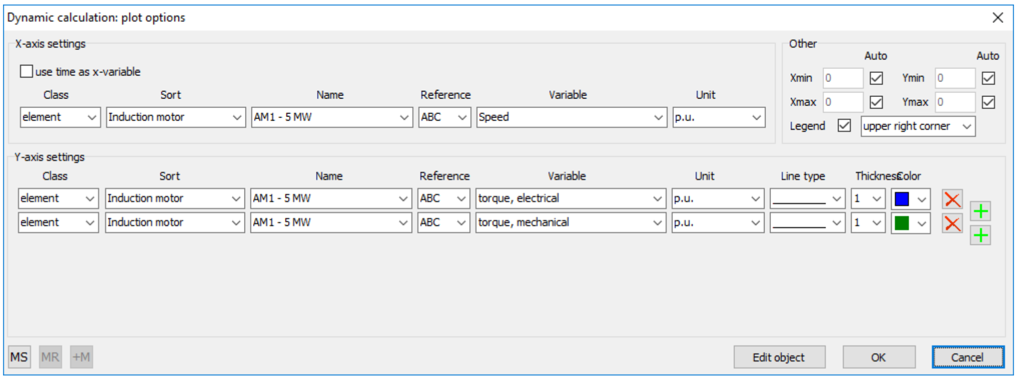
Initialization procedure
The initialization of the dynamic model in Vision is based on the loadflow results. The initial states are computed for specific operating point from the loadflow results using initialization procedures. Depending on the network and used elements, the operating point of the loadflow model and that of the dynamic model might slightly deviate from each other. This deviation is directly visible during time domain simulation since it does not begin in steady-state anymore (some transients in the begin of the simulation are to be observed, even if no dynamic case is executed). In case the network is stable (this can be easily checked by means of eigenvalue analysis), it can be chosen to determine the correct operating (steady-state) point by means of time domain simulation. During start of a dynamic analysis a pre-dynamic simulation can be executed, and the states at the end time (which is set by the user) can be used in order to initialize the system for the actual simulation. The initialization end time is dependent on the deviation of the initial operating point and the damping of the system. This time is set by default to 10 seconds.





6.16.5 Result

Results of a dynamic calculation are shown in the form of graphical plot. If you click an object with the right mouse button after performing a dynamic calculation, the form with the options of the plot will appear.



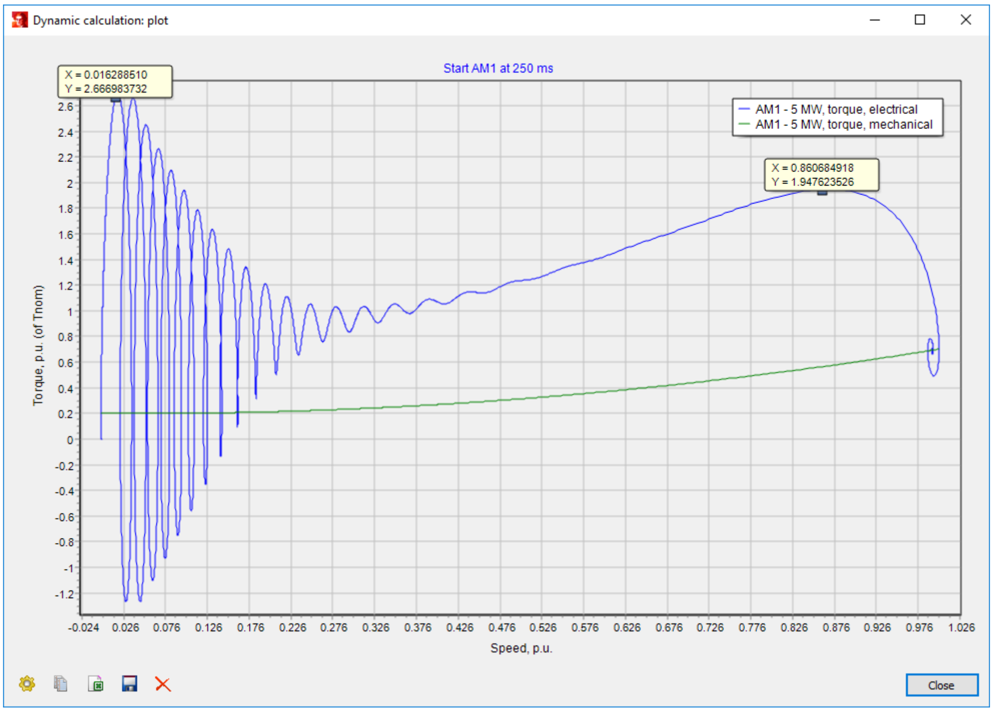
The plot options can be saved in memory by means of MS button. MR button sets the options from the memory to the form (options that are already entered in the form will be erased). +M button adds saved options to the initially entered options. These functions are handy in case there are plot options that needed to be used often.

You can choose variables that will be shown on the plot. It is also possible to choose variables of other object, for example, to show currents of a synchronous generator and currents through a cable on the same plot. Adding and removing variables can be done by button in the right part of the form.

Class gives access to the list of the following types of objects:

node: only nodes;
element: synchronous generator and motor, induction generator and motor, grid, load, transformer load, shunt capacitor, shunt reactor, zigzag transformer;
branch: cable, cable/line equivalent, link, reactor, transformer;
Workspace: saved or imported variables.

The variables to be plotted can be chosen using the form shown above. Time is used by default as x-axis variable, but it is also possible to choose another x-axis variable. An example of this, the torque-speed curve of an induction machine is plotted below:



The following buttons are available:

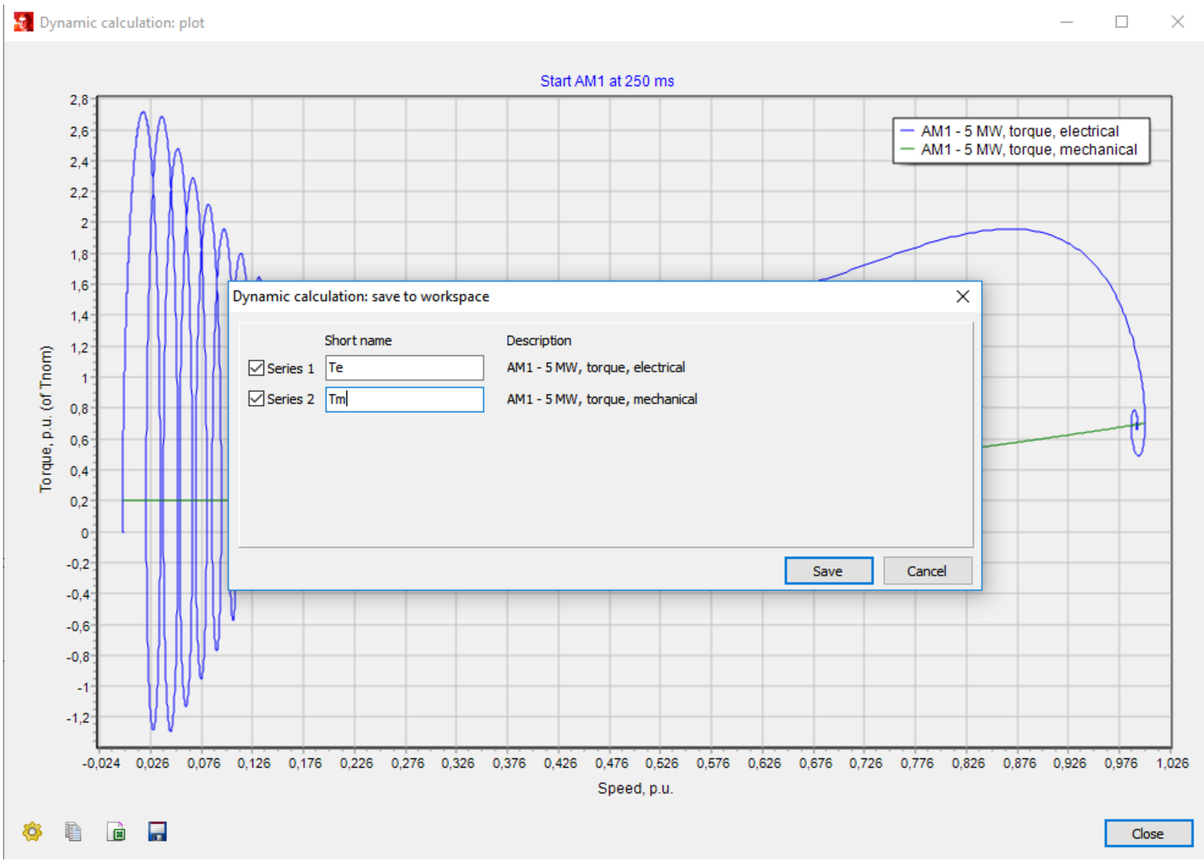
- Options: go back to the options of the plot (for instance, to adjust the thickness of lines or add new variable)
- Copy: copies the plot to the clipboard. Then the plot can be pasted in the form of picture, for instance, in Microsoft Word.
- Export: exports the numerical values to Microsoft Excel.
- Save to workspace: saves numerical values to the workspace.
- Delete marks: the marks on the plot can be deleted.

The title of the plot as well as the x- and y-axis labels can be adjusted by clicking on the respective text. Also the legend can be changed using the same principle. By clicking on a specific point of the curve, corresponding numerical values for x- and y-axis coordinates of the point can be obtained.

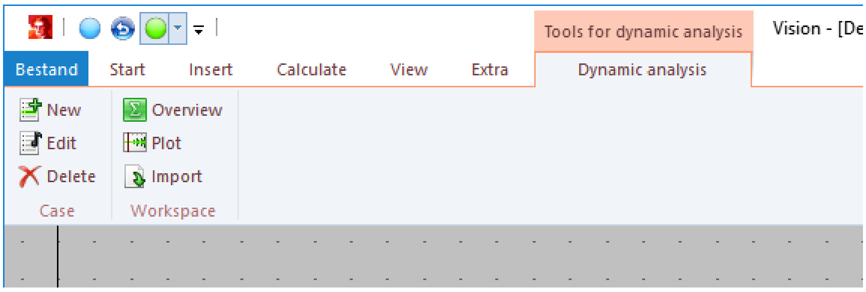
6.16.6 Workspace

To analyse different scenario's or to validate simulation results with external (measurement) data, variables can be saved or imported into the workspace. Those variables can now be used during the session to be compared with other workspace variables or with current simulation data.

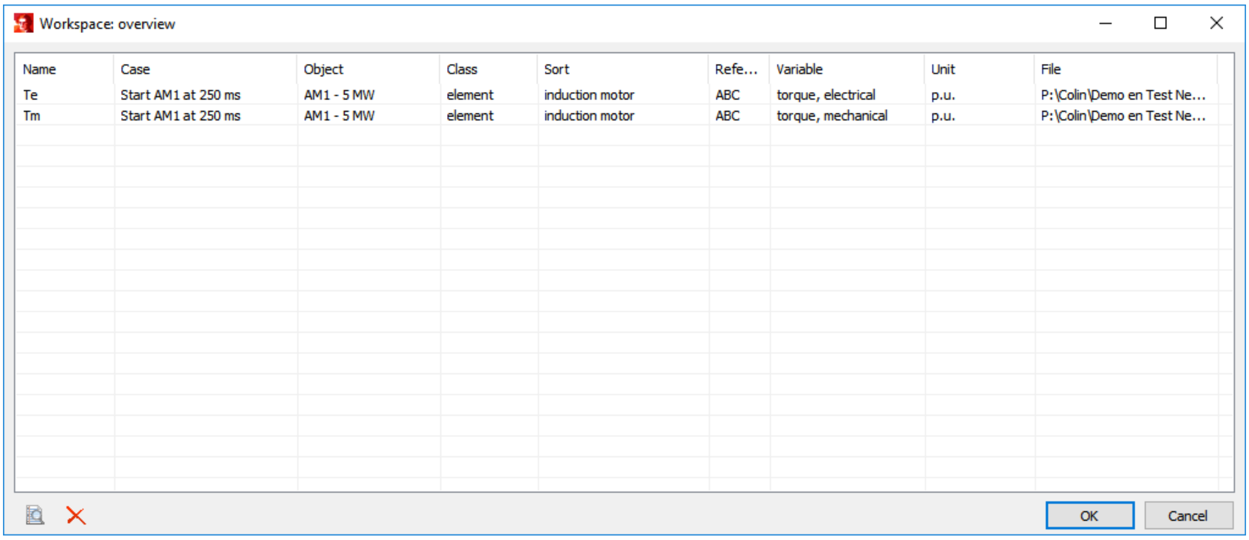
By choosing ***Save*** in the graphical plot of a variable the form below will open. Using this form one can choose which variable to save, each variable has to be provided with a name. The x- and y-axis variables (over the complete simulated period) of each signal are saved together with the short name, case, class, sort, reference, variable, unit, and the filename of the Vision Network File (.vnf).



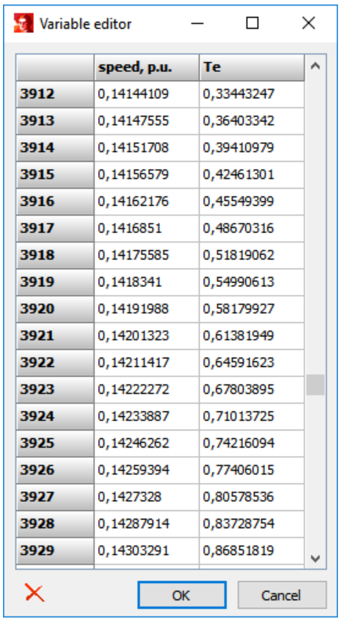
The workspace is accessible via the menu **Start | Dynamical analysis | Workspace**. Here variables can be viewed, plotted or imported.



By choosing ***Overview*** the saved or imported variables are shown. Using this form variables can be changed, deleted, or the numerical data can be shown.

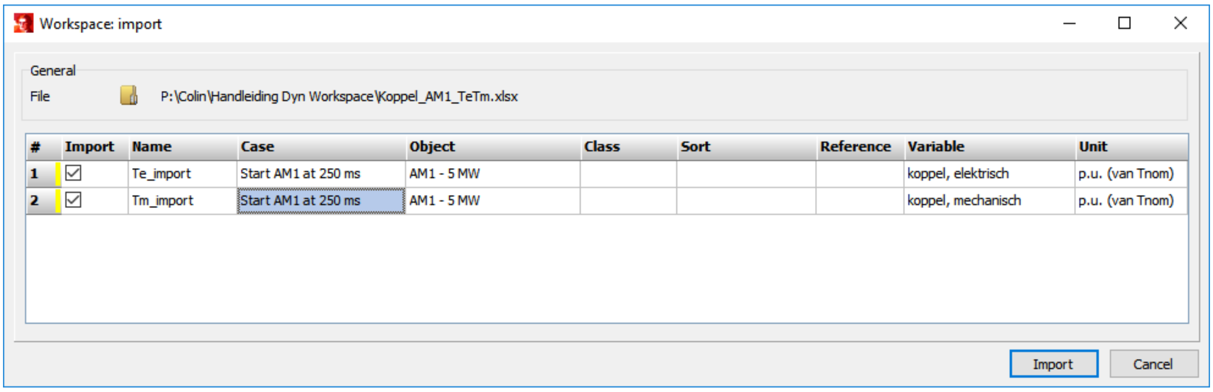


By double-clicking on a variable or by selecting a variable and choosing the magnifying glass the following form will be shown.



Here, the numerical values of the variable are shown and can be adjusted, deleted, or copied (Ctrl+C) to the clipboard.

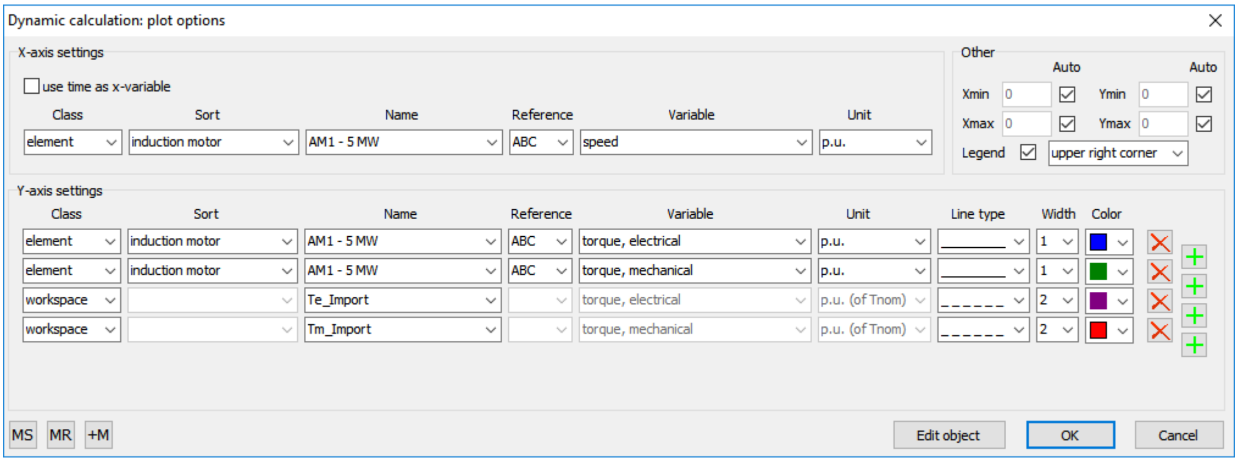
To validate simulation results, measured data can be imported into the workspace via **Dynamical analysis | Workspace | Import**. Besides the import of measured data exported data from previous Vision sessions can be imported, this is a convenient method to use simulation results over multiple sessions (all the workspace variables are deleted after each session).



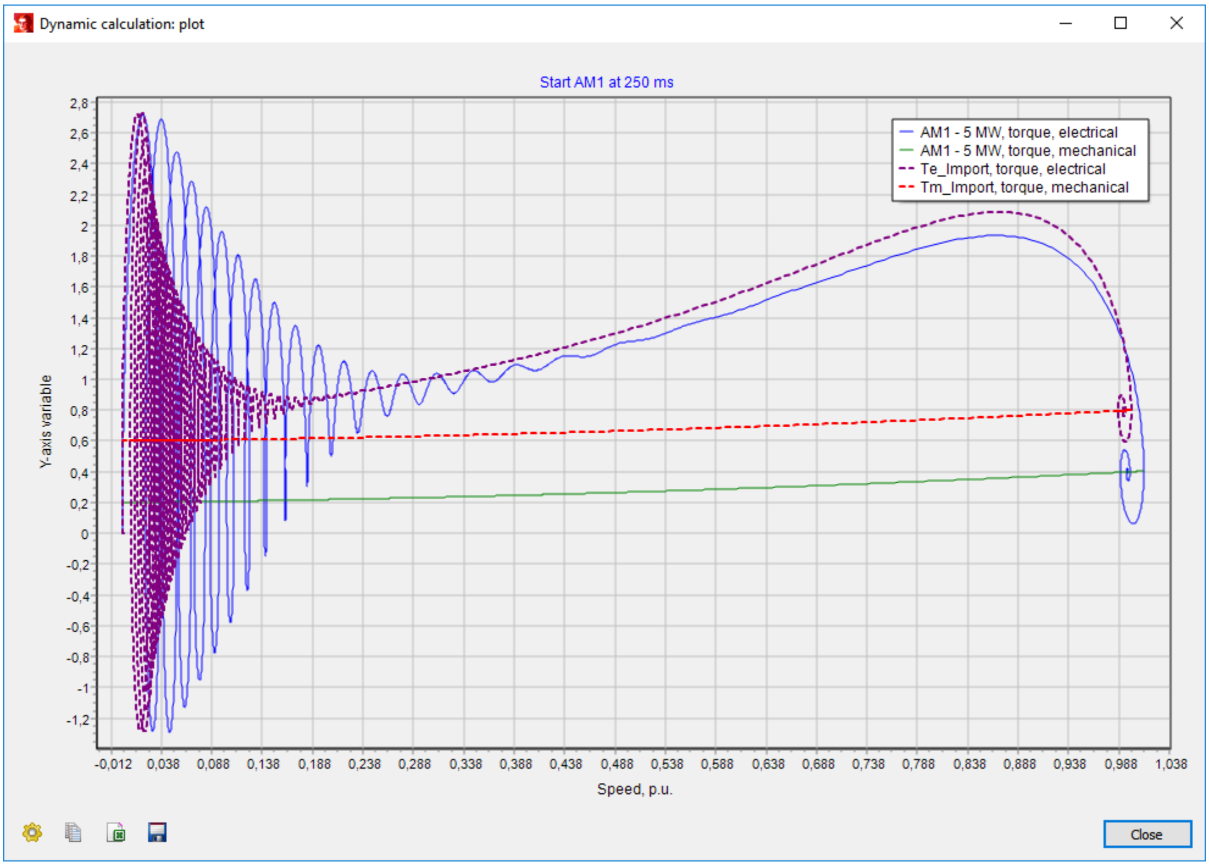
Vision can read files of five different extensions: .txt, .csv, .xls, .xlsx, and .adf files. A file with the extension .adf is the standard export file used by PlotXY (a program commonly used to plot ATP/EMTP results). The columns in a .csv file have to be separated by a semicolon symbol ';' (in some countries the comma is used as decimal mark), for a .txt file the separator is a tab. The first column contains information of the x-axis variable and the other columns – y-axis variables. The first row of each column is used to provide the variable description and the second row gives information about the unit of the variable. The format of the import file is identical to that of the export file of Vision Dynamical Analysis. Below an example of a .csv file is provided:

```
AM1 - 5 MW, speed;        AM1 - 5 MW, torque, electrical;        AM1 - 5 MW, torque, mechanical
p.u.;                     p.u. (of Tnom);                        p.u. (of Tnom)
0,000117484;              1,30153442;                            0,600008006
0,000132903;              1,30667197;                            0,600009057
0,000148435;              1,311813221;                           0,600010116
0,000164079;              1,316958593;                           0,600011183
0,000184183;              1,323523549;                           0,600012553
0,000200306;              1,32875156;                            0,600013653
0,000216545;              1,333984883;                           0,60001476
```

The workspace variables can be plotted by choosing **Dynamical analysis | Workspace | Plot** or directly after performing a dynamic simulation by a right mouse click on an node, element, or branch.



The workspace variables can be accessed by choosing 'workspace' in the ***Class*** pull-down menu. An example of the results of two different dynamic simulations of the start of a 5 MW asynchronous motor with different load characteristics is provided below. The dotted lines represent the responses of workspace variables and the solid lines show current simulation results.



6.16.7 Troubleshooting

Symptom	Cause	Possible solution
The simulation does not start in steady-state	Incorrect initialization	Set limits of controllers to the maximum value (for instance, for the excitation system of a synchronous generator)
	An event starts at time 0	Check the dynamic case
	Network contains induction machines*	The system will finally reach equilibrium, so just set the start time of an event after this moment.
Numerical instability	Maximum time step is too large	Chang***Maximum time step*** on **Dynamic analysis | Advanced**
	Tolerance is too large	Change tolerance on **Dynamic analysis | Advanced**
	Short cables with small shunt capacitances	Neglect cable capacitances of short cables via: **Dynamic analysis | Advanced | Neglect capacitances of cables** Or represent the respective lines/cables without shunt capacitances.
Slow simulation	Maximum time step is too small	Chang***Maximum time step*** on **Dynamic analysis | Advanced**
	Tolerance is too small	Change tolerances on **Dynamic analysis | Advanced**

	Network contains too many elements	Represent parts of the network by equivalents Set checkbox *Parallel Jacobian* on **Dynamic analysis | Advanced** Set checkbox *Eliminate links* on **Dynamic analysis | Advanced**
	Short cables with small shunt capacitances	Neglect capacitances of short cables via: **Dynamic analysis | Advanced | Neglect capacitances of cables**. Or represent the respective lines/cables without shunt capacitances.
Range check error	Internal	Inform Phase to Phase via: **OK | Save as |** *RangeCheckError.vnf* **| Send | By e-mail |** *info@phasetophase.nl*

* Mismatches can appear during the initialization of the network model due to differences in static/dynamic modelling of induction machines

6.17 IEC 61363

The calculation of short-circuit current according to IEC 61363 standard: “Electrical installations of ships and mobile and fixed offshore units – Procedures for calculating short-circuit currents in three-phase a.c.”.

6.17.1 General

The aim of IEC 61363 standard is the calculation of short-circuit currents in electrical networks of ships and offshore units. The important property of such networks is that there is no external network present. Networks of ships and offshore units operate typically in island mode. Due to relative weakness of the network the decrease of short-circuit current in time is of big importance. The standard considers only symmetrical three phase to earth bolted faults.

6.17.2 Model

IEC 61363 standard describes models of the following active elements:
- synchronous machines (see p.29, Section 5.1.1 of the standard)
- asynchronous motors (see p.37, Section 5.1.2 of the standard)
- converter-connected motors (see p.45, Section 5.1.4 of the standard)

Further, the models of the following branch components are given:
- cables (see p.47, Section 5.2.2 of the standard)
- transformers (see p.47, Section 5.2.3 of the standard)
- reactors (see p.49, Section 5.2.4 of the standard)

The short description of these models is provided below.

The following elements of Vision are not supported by the IEC 61363 calculation:
- external network (source): networks of ships/offshore units operate typically in island mode
- wind turbine
- PV
- accumulator
- grounding transformer (zigzag coil)
- shunt capacitor
- shunt reactor
- transformerload (transformer and load as one element)
- asynchronous motor group (use equivalent asynchronous motor instead)

Synchronous generator and motor

The synchronous machine is represented by an internal e.m.f. (electromotive force) behind resistor and reactor. The short-circuit current is divided in three periods: subtransient, transient and steady-state. The parameters of machine have to be specified for each period. IEC 61363 uses the approximation of synchronous machine with only d-axis reactances (q-axis reactances are neglected).

The envelope of the total short-circuit current in time (instantaneous values) is:

$$i_k(t) = \sqrt{2} * I_{ac}(t) + i_{dc}(t)$$

AC-component of the short-circuit current (RMS values) is:

$$I_{ac}(t) = \left(I''_{kd} - I'_{kd}\right) \cdot e^{-t/T''_d} + \left(I'_{kd} - I_{kd}\right) \cdot e^{-t/T'_d} + I_{kd}$$

where subtransient and transient components of the short-circuit current are calculated as follows:

$$I''_{kd} = \frac{E''_{q0}}{\sqrt{R_a^2 + \left(X''_d\right)^2}}$$

$$I'_{kd} = \frac{E'_{q0}}{\sqrt{R_a^2 + \left(X'_d\right)^2}}$$

Internal e.m.f.'s are dependent on the voltage, current and power factor just before the short-circuit (pre-fault situation):

$$E''_{q0} = \sqrt{\left(\frac{U_0}{\sqrt{3}} \cdot \cos\phi_0 + R_a I_0\right)^2 + \left(\frac{U_0}{\sqrt{3}} \cdot \cos\phi_0 + X''_d I_0\right)^2}$$

$$E'_{q0} = \sqrt{\left(\frac{U_0}{\sqrt{3}} \cdot \cos\phi_0 + R_a I_0\right)^2 + \left(\frac{U_0}{\sqrt{3}} \cdot \cos\phi_0 + X'_d I_0\right)^2}$$

Steady-state short-circuit current is calculated in an analogical manner. If Ikd parameter (tab Dynamic of the synchronous machine) is specified, the correction to the synchronous reactance Xd is applied such that the steady-state short-circuit current is equal to the specified value. If the option 'Use Ikd parameter of synchronous machines' is checked (see Vision Options, tab Calculation and then tab IEC 61363), then the synchronous reactance also corrected such that Ikd is at least 3 times larger than the nominal current of the machine.

DC-component of the short-circuit current (instantaneous values) is:

$$i_{dc}(t) = \sqrt{2} \cdot \left(I''_{kd} - I_0 \sin\phi_0\right) \cdot e^{-t/T_{dc}}$$

where DC-time constant Tdc can be specified explicitly (see tab Dynamic of the synchronous machine) or determined implicitly via the following equation (if 'Tdc unknown' option at the tab Dynamic of the synchronous machine is checked):

$$T_{dc} = \frac{X''_d}{R_a \cdot \left(2 \cdot \pi \cdot f_{nom}\right)}$$

The peak current of the short-circuit is defined by the standard as the total short-circuit current ik at time t = T/2 (for 50 Hz: 10 ms, for 60 Hz: 16.7 ms).

Asynchronous motor

The asynchronous motor is represented by an internal e.m.f. behind resistor and inductor. Asynchronous motors feed only subtransient short-circuit currents to the network. There is also aperiodical (DC) component present in the short-circuit current of the machine.

The envelope of the total short-circuit current in time (instantaneous values) is:

$$i_M(t) = \sqrt{2} \cdot I_{acM}(t) + i_{dcM}(t)$$

AC-component of the short-circuit current (RMS values) is:

$$I_{acM}(t) = I''_M \cdot e^{-t/T''_M}$$

where the subtransient short-circuit current is:

$$i_M(t) = \sqrt{2} \cdot I_{acM}(t) + i_{dcM}(t)$$

Internal subtransient e.m.f. is dependent on the pre-fault situation (voltage, current and power factor of the motor):

$$E''_M = \sqrt{\left(\frac{U_{0M}}{\sqrt{3}} \cos\phi_{0M} - R_M I_{0M}\right)^2 + \left(\frac{U_{0M}}{\sqrt{3}} \sin\phi_{0M} - X''_M I_{0M}\right)^2}$$

Equivalent resistance and reactance of the motor are:

$$R_M = R_R + R_S$$
$$X''_M = X_R + X_S$$

DC-component of the short-circuit current (instantaneous values) is:

$$i_{dcM}(t) = \sqrt{2} \cdot \left(I''_M + I_{0M} \sin\phi_M\right) \cdot e^{-t/T_{dcM}}$$

Time constants of the motor are calculated from stator and rotor resistances and reactances:

$$T''_M = \frac{X_R + X_S}{R_R \cdot (2 \cdot \pi \cdot f_{nom})}$$

$$T''_M = \frac{X_R + X_S}{R_R \cdot (2 \cdot \pi \cdot f_{nom})}$$

The peak current of the short-circuit is defined by the standard as the total short-circuit current iM at time t = T/2 (for 50 Hz: 10 ms, for 60 Hz: 16.7 ms).

Parameters of the asynchronous motor (R_S, R_R, X_S, X_R) can be filled-in on tab *Dynamic* of the respective motor. The option ‘Own parameters’ has to first checked in order to do this. In case this option is not checked, the resistances and reactances are estimated from the locked-rotor data, critical torque and the nameplate data. In case ‘double cage’ model is chosen, the equivalent rotor impedance is calculated using parallel connection of the first and second rotor circuit.

Converter-connected motors
Converter-connected motors do not contribute to the short-circuit current.

Cable
All cables are represented by a series connection of resistor and inductor. According to the standard the shunt capacitances of cable are neglected. The resistance of cable is adjusted based on the conductor temperature. This occurs in case the option ‘Apply conductor temperature’ in Vision Options on tab Calculation | General is checked. The adjustment due to temperature takes place in the same manner as for IEC 60909. The correction factor is equal to:

$$\frac{1+0.004\cdot\left(T_{act,\circ}-20^\circ\right)}{1+0.004\cdot\left(T_{ref,\circ}-20^\circ\right)}$$

where $T_{ref,\circ}$ is the reference temperature (specified in the type-file) and $T_{act,\circ}$ is the actual temperature (specified in Options).

Transformer
The transformer is modelled by a series connection of resistor and inductor. Parameters are calculated from data of the short-circuit test. Taps of the transformers are set to the nominal positions.

Reactor
The reactor is represented by a series connection of resistor and inductor.

Link
The impedance of link is neglected in the IEC 61363 calculation. Nodes (busses) connected to each other by the links are considered internally as one node (bus).

Load
The load does not feed short-circuit current to the network. Therefore the loads are not considered during short-circuit calculation. Loads have influence only in case the loadflow calculation is used for initialization of IEC 61363 calculation.

6.17.3 Calculation

First, nodes (or a node) have to be selected in order to start IEC 61363 calculation. After that the calculation can be started from the menu **Calculate | IEC 61363**.

Options
The following calculation options can be set in Options:
- Calculation times in periods of nominal frequency or in milliseconds. These are the moments in time, for which the short-circuit current is to be calculated.
- Three initialization options: initialization using nominal data (Uo=Unom, Io=Inom), initialization by the loadflow calculation (Uo=Uloadflow, Io=Iloadflow) and the calculation from no-load conditions (Uo=Unom, Io=0). The choice of initialization option has influence on the internal e.m.f.’s of machines and on the resulting short-circuit currents. In case of initialization using loadflow calculation attention must be paid to the convergence of the loadflow in island mode (for more details see Island mode).

- *Use Ikd parameter of synchronous machines* : if this option is used, the steady-state short-circuit current is adjusted in such a way that it becomes equal to the data entered on tab *Dynamic / IEC 61363* for respective machine. If Ikd of a synchronous machine is set to zero, then Ikd for this machine is calculated automatically.
- *force Ikd of synchronous machines to at least 3xInom* : in case this option is set, the steady-state short-circuit current is forced to be at least 3 times the nominal current for each synchronous machine. This is valid for the case of short-circuit at the generator terminals. With increase of (electrical) distance to the short-circuit point the short-circuit current decreases. The forcing of the steady-state short-circuit current (that represents the forcing of the field voltage/current of a synchronous generator) takes place only if the steady-state short-circuit current is smaller than 3 times Inom.
- *display warnings* : warnings, for instance, for the forcing of steady-state short-circuit current of synchronous machines can be switched on and off. Error messages are always displayed.

Algorithm

The algorithm of the calculation is as follows. First, the short-circuit currents for all synchronous and asynchronous machines are calculated (at times set in Vision Options). These short-circuit currents are equal to the currents during short-circuits at machines terminals. Further, equivalents of the machines that are connected to the same node are found according to Sections 7.3 and 7.4 of the standard. If there are only asynchronous motors connected to a node, then parameters of equivalent asynchronous motor are determined (Section 7.3). If there are synchronous machines present (or a combination of synchronous and asynchronous machines), then parameters of equivalent synchronous generator are computed (Section 7.4). Decrease of the short-circuit current with (electrical) distance is modelled by adjustment of the time constants and impedances of equivalent machines. Resistances and reactances of passive branches (that are connected to machines in series) are used for this adjustment. The manner, in which it is done, is described in Section 8.2 of the standard. Vision applies equivalencing of machines and passive branches step by step until the network becomes fully equivalenced. In the end situation there remains only one synchronous generator, which is connected to the short-circuited node. Currents of this fictive generator are equal to the total short-circuit currents during short-circuit at the selected node.

6.17.4 Result

Nodes (or a node) have to be selected in order to start IEC 61363 calculation. If only one node is selected, the results for the three phase fault at this node are shown. If more than one node is selected, the results of the short-circuit calculation for three phase faults at all selected nodes are shown.

Results that are shown on the network scheme:
- peak current
- total short-circuit current (instantaneous values) at 5 time points defined in Options

Results that are shown in the details (Calculation | Results | Details):
- peak current
- subtransient, transient and steady-state short-circuit currents (RMS values) of fictive equivalent synchronous generator
- AC-component (RMS values), DC-component (instantaneous values) and total short-circuit current (instantaneous values) at 5 time points defined in Options

6.18 Arc flash

The Arc Flash module determines the energy that is emitted by the arc in case of a short circuit in an installation. Based on the arc energy the category of Personal Protective Equipment (PPE) is chosen. The module contains two methods of the arc flash calculations: according to the IEEE 1584 standard and according to the closed box text method of International Social Security Association (ISSA).

6.18.1 General

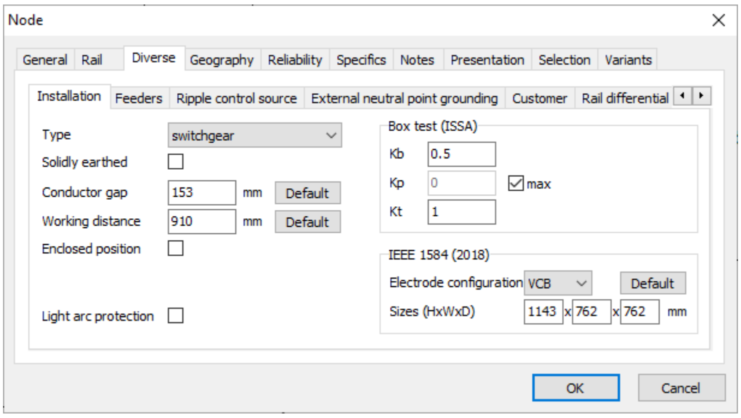
It happens quite often in practice that work has to be performed in an electrical installation (distribution station, switching room, etc.). Examples of this work are racking in/out the withdrawable circuit breaker unit, replacement of a fuse and so on. Sometimes things can go wrong during the work in the installation (due to human error and/or defect in the installation) and a short circuit can occur. The short circuit shows itself in the form of an arc that can have various effects on the working personnel. The arc flash phenomena include very strong light, shock wave and very loud sound blast (can be compared to that of an explosion). Also a lot of thermal energy is released that can cause serious burns to the personnel.

There exist two methods for calculation of the thermal arc flash energy (incident energy):
- IEEE 1584 method: according to "IEEE Guide for Performing Arc-Flash Hazard Calculations";
- closed box test method of ISSA: "Guideline for the selection of personal protective equipment when exposed to the thermal effects of an electric fault arc".

Both methods are based mainly on the results of experiments. The choice between two methods is possible via **Options** (F11, tab **Calculation | Arc flash**).

6.18.2 Model

The parameters used for the arc flash calculation are to the large extent the same as for the short circuit current and protection calculations. There are several extra parameters necessary that can be set via node input data. On tab Specials -> Installation type and parameters of an installation are specified.



It is possible to choose between four different types of the installations: open air, switchgear, cable and motor control center MCC (the last option only for the nominal voltage up to and including 1 kV). Type of installation has influence on the distance factor in the IEEE 1584 calculation.

Solidly earthed checkbox specifies whether the network neutral is solidly earthed. This has influence on the coefficient K2 in the IEEE 1584 calculation.

Conductor gap is the distance between the conductors where the arc flash occurs. Default button fills in the typical conductor gaps from Table 2 of the IEEE 1584. However, it is preferable to use the real values of conductor gaps. For varying conductor gaps it can be advised to perform calculations for minimum, maximum and average gaps. In the IEEE 1584 calculation the conductor gap has influence on the arc current and the incident energy. In the ISSA calculation the conductor gap is in principle not used. The user can manually set the Kp factor based on the conductor gap value (using Table A1.1 of the ISSA).

Working distance is the distance between the conductors and the head/torso of a person (this is not the distance to hands of a person!). Typical working distances can be set using Default button (Table 3 of the IEEE 1584). However, it is preferable to use the real values of working distances. The working distance is used in both IEEE 1584 and ISSA.

Enclosed position checkbox specifies whether it is possible to escape from the arc in 2 seconds. In case the working position is enclosed, this is not possible and the calculation continues until the short circuit is completely isolated. Otherwise the calculation stops on 2 seconds (this is the rule of thumb from IEEE 1584). This option is applicable for both IEEE 1584 and ISSA.

'Box test' parameters are the parameters that are used only by ISSA. Their meaning is explained below.

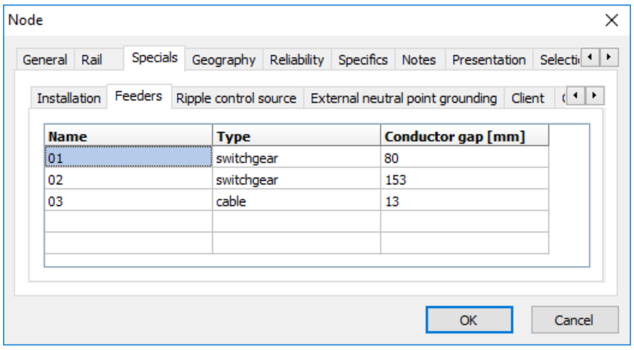
Kb is the current attenuation factor. The arc current is equal to the product of the minimum short circuit current and the current attenuation factor. The typical value of Kb is 0.5.

Kp is the coefficient of the arc power. The arc power is equal to the product of the short circuit power and the Kp-factor. The value of *Kp* can be set manually (in case if the checkbox max is not checked) based on Table A1.1 of the ISSA. If the checkbox max is checked, then the coefficient is computed according to the following formula (dependent on the R/X ratio of the short circuit):

$$K_{p\_max} = 0.29 \cdot \left(\frac{R}{X}\right)^{-0.17}$$

Kt is the transmission factor used for the calculation of the PPE protection level. This factor is dependent on the volume of the installation and varies between 1.0 and 2.4. The larger the volume is, the higher is the transmission factor. This means that the arc energy is evenly distributed in space (which reduces the negative effects of the arc on person). For example, the value of 2.4 are applied to open installations, while the value of 1.0 is typical for closed installations. Larger transmission factor results in higher protection levels of PPE.

It is also possible to specify deviating parameters for ingoing and outgoing feeders (that are connected to the node). Namely, different types of installations and conductor gaps can be set. In case feeders are not specified, the parameters of the node are used also for connected feeders. Feeders can be coupled as given in Field 236.



The recent edition of the IEEE 1584 standard from 2018 introduces choice between different types of electrode configurations (open or closed, vertical or horizontal). Description of the types of electrode configurations and their photos are to be found in the standard. Further it is possible to specify dimensions for closed installations. Typical dimensions are given in Table 8 of the standard. It is however advised to use the actual dimensions. Specific parameters that are necessary for IEEE 1584 and ISSA calculation in Vision can be summarized in table:

Parameter	**IEEE 1584-2002**	**IEEE 1584-2028**	**ISSA**
vpe installation	Yes	Yes	No
olidly earthed	Yes	Yes	No
onductor gap	Yes	Yes	No
'orking distance	Yes	Yes	Yes
nclosed position	Yes	Yes	Yes
b	No	No	Yes
o	No	No	Yes
t	No	No	Yes
lectrode configuration	No	Yes	No
'imensions	No	Yes	No

6.18.3 Calculation

The arc flash calculation can be started as follows. Select one or more nodes and optionally one or more branches/elements that are connected to these nodes. Selection of the whole network is also possible (Ctrl+A shortcut key). After that, start the calculation via ribbon **Calculation | Arc Flash**. The choice between two calculation methods (IEEE 1584 and ISSA) is possible via **Options** (press F11 and go to tab **Calculation | Arc flash**). Algorithms for IEEE 1584 and ISSA are slightly different from each other, below those algorithms are explained:

Algorithm of IEEE 1584-2002:
- first, the bolted fault current is determined using Fault Analysis module of Vision;
- after that, the arc current is calculated according to Section 5.2 of the standard;
- based on the arc current the equivalent fault resistance Rff is determined that corresponds to this current;
- then, the three phase short circuit with the fault resistance Rff is simulated and the operation of protection is analyzed (module Protection, Single Fault function);
- the incident energy for each switching sequence is determined from the currents and times of the switching sequences according to Section 5.3 of the standard;
- the total incident energy is equal to the sum of the energies of all sequences.

The steps mentioned above are executed two or four times (dependent on the nominal voltage of an object). In case of the nominal voltage up to 1 kV four situations are computed:
- maximum short circuit power of grid and 100% arc current;
- maximum short circuit power of grid and 85% arc current;
- minimum short circuit power of grid and 100% arc current;
- minimum short circuit power of grid and 85% arc current.

In case the nominal voltage is above 1 kV, only the situation corresponding to 100% arc current are computed. For the installations above 15 kV or conductor gap outside the gaps specified by the standard (G<13 mm or G>153 mm) theoretical Lee model is applied (Section 5.4 of the norm). Lee model leads often to too conservative results, therefore Vision gives a warning message in case this model is used.

Algorithm IEEE 1584-2018:
The algorithm is to a large extent the same as that of IEEE 1584-2002, but the formulas are quite different. Therefore results in some cases can differ significantly from that of the old version of the standard. Important characteristics of IEEE 1584-2018 with respect to IEEE 1584-2002 are as follows:
- Lee-model is not supported anymore, the upper limit for the nominal voltage is 15 kV;
- calculations are performed at 0.6, 2.7 and 14.3 kV nominal voltages, then the values of the arc current, arc energy and arc flash boundary are interpolated/extrapolated to the actual nominal voltage;
- the reduced arc current is no more equal to 85% of the original value, but is determined in a special manner dependent on the electrode type and the dimensions of the installation.

Algorithm of ISSA:
- first, all motors and induction generators are temporarily switched off and short circuit power of grid is set to the minimum value, then the minimum short circuit current is determined using Fault Analysis module of Vision (this is an equivalent of the minimum short circuit calculation of IEC 60909);
- the arc current is equal to the minimum short circuit current times the current attenuation factor Kb;
- based on the arc current the equivalent fault resistance Rff is determined;
- then, the three phase short circuit with the calculated above fault resistance value Rff is simulated and the operation of protection is analyzed (module Protection, Single Fault function), the results of this step are the (maximum) tripping times of the protective relays;
- for each switching sequence the maximum short circuit current is calculated according to IEC 60909;
- energy for each switching sequence is computed from maximum short circuit currents and maximum tripping times;
- the total incident energy is equal to the sum of energies of all sequences.

Detailed calculation results with details about switching sequences can be get via button **Details** (right mouse click on an object with the arc flash results and after that click on Details button).

6.18.4 Result

The result of the calculation is the arc incident energy and the category/class of PPE (that limits the potential burn wounds to maximum the second degree burn). PPE classification is different for IEEE 1584 and ISSA. IEEE 1584 follows the classification of the NFPA (National Fire Protection Association). According to NFPA there exist the following PPE categories (see Table 130.7(C)(15)(c) of NFPA 70 E (2018)):

PPE category	Incident energy (E) [cal/cm²]
0	E 1.2
1	1.2 < E 4
2	4 < E 8
3	8 < E 25
4	25 < E 40

The PPE category 0 is eliminated in the 2015 edition of the NFPA 70E, in Vision this category is still in use to indicate that the incident energy 1.2 cal/cm². The ISSA specifies two PBM classes:

PPE class	Arc energy* (W) [kJ]
1	W 168
2	168 < W 320

* arc energy is specified for the installation with Kt = 1 and the working distance of 30 cm

The results are displayed slightly differently for IEEE 1584 and ISSA.

Basic results of IEEE 1584 are:

Earc	the total incident energy in cal/cm2 at working distance
PPE category	Personal Protection Equipment specified by the NFPA ('X' in case if the incident energy is higher than 40 cal/cm²)
FPB	arc Flash-Protection Boundary in mm (the minimum distance at which potential burn wounds are limited to maximum the second degree burn, without PPE)

Extended IEEE 1584 results are (right mouse click on an object with the arc flash results):

Ibf	bolted fault current in kA
Iarc	arc current in kA
Earc	the total incident energy in cal/cm² at working distance
PPE category	Personal Protection Equipment specified by the NFPA ('X' in case if the incident energy is higher than 40 cal/cm²)
SWD (or Dbn)	Safe Working Distance in mm, IEEE 1584-2002 only (SWD is the minimum distance at which potential burn wounds are limited to maximum the second degree burn, with the specified PPE category (n))
FPB (or Db0)	arc Flash-Protection Boundary in mm (the minimum distance at which potential burn wounds are limited to maximum the second degree burn, without PPE)
Rpp	equivalent fault resistance (can be used for further analysis with **Fault analysis | Fault | symmetric** or **Protection | Single fault | symmetric**)

Basic results of ISSA are:

Warc	the total arc energy in kJ
PPE class	Personal Protection Equipment specified by the ISSA ('X' in case if the arc energy is higher than energy for PPE Class 2)
Dbn	safe working distance with PPE class n in mm

Extended ISSA results are (right mouse click on an object with the arc flash results):

Ibf	bolted fault current in kA
Iarc (or IkLB)	arc current in kA

Wprot1	maximum protection energy using the specified work conditions with PPE class 1
Wprot2	maximum protection energy using the specified work conditions with PPE class 2
Warc	the total arc energy in kJ
PPE	PPE class ('X' in case if the arc energy is higher than energy for PPE Class 2)
Rpp	equivalent fault resistance (can be used for further analysis with **Fault analysis | Fault | symmetric** or **Protection | Single fault | symmetric**)
Dbn	Safe Working Distance in mm (SWD is the minimum distance at which potential burn wounds are limited to maximum the second degree burn, with the specified PPE category (n))

Detailed calculation results with details about switching sequences can be get via button **Details** (right mouse click on an object with the arc flash results and after that click on Details button).

Results of protection calculation
In case arc flash calculation is performed only at one point (for instance, at one node or one side of a branch), the results of corresponding protection calculation can also be shown. This can be done by clicking on the ribbon **Extra | Result | Protection – Single fault** (by Result the small arrow at the bottom of the icon has to be clicked). Results of the protection calculation for three-phase symmetric fault with Zpp equal to the arc resistance will be given and the details of protection operation can be checked. After that, it is possible to switch back to the arc flash results (this can be done in a similar manner as it was done for protection results).

6.19 Netcheck

The netcheck helps to assess a request for a new load or generation.
To this goal, two network load calculations are performed: one of the current situation and one in which the new element has been added. In both network load calculations the evening and afternoon situation are calculated.
The change in current or voltage is calculated per object.
The deterioration is assessed and, if necessary, objects are coloured if they exceed the limit.

Calculation

Select only the node where the load is to be applied.
Start the calculation with **Calculate | Special | Netcheck**.
A form appears in which you can enter the power and the application (load, PV, wind or generation).
Exit the form with **OK**.

First a network load calculation is done where the load is not yet added. The results are stored in memory.
Now the load, PV, windturbine or synchronous generator is added.
The second network load calculation is done.

Results
The results are per object type:

Node
- U,afternoon,before and U,afternoon,after
- U,evening,before and U,evening,after
- dU,before and dU,after

Branch
- Maximal load rate,before and maximal load rate,after

Element
- Maximal load rate,before and maximal load rate,after

The options for viewing the results are:

- in the scheme
- in **Calculate | Results | Overview**
- in **Calculate | Results | Details**

Scheme
For nodes, the two lines are the voltages for afternoon and evening situation.
For branches and elements, it is one line with the maximum load rate in any situation.
The color of the objects has a meaning after performing a calculation. The colors can be set in th***Options*** with **Calculation | General**. The limits can be set in **Calculation | Limits**. Below, the default color is indicated between brackets.

Nodes
- Black: no details
- Too high color (red): U,after too high and higher than 1.01*U,before
- Too low color (blue): U,after too low and smaller than 0,99*U,before
- Too high color (red): dU,after too big and greater than 1.05*dU,before
- Island color (green): no voltage

Branches and elements :
- Black: no details
- Too high color (red): load rate,after too high and load rate,after greater than 1,05*load rate,before
- Island color (green): no voltage

The factors relative to the pre-values are to ignore already existing exceedances.

Calculation | Results | Overview
This screen gives an overview of all the problem objects. These are the objects that have been given the high color or low color in the scheme.

Calculation | Results | Details
The results of selected objects are shown.

6.20 Power generating module

In the Netbeheer Nederland document “Power generating module Document (“PGMD”)” for type B and C electricity generation units, a calculation is required to demonstrate that a wind or solar farm meets the grid code requirements for reactive power.
The calculation Power generating module calculates the active and reactive power at the transfer point and shows the results in a table and graph. These results can be appended to the document.

Preparation

A network consisting of solar panels and/or wind turbines with associated infrastructure (cables, transformer) must be entered.
At the transfer point, the 'grid' must be modeled as a source.

Calculation

Start the calculation with **Calculate | Special | Power generating module**.

The computation performs 14 loadflows with different settings:

Loadflow	Source.Uref (pu)	PV.p and Windturbine.p (pu)	PV.q and Windturbine.q (pu)
0	1	1	0
1	1	0.8	-0.6
2	1	0.8	0.6
3	1	0.2	-0.6
4	1	0.2	0.6
5	1	0	0
6	1.1	0.8	-0.6
7	1.1	1	0
8	1.05	0.8	0.6
9	0.95	0.8	0.6
10	0.9	0.8	0.6
11	0.9	1	0
12	0.95	0.8	-0.6
13	0.85	0.8	0

Any controls (except P(I) control) of PVs and wind turbines are switched off. The requested power is supplied anyway and reactive power possibly absorbed.

The setting of each PV is:
P := p (pu) * Inverter.$_{Snom}$, but not greater than the power of the panels
Q := q (pu) * Inverter.$_{Snom}$
During the load flow at low voltage, P and Q are still reduced so that the current does not exceed de I_{nom} (calculated from S_{nom}) of the inverter.

The setting of each wind turbine is:
P := p (pu) * Type.P_{nom}
Q := q (pu) * Type.P_{nom}

Results

Standard load flow results are available from each load flow:

- Nodes: U
- Branches: P, Q, S, I, load rate, P_{loss}
- Elements: P, Q, S, I, cos phi, load rate (S/S_{nom}), I/I_{nom}, U

These results are aggregated to:

- Nodes: the minimum and maximum voltage
- Branches: the minimum and maximum load rating
- Elements: the minimum and maximum active power and reactive power

The options for viewing the results are:

- in the diagram
- in **Calculate | Results | Overview**
- in **Calculate | Results | Details**

Scheme
At nodes, the minimum and maximum voltage.
At branches, the minimum and maximum load rating.
At elements the minimum and maximum active power and reactive power.
The objects are colored when voltage is exceeded or overloaded.

Calculate | Results | Overview
This screen does not provide much information yet.

Calculate | Results | Details
The results of selected objects are shown.
The button **Details** shows the results of all load flows in a table.
With the button **Graph** at elements two graphs are shown successively.

6.21 Switchability

The calculation analyzes the restoration of electricity supply during grid failures.

Preparation

The voltage and load rate limits must be defined in the Options, at Calculation | Limits.
The afternoon and evening load and generation rates should be defined in the Options, at Calculation | Presets.
The disturbance analysis options must be defined in the Options, under Calculation | Network analysis | Failure analysis.

All circuit breakers and fuses must be modeled in the network. It is not necessary to specify circuit breaker protections.

Enexis

For Enexis, the percentages and maximum number of switching operations are hard-wired in:
- The maximum number of switching operations is three.
- In the load situation, the load is 100% and the generation, PV and wind are 0%.
- In the generation situation, PV and wind are 100% and load is 25%.

These options are automatically applied when using the Enexis network key.

Calculation

Start the calculation with **Calculate | Special | Customized | Switchability**.

The calculation performs the failure analysis for all non-mesh medium-voltage cables in load situation (evening) and generation situation (afternoon).

Resultaten

The following results for each cable are available for each load/generation situation:
- Offshoot
- Possible switching points
- Switched points
- Good and fast solution
- Weakest branch load rating
- Number of overloaded branches
- Lowest-node voltage
- Highest-node voltage

The options for viewing the results are:
- in the scheme
- in **Calculate | Results | Overview**
- in **Calculate | Results | Details**
- in **Calculate | Results | Export**

Scheme
For cables, the number of switching operations.
The color of the cables has a meaning after performing the calculation. The colors are not adjustable.

Color indication
A cable that can be switched with few switching operations in both situations is drawn in the color green.
A cable that can be switched in both situations with many switching operations is drawn in the color orange.
A cable that cannot be switched in at least one of the situations is drawn in the color red.

For up to one, two or three switch actions, one switch action is little and two or three is much.
At a maximum of four, five or six switching acts, one, two or three switching acts is few and four, five or six is many.

Calculate | Results | Overview
This screen lists:

- Offshoot cables (where in fault cannot be switched)
- Non-offshoot cables in which in failure (complete) switching cannot be done
- Cables that cannot be rapidly switched.

Calculate | Results | Details
Of selected cables, the number of switching operations in the two situations is shown.
The **Details** button shows all results of the two situations in a table.

Calculate | Results | Export
Of all cables, all results are exported to an Excel file.

6.22 Frequency disconnection

The calculation performs load flows at different frequencies, applying the frequency protections present to shut down portions of the network.

Calculation

Start the calculation with **Calculate | Special | Customized | Frequency disconnection**.

The calculation performs load flows at the following frequencies:

- 1 pu
- 0,996 pu
- 0,98 pu
- 0,976 pu
- 0,972 pu
- 0,968 pu
- 0,964 pu
- 0,96 pu

With a system frequency of 50 Hz specified in the options, this means 50, 49.8, 49, 48.8, 48.6, 48.4, 48.2 and 48 Hz.

Results

The options for viewing the results are:

- in the one-line diagram
- in **Calculate | Results | Overview**
- in **Calculate | Results | Details**

- in **Calculate | Results | Graph**

The results are similar to the load flow results.

Color indication
Circuit breakers tripping at any time are shown in the attention color.
Otherwise, the colors are according to the load flow colors.

6.23 Data driven loadflow

The Data driven loadflow (also known as State estimation) determines the most probable network state (voltages, currents and powers) based on the measurements provided. In case of gaps in measurement data, they can be automatically filled up using built-in preprocessor tool.

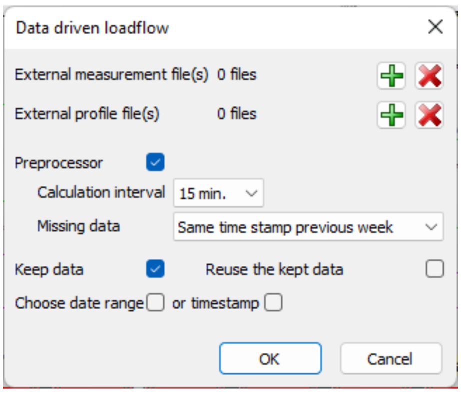
6.23.1 General

In the traditional load flow method, the powers of all loads and generators have to be defined at the start of the calculation, and no uncertainty is considered. The results are exactly as they were specified. This is perfect in an ideal scenario but in reality, that is often not the case. Some of the powers are unknown/not measured, measurements are not exact due to sensor errors, and might represent the variables averaged over some time period. Further, in the load flow formulation no powers/currents through the branches can be specified explicitly. Data driven loadflow, on the contrary, is flexible in this respect since it allows to use different types of measurements. It takes into account the available measurement data, and with the help of pseudo-measurements the gaps are filled with some variance associated so that after computation the most probable estimate of network state can be found out. In certain sense, this process can be seen as an extension of the load flow method, therefore state estimation can be also referred to as Data Driven Load Flow. For more information, see State Estimation / Data Driven Load Flow.

6.23.2 Calculation

The calculation of Data driven loadflow is quite similar to the profile loadflow.

It is carried out as follows:
- Choose **Calculate | Analyses | Data driven loadflow**
- Specify the settings.



Measurement and profile files
The measurement files available can be added. These can include active and reactive power injections, currents, voltages, branch power flows. These are coupled with the MV/LV transformers, the large consumers as well as specified for the measuring devices at the beginning of the feeders with the external measurement file(s) option. If a reference profile file is intended to be used, the profile can be added into the second option i.e. external profile

file(s). Data from the reference profile can be used to fill in the missing gaps in measurement data. Also in case measurement for a (transformer-)load is completely missing, synthetic or typical profile can be used to improve the estimation process. More information about an external profile can be found in External profile 232.

Pre-processor

To make sure that the measurement data which has been added with the external files is complete, the user has an option to fill in the missing gaps with the pre-processor tool. The available pre-processing methods are described in detail at: State Estimation / Data Driven Load Flow. Below the short summary is provided.

Calculation interval

The calculation interval can be manually selected if needed. It has to be equal or greater than the interval used in the measurement/profile files to make sure the data is comprehendible and as accurate as possible.

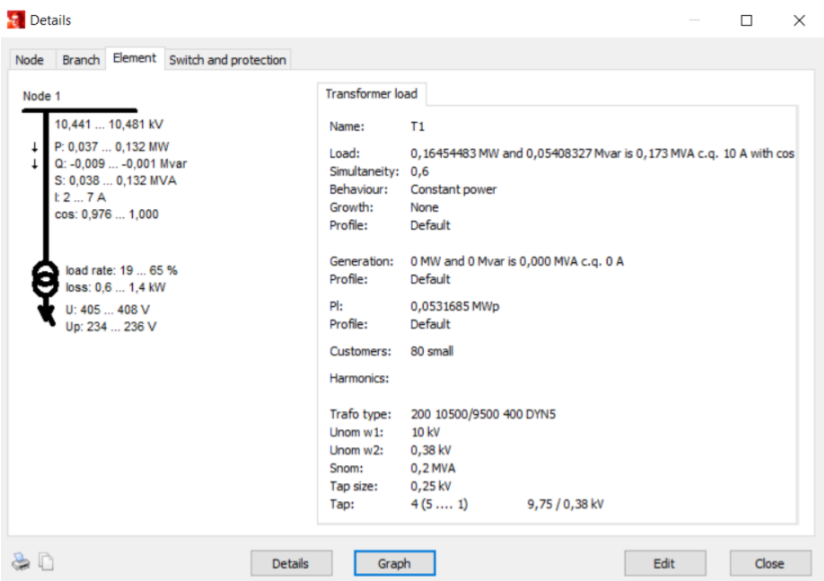
Missing data

The missing gaps in the measurement profiles can be filled by using the various techniques under this option:

- Same timestamp value from previous week
- Same timestamp value from previous day
- Same value from previous timestamp
- Average value of same timestamps (previous 10 days)
- Reference profile

6.23.3 Result

After computation, the results can be viewed for any object by right clicking it and using the ***Details*** button to display numerical results and the ***Graph*** button for making a plot.



As seen, the values shown are the range between maximum and minimum in which the variable varies in a computed time period. It is to be noted that these maximum or minimum values of different variables do not necessarily occur at the same instance, i.e. Pmax = 0,132 MW and Qmax = –0,001 Mvar shown in the example above might happen at different times.

The different types of variables like loading percentage, active power, reactive power, voltage, current and so on that need to be plotted can be selected in the graph view with the dropdown box at the bottom. The graph can also be exported in multiple formats (metafile and bitmap) using the right mouse button context menu. The plotting of individual points can be eliminated to display only the continuous line by unchecking the "Points" option. If multiple objects were selected before clicking on ***Graph*** button, the results for all these objects will be plotted.
The colors and the details when Data driven load flow is performed is similar to that of result from load flow with profiles.

7 Macros

Vision supports a number of individual calculations. Sometimes, however, you may want to make a particular calculation several times in quick succession, changing the input data slightly each time. To enable you to do this, Vision is provided with a programming language: a macro language.

Macros are saved as text files. An advanced macro editor is provided for writing macros.

Results can be automatically reported in Excel, with the user determining what data is included in the spreadsheet printout. The user can also control the spreadsheet layout to a large extent.

7.1 Macro editor

A macro editor is provided for writing macros. Since macros are not linked to network files, the macro editor is located at **Tools | Macros**. The editor reads and writes macros from/to separate files, each with the extension 'vmf' (Vision Macro File). Vmf files are text files.

The macro editor uses styles to indicate commands, parameters, variables and comments. Also the user is assisted with "code inside" and "code completion" functions. These enhancements reduce the chances of typing errors and erroneous usage of attributes.

The editor uses the following styles:

Commands	**bold**
Objects and variables	normal
Numbers	blue
Texts	'red'
Comments	//green

A number of macro command lines will be interpreted as comments if it has been enclosed mit **(*** and ***)**. The comment block starts by positioning (* at the command line begin. The comment block ends by positioning *) at the command line end.

The "code inside" function supports the user with help on the remainder of the parameters of commands. The "code inside" is activated automatically when the command and its left parenthesis are typed.

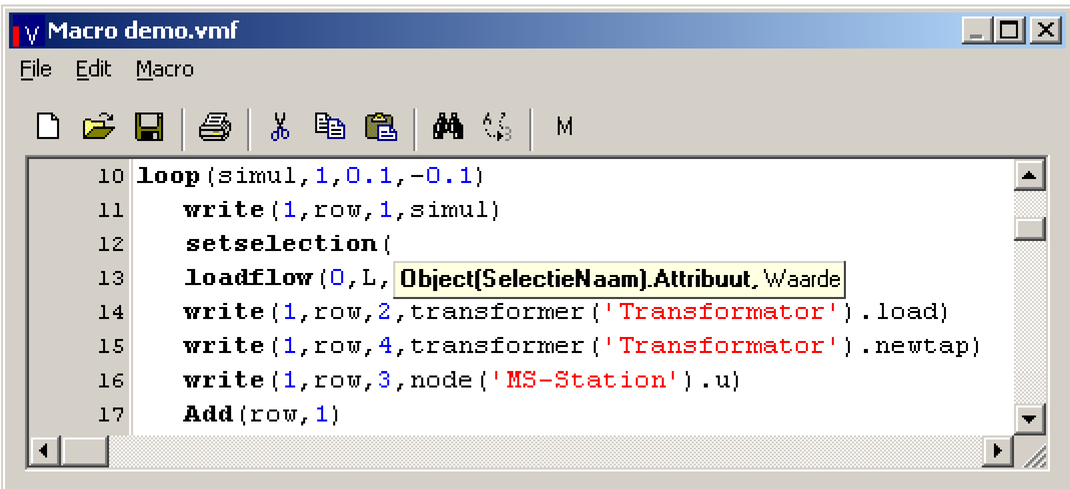


Figure: Code Inside

The "code completion" function supports the user with a typing help for the objects attributes. The "code completion" is activated automatically when the object and its dot are typed.

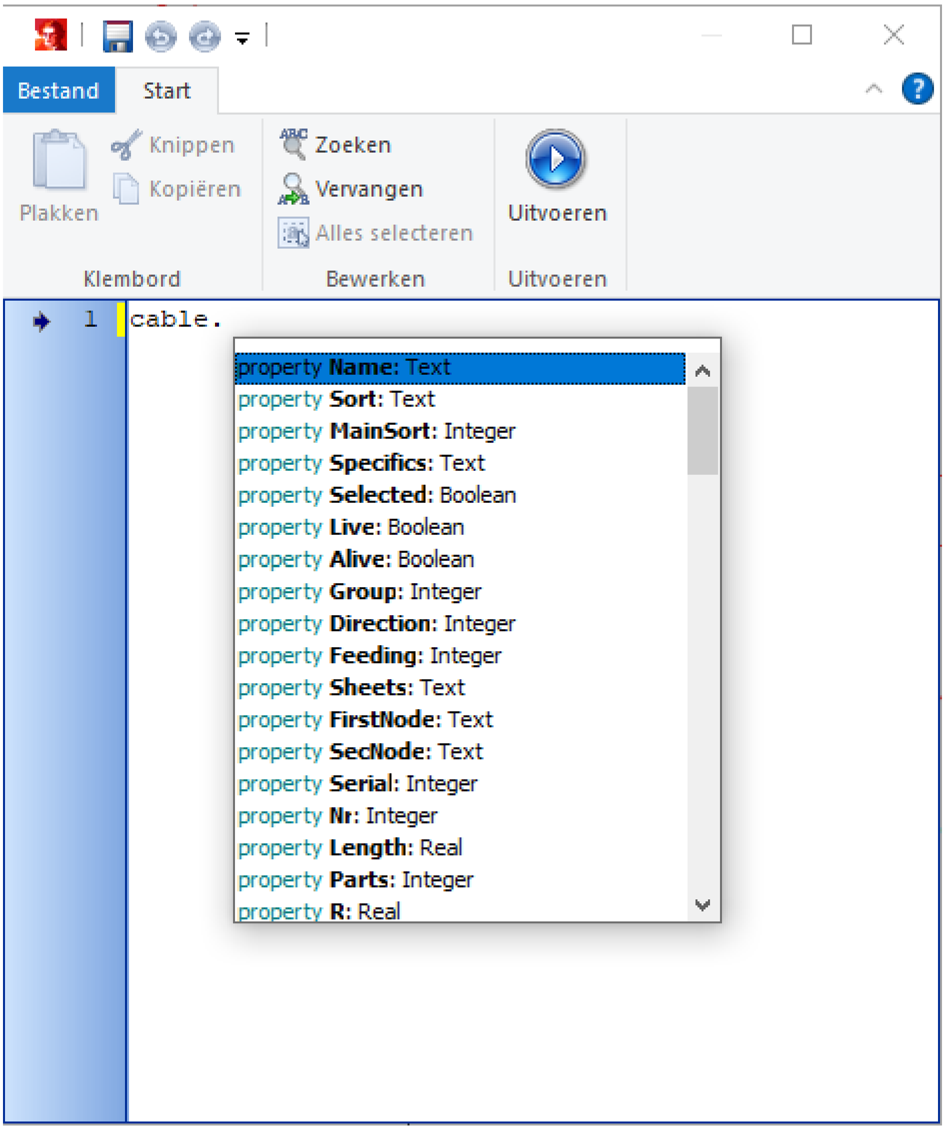


Figure: Code Completion

The macro editor reads and writes the macros using text files with the extension vmf.

7.2 Macros: calculations

A macro is run on the current network, via **Calculation | Macro**, where you select the macro file you want. It is also possible to run the macro directly from the macro editor, using **Macro | Execute** or the **F9-key**.

To run the macro, a copy of the network is made in the memory. This means macros can be run without affecting the current network. It also means that changes made to the settings by the macro are no longer available once the macro calculations have been completed.

First, a quick test is performed to make sure that the macro meets a number of basic conditions concerning commands, number of parameters and loops. If everything is OK, the macro is run.

The results of the calculations are written to Excel or to a text by the macro. The user can determine what data is included in the printout. He or she also has control over the spreadsheet layout. The results are not available in the current network (in the Vision editor).

Because the macros make use of network component names, they are often specific to a particular network. Generally, therefore, macros will not work on other networks. However, they can easily be adapted for other networks, simply by changing the component names.

Maximum number of iterations

The maximum number of iterations in loops like while and repeat may be limited, because a macro can not be interrupted by the user in the case of an "infinite loop". See th***Options*** : **Calculations | Macro**.

Maximum execution time

The maximum execution time of a macro may be limited, because a macro can not be interrupted by the user in the case of an "infinite loop". See th***Options*** : **Calculations | Macro**.

7.3 Macro structure and syntax

Vision supports a number of individual calculations. Sometimes, however, you may want to make a particular calculation several times in quick succession, changing the input data slightly each time. To enable you to do this, Vision is provided with a programming language: a macro language.

The Vision macro language supports:

- commands 393
- objects 367
- values 369
- variables 369
- attributes 370
- standard objects 369

A Vision macro consists of commands, followed by parameters, attributes and variables.
Lines beginning with // are ignored and may contain comments.
Commands, variables, objects, attributes and values are not case sensitive. However, object names and selection names are case sensitive.

7.3.1 Macro objects

In the macro language, all network components are referred to collectively as Objects. So, for example, nodes, cables and loads are all Objects. The following Objects are defined in Vision's macro language:

Macro language-Object	Vision-Object
Node	Node
Link	Link
Cable	Cable
Line	Connection
ReactanceCoil	Reactance coil
Transformer	Transformer
SpecialTransformer	Special transformer
3WTransformer	Three windings transformer
Source	Source
SynGen	Synchronous generator
SynMot	Synchronous motor
AsynGen	Asynchronous generator
AsynMot	Asynchronous motor
AsynMotGroup	Asynchronous motor group
Load	Load
TransformerLoad	Transformer load

Capacitor	Capacitor
Coil	Coil
ZigZagCoil	Zigzag coil
Accu	Accumulator
Switch	Load switch
Fuse	Fuse
Breaker	Circuit breaker
Indicator	Short-circuit current indicator
Protection	Protection
Measurefield	Measuring field
LoadBehaviour	Load behaviour
Selection	Selection
Sheet	Sheet
Profile	Profile

In this document, objects appear in **bold** type.

Individual Objects are referred to by name. A name may be in the form of *text* or a text variable. The name of an object is case sensitive. The general notation is:

Object(ObjectName).

So, for example, a particular node might be referred to as:

Node('MyNode').

Branches (links, cables, connections, inductors, transformers, special transformers) are also referred to by name. Since some users use names to refer to circuits (white/black), it is also possible to indicate from-nodes and to-nodes. This is done by giving the name of the branch followed by a colon, then the name of the from-node, then a dash and finally the name of the to-node. No spaces are allowed either side of the colon or dash.

If the branch name, from-node name or to-node name does not exist, or if the names of the from and to-nodes are reversed, the Object will not be found.

If the user does not know beforehand what order the from and to-node names are defined in, an equals sign (=) may be used instead of a dash. If an equals sign is used, it does not matter what order the from and to-node names are given in. No spaces may be used either side of an equals sign.

The general notation for branches is:

Object(ObjectName)

or

Object(ObjectName:FromNodeName-ToNodeName)

or

Object(ObjectName:FromNodeName=ToNodeName)

Examples:

Link('MyLink')
Cable('MyCable:MyFromNode-MyToNode')
Line('MyOverheadLine:MyFromNode=MyToNode')

Elements (sources, synchronous generators, synchronous motors, asynchronous generators, asynchronous motors, asynchronous motor groups, loads, transformer loads, capacitors, coils, zero-point transformers) are similarly referred to by name. If an element name is not unique, it can be identified by adding the name of the node to which it is connected. This is done by giving the name of the element, followed by a colon, then the name of the relevant node. Spaces are not allowed either side of the colon.

The general notation for Elements is:

Object(ObjectName)

or

Object(ObjectName:ConnectedNodeName)

Examples:

Load('MyLoad')

or

SynMot('MyMotor:MyConnectedNode')

7.3.2 Macro values

This document makes use of the term value. A value may be:

- A direct value
- The value of a variable
- The value of an attribute

A direct value may be in the form of text between single inverted commas ('Abcde...'), a number, an object (Node('MyNode')) or a reserved term. The reserved terms are:

- Boolean logical statements *true/false*
- Switch positions *open/closed*
- Power directions *supply/absorb* .

Variables and attributes are considered in the following subsections.

In this document, the direct values are shown in *italics* .

7.3.3 Macro variables

The user can define variables in a macro. These may be used as counters or as support variables for the processing of attributes. A variable may contain text, a number, a logical value (Boolean), a switch position or a power direction. The various options and the corresponding permissible values are listed in the following table.

Variable type	Possible values	Initial value
Text	'ABC...', 'abc...', '0123...'	empty
Number	1, 2, 3, ... , 1.1, 1.2, 1.3, ... , 1.2E3, ...	0
Boolean	TRUE or FALSE	FALSE
Switch position	OPEN or CLOSED	OPEN
Power direction	SUPPLY or ABSORB	ABSORB
Object		NIL

A variable may be defined in a macro by means of the command Set, assigning a particular value. If a variable is not defined, its initial value (i.e. its value when first used) is as indicated in the table above.

The name of a variable may contain letters, numbers and underscore characters (_).

- Arrays 398: defined to store a large amount of calculated values

7.3.4 Standard objects

In the macro language a number of standard variables is present. These can be consulted in a macro. With these variables the names of directories can be consulted and it can be tested if a calculation has been carried out correctly.

Standaard variable	Alterable	Type	Description
ThisSheet	no	Text	Name of the current sheet
Options.Version	no	Text	Version number of Vision
Options.TypeFile	no	Text	Name of the basic type file
Options.NetworkDir	no	Text	Name of the directory with network files
Options.MacroDir	no	Text	Name of the directory with macro files
Options.TempDir	no	Text	Name of the directory with temporary files
Options.BackupDir	no	Text	Name of the directory with back up files
Options.ArchiveDir	no	Text	
Options.Frequency	yes	Number	Set system frequency (50/60 Hz)
Options.UseConductorTemperature	yes	Boolean	Apply conductor temperature

Options.ConductorTemperature_PILC	yes	Number	Applicable conductor temperature for PILC
Options.ConductorTemperature_NonPILC	yes	Number	Applicable conductor temperature for non-PILC
Network.FileName	no	Text	Naam of the current network file
Network.FilePath	no	Text	Naam of the path of the current network file
Network.FileDir	no	Text	Naam of the directory of the current network file
Network.Result	no	'NO'/'LF'/ 'IEC'/'FA'/ 'REL'/'SEL'/ 'RIP	Indicates whether the calculation has been correctly carried out or not
Network.SubResult	no	Text	
Network.Year	yes	Number	Year for altering loads (as result of growth)
Network.Date	yes	Text	Date for active variant or scenario
Network.Client	no	Text	
Network.Place	no	Text	
Network.Country	no	Text	
Network.Project	no	Text	
Network.Description	no	Text	
Network.Version	no	Text	
Network.State	no	Text	
Network.By	no	Text	
System.Date	no	Text	System date
System.Time	no	Text	System time
System.TimeStamp	no	Number	System time in seconds, starting from 0:00 h
Macro.Error	no	Number	The current error number
Macro.ErrorText	no	Text	The current error text
Macro.LoadflowErrorText	no	Text	The latest loadflow error text
Macro.LoadflowWarningText	no	Text	The latest loadflow warning text

Standard the object with the name **'Network'** is available. This object contains the current network. From this object the attribute ***'Result'*** can be consulted by means of: **Network**.Result. With this attribute it can be tested if the results for the whole network are available.

Almost all objects have the attribute ***'Result'***. This is a text, containing the value *'NO'* if no calculation results are available. After successful completion of a calculation this attribute contains the values:

'LF' : loadflow result available
'IEC' : IEC 60909 result available
'FA' : Fault Analysis result available
'REL' : Reliability analysis result available
'SEL' : Selectivity analysis result available
'RIP' : Ripple control calculation result available

This is used to test if a calculation has been carried out successfully. E.g.:

```
if( Node('MyNode').Result, =, 'LF' )
    ...
end
```

The file locations can be consulted with options.typedir, options.macrodir, options.networkdir, options.tempdir and options.backupdir.

7.4 Macro attributes

All objects have attributes. These include, on the one hand, input data, such as the data that the user may enter in Vision (on the Forms), and, on the other hand, calculated output data, such as the data that is visible on a network diagram or on a detail screen once a calculation has been made.

See:

- All the attributes that can be altered in the macro language: input data. 371
- All the other attributes that can only be read (for use in a printout or for allocation to a variable): input and output data. 376

An attribute cannot be used in isolation – it must always be associated with an object. The object name is given first, immediately followed by a full stop, then the attribute name. The general notation is:

Object(ObjectName).Attribute

Examples:

Cable('MyCable').P1

or

SynMot('MyMotor').Pref

Almost all objects have the attribute ***'Result'*** . This is a text containing the value *'NO'* if no loadflow results are available. After a calculation this attribute may contain the values:

'LF' : loadflow results available
'IEC' : IEC 60909 results available
'FA' : Fault analysis results available.

The standard objectvariable **'Network'** contains the actual network. From this variable the attribute 'Result' can be examined using: **Network**.Result. With this combination one can test whether the results for the whole network are available.

7.4.1 Macro alterable attributes

The attributes that can be altered (settings and input data) are described in a table. All these attributes can be altered or printed using macro language commands. If a non-integer real number is assigned to an Integer Number attribute, it is rounded off to the nearest whole number. Each attribute can be linked only to particular types of object. So, for example, the attribute Tap cannot be linked to the object Node. The alterable attributes that may be linked to each type of object 372 are listed in a table.

An attribute cannot be used in isolation – it must always be associated with an object. The object name is given first, immediately followed by a full stop, then the attribute name. The general notation is:

Object(ObjectName).Attribute

Examples:

Cable('MyCable').Type1

or

SynMot('MyMotor').Pref

There are also calculated output data, such as the data that is visible on a network diagram or on a detail screen once a calculation has been made. See: all the other attributes that can only be read (for use in a printout or for allocation to a variable): input and output data. 376

7.4.2 Macro alterable attributes table

Nodes

Object/ Attribute	Type	Unit	Description
Simultaneousness	R		Simultaneousness
RailType	T		Rail type name
Specifics	T		Remarks
TF_Frequency	R	Hz	Ripple control frequency
TF_U	R	%	Ripple control voltage
TF_Angle	R	degrees	Ripple control voltage angle
GX	R	m	Geographical X-coordinate
GY	R	m	Geographical Y-coordinate
FailureFrequency	R	/jr	Failure frequency
RepairDuration	R	min	Repair duration
MaintenanceFrequency	R	/jr	Maintenance frequency
MaintenanceDuration	R	min	Maintenance duration
MaintenanceCutOffDuration	R	min	Maintenance cut off duration
RemoteStatus	B		Remote status report
Selected	B		Object selected in user interface
Bool, Bool1, Bool2	B		Free useable boolean attribute
Real, Real1, Real2	R		Free useable real attribute
String, String1, String2	T		Free useable text attribute
Object, Object1, Object2	O		Free useable object attribute

Branches

lk: Link **cb**: Cable **tf**: Transformer **3w**: 3WTransformer
li: Line **rc**: ReactanceCoil **st**: SpecialTransformer

Object/ Attribute	lk	li	cb	rc	tf	st	3w	Type	Unit	Description
FirstSwitch	*	*	*	*	*	*	*	S		Branch switch position at from-node
SecSwitch	*	*	*	*	*	*	*	S		Branch switch position at to-node
ThirdSwitch							*	S		Three windings transformer switch position at third node
SwitchState	*	*	*	*	*	*	*	I		Binary representation of the 2 (or 3) switches; 0=open; 1=closed. Branch, no 3WTransformer: 0, 1, 2, 3 3WTransformer: 0, 1, 2, 3, 4, 5, 6, 7
FirstNodeObject	*	*	*	*	*	*	*	O		Branch From node
SecNodeObject	*	*	*	*	*	*	*	O		Branch To node
ThirdNodeObject							*	O		Branch third node
Specifics	*	*	*	*	*	*	*	T		Remarks
R		*	*					R	Ohm	Total positive sequence resistance
X		*	*					R	Ohm	Total positive sequence reactance
C		*	*					R	μF	Total positive sequence capacity
R0		*	*					R	Ohm	Total zero sequence resistance
X0		*	*					R	Ohm	Total zero sequence reactance
C0		*	*					R	μF	Total zero sequence capacity
Inom	*	*	*					R	A	Rated current inclusive derating factor
Ik1s	*	*	*					R	kA	Admissible short circuit current for 1 second
Snom				*	*			R	3)	Rated apparent power
uk				*	*			R	%	Relative short-circuit voltage
Pk				*	*	*		R	kW	Short-circuit loss
Tap					*	*		I		Tap changer position
TapControl							*	I		Controlled winding tap changer position
TapAdjust							*	I		Adjustable winding tap changer position
Type				*	*	*	*	T		Type of component
Type1 ... 9			*					T		Type of cable of cable part
Length1 ... 9			*					R	m	Length of cable part
Gselect1 ... 9			*					I		Selected G (0/1/2/3) for cable part
Rating1 ... 9			*					R		Load factor for Inom
Smax					*	*		R	3)	Maximum power
Smax1							*	R	3)	Maximum power winding 1
Smax2							*	R	3)	Maximum power winding 2
Smax3							*	R	3)	Maximum power winding 3
PhaseShift					*	*		R	grad.	Transformer phase shift
Ucontrol					*	*	*	B		Voltage control in/out
Umin					*	*	*	R	kV	Controlled voltage, minimum value
Umax					*	*	*	R	kV	Controlled voltage, maximum value
Rc					*	*	*	R	Ohm	Compensation resistance
Xc					*	*	*	R	Ohm	Compensation reactance
FailureFrequency	*	*	*	*	*	*	*	R	/jr	Failure frequency
RepairDuration	*	*	*	*	*	*	*	R	min	Repair duration
MaintenanceFrequency	*	*	*	*	*	*	*	R	/jr	Maintenance frequency
MaintenanceDuration	*	*	*	*	*	*	*	R	min	Maintenance duration
MaintenanceCutOffDuration	*	*	*	*	*	*	*	R	min	Maintenance cut off duration
Sleeves			*					I		Number of sleeves
SleeveFailureFrequency			*					R	/jr	Sleeve failure frequency
Selected	*	*	*	*	*	*	*	B		Object selected in user interface
Bool, Bool1, Bool2	*	*	*	*	*	*	*	B		Free useable boolean attribute
Real, Real1, Real2	*	*	*	*	*	*	*	R		Free useable real attribute
String, String1, String2	*	*	*	*	*	*	*	T		Free useable text attribute
Object, Object1, Object12	*	*	*	*	*	*	*	O		Free useable object attribute

1) kW or MW, to be defined with: SetPQS(k / M); default: MW
2) kvar or Mvar, to be defined with: SetPQS(k / M); default: Mvar
3) kVA or MVA, to be defined with: SetPQS(k / M); default: MVA

Elements

so: Source
sg: SynGen
sm: SynMot
ag: AsynGen
am: AsynMot
amg: AsynMotGroup
ld: Load
tl: TransformerLoad
ca: Capacitor
co: Coil
zz: ZigZagCoil
wt: WindTurbine

Object/ Attribute	so	sg	sm	ag	am	amg	ld	tl	ca	co	zz	wt	Type	Unit	Description
Switch	*	*	*	*	*	*	*	*	*	*	*	*	S		Switch position
SwitchState	*	*	*	*	*	*	*	*	*	*	*	*	I		Binary representation of switch position (0=open; 1=closed)
NodeObject	*	*	*	*	*	*	*	*	*	*	*	*	O		Element node
Specifics	*	*	*	*	*	*	*	*	*	*	*	*	T		Remarks
Snom		*	*	*				*				*	R	3)	Nominal apparent power
Tap								*					I		Tap changer position
Uref	*	*											R	p.u.	Reference voltage
UQStatic		*											R	%	U/Q static
Sk2nom	*												R	MVA	Nominal short circuit power
Sk2min	*												R	MVA	Minimal short circuit power
Sk2max	*												R	MVA	Maximum short circuit power
Angle	*												R	degr.	Voltage angle
Zo_Z1	*												R		Zero sequence to normal sequence ratio
R_X	*												R		R/X ratio
Pnom				*	*	*							R	1)	Nominal power
Pref		*	*									*	R	1)	Reference power
FPStatic		*											R	%	Frequency/Power static
Control		*											T	U / C	Voltage control or cos-phi control
CosRef		*	*									*	R		Power factor
Qdirection		*	*									*	V		Reactive power direction (supply/absorb)
PmRef				*	*								R	1)	Mechanical power
IsInom					*								R		Relation starting current to nominal current
InUse						*							I		Number of motors in service
Lref						*							R	%	Motors load factor
Pl							*	*					R	1)	Active power
Ql							*	*					R	2)	Reactive power
Qc									*	*			R	2)	Reactive power
Large							*	*					I		Number of large customers
Small							*	*					I		Number of small customers
Windspeed												*	R	m/s	Wind speed
Rg												*	R	p.u.	Stator resistance
Xd2												*	R	p.u.	Stator reactance
Type		*	*	*	*	*		*			*	*	T		Type of component
N		*	*										B		Wye star point grounded yes/no
Re		*	*										R	Ohm	Grounding resistance
Xe		*	*										R	Ohm	Grounding reactance
FailureFrequency	*	*	*	*	*	*	*	*	*	*	*	*	R	/jr	Failure frequency
RepairDuration	*	*	*	*	*	*	*	*	*	*	*	*	R	min	Repair duration
MaintenanceFrequency	*	*	*	*	*	*	*	*	*	*	*	*	R	/jr	Maintenance frequency
MaintenanceDuration	*	*	*	*	*	*	*	*	*	*	*	*	R	min	Maintenance duration
MaintenanceCutOffDuration	*	*	*	*	*	*	*	*	*	*	*	*	R	min	Maintenance cut off duration
Selected	*	*	*	*	*	*	*	*	*	*	*	*	B		Object selected in user interface
Bool, Bool1, Bool2	*	*	*	*	*	*	*	*	*	*	*	*	B		Free useable boolean attribute
Real, Real1, Real2	*	*	*	*	*	*	*	*	*	*	*	*	R		Free useable real attribute
String, String1, String2	*	*	*	*	*	*	*	*	*	*	*	*	T		Free useable text attribute
Object, Object1, Object2	*	*	*	*	*	*	*	*	*	*	*	*	O		Free useable object attribute

1) kW or MW, to be defined with: SetPQS(k / M); default: MW
2) kvar or Mvar, to be defined with: SetPQS(k / M); default: Mvar
3) kVA or MVA, to be defined with: SetPQS(k / M); default: MVA

Switches and protections

sw: Switch **fu**: Fuse **br**: Breaker **in**: Indicator
pr: Protection

Object/ Attribute	sw	fu	br	in	pr	Type	Unit	Description
Specifics	*	*	*	*	*	T		Remarks
Failurefrequency	*		*			R	/year	Failure frequency
Repairduration	*		*			R	min	Repair duration
Remotestatus			*			B		Remote status report
Remotecontrol	*		*			B		Remote control
Refusechance			*			R		Possibility that the switch refuses to operate
Current1_present			*			B		Current protection 1 present
Current1_active			*			B		Current protection 1 active
Current1_direction			*			I	0/1/-1	Directional sensitivity (0: not; 1: in; -1: out)
Current1_RCA			*			R		
Current2_present			*			B		Current protection 2 present
Current2_active			*			B		Current protection 2 active
Current2_direction			*			I	0/1/-1	Directional sensitivity (0: not; 1: in; -1: out)
Current2_RCA			*					
Earth1_present			*			B		Earth fault protection 1 present
Earth1_active			*			B		
Earth2_present			*			B		Earth fault protection 2 present
Earth2_active			*			B		
Voltage_present			*			B		Voltage protection present
Voltage_active			*			B		
Distance_present			*			B		Distance protection present
Distance_active			*			B		
Type		*	*			T		Type of circuit breaker / fuse
Current				*		I	A	Short circuit indicator current value
Differential_present			*		*	B		Differential protection present
Differential_active			*			B		
Current1_type			*			T		Type of current protection 1
Current1_ShortType			*			T		Short type name
Current1_Inom			*			I	A	Nominal current
Current1_Sort			*			I	1)	Sort of characteristic
Current1_I>			*			R	A	Slow switching current
Current1_t>			*			R	s	Slow switching time
Current1_I>>			*			R	A	Medium switching current
Current1_t>>			*			R	s	Medium switching time
Current1_I>>>			*			R	A	Fast switching current
Current1_t>>>			*			R	s	Fast switching time
Current2_type			*			T		Type of current protection 2
Earth1_type			*			T		Type of earth fault 1 protection
Earth2_type			*			T		Type of earth fault 2 protection
Voltage_type			*			T		Type of voltage protection
Distance_type			*			T		Type of distance protection
Selected	*	*	*	*	*	B		Selected
Bool, Bool1, Bool2	*	*	*	*	*	B		Free useable boolean attribute
Real, Real1, Real2	*	*	*	*	*	R		Free useable real attribute
String, String1, String2	*	*	*	*	*	T		Free useable text attribute
Object, Object1, Object2	*	*	*	*	*	O		Free useable object attribute

1) Sort of characteristic: 0: curve; 1: fixed time; 11: normal inverse; 12: very inverse; 13: extreme inverse; 14: long time inverse; 15: RI inverse; 21: special; 31: specific HV-fuse; 32: specific FR-fuse.

Load behaviour

Object/ Attribute	Type	Unit	Description
ConstantP	R	%	Percentage constant active power
ConstantQ	R	%	Percentage constant reactive power
Scaling	R		Scaling factor
Growth	R	%/jr	Yearly growth
LinearGrowth	B		True: linear growth; false: exponential growth

There are also calculated output data, such as the data that is visible on a network diagram or on a detail screen once a calculation has been made. See: all the other attributes that can only be read (for use in a printout or for allocation to a variable): input and output data. 376

7.4.3 Macro non alterable attributes

In addition to the forms of input data that can be altered, there are other forms of input data that cannot be altered, plus, of course, output data that cannot be altered. Non-alterable forms of data are nevertheless available in the macro language for reporting purposes. Furthermore, the values of the attributes in question may be assigned to variables. These additional variables are listed in a table. All these attributes listed above can be printed using macro language commands. Each attribute can be linked only to particular types of object. So, for example, the attribute Ploss cannot be linked to the object Node. The non-alterable attributes that may be linked to each type of object 377 are listed in a table.

An attribute cannot be used in isolation – it must always be associated with an object. The object name is given first, immediately followed by a full stop, then the attribute name. The general notation is:

```
Object( ObjectName ).Attribute
```

Examples:

```
Cable( 'MyCable' ).P1
```

or

```
SynMot( 'MyMotor' ).Name
```

There are also attributes containing input data. See: all attributes that can be altered: input data. 371

7.4.4 Macro non alterable attributes table

Nodes

Object/ Attribute	Type	Unit	Description
Name	T		Object name
Nr	I		Internally generated serial number
Live	B		Node present on active sheet
Alive	B		Node present and visible on active sheet
Sheets	T		Indication of sheets where node is present
Sort	T		Type of Object (NODE)
MainSort	I	0	0 (integer designation of main object sort)
Group	I		Group number (Reliability)
Short	T		Node short name
ID	T		Node ID
Unom	R	kV	Nominal voltage
BusbarSystem	T		Name of busbar system
Serial	I		Serial number, based on trace
Result	T		Calculation result (LF/NO)
U	R	kV	Calculated phase to phase voltage
Uang	R	degr.	Calculated phase to phase voltage angle
Upu	R	p.u.	Calculated voltage
P	R	MW	Summed real power of the elements according to generator convention
Ika, Ikb, Ikc	R	kA	Subtransient short-circuit current per phase
Ika_ang, Ikb_ang, Ikc_ang	R	degr.	Subtransient short-circuit current angle per phase, after a Fault Analysis calculation
Ike	R	kA	Short-circuit current to ground
Ike_ang	R	degr.	Short-circuit current to ground angle
Ip	R	kA	Peak short-circuit current
Sk	R	MVA	Subtransient short-circuit power
Ri	R	mOhm	Resistance of the network impedance at the node
Xi	R	mOhm	Reacttance of the network impedance at the node
RX	R		R/X ratio of the network impedance at the node
Tmax	R	s	Admissible short-circuit time
Faulted	B		Indicates whether an IEC calculation has been carried out successfully or not
Ik	R	kA	Stationary short circuit current, after a single node calculation
Selective	B		Selectively protected
Ua, Ub, Uc	R	kV	Fault Analysis nodal voltages
Ua_ang, Ub_ang, Uc_ang	R	degr.	Fault Analysis nodal voltages angle
Freq1, Freq2	R	Hz	Ripple control source frequency (sources 1 and 2)
Ufreq1, Ufreq2	R	kV	Phase to phase voltage for signals with Freq1 and Freq2
Ufreqproc1, Ufreqproc2	R	&	Voltage for signals with Freq1 and Freq2, relative to the rated voltage
F	R	/year	Outage Frequency
D	R	min	Outage Duration
P	R	%	Outage Probability
Pmy	R	min/year	Outage Duration per year

Branches

lk: Link **li**: Line **cb**: Cable **rc**: ReactanceCoil **tf**: Transformer **st**: SpecialTransformer **3w**: 3WTransformer

Object/ Attribute	lk	li	cb	tc	tf	st	3w	Type	Unit	Description
Name	*	*	*	*	*	*	*	T		Object name
Nr	*	*	*	*	*	*	*	I		Internally generated serial number
Live	*	*	*	*	*	*	*	B		Branch present on active sheet
Alive	*	*	*	*	*	*	*	B		Branch present and visible on active sheet
Sheets	*	*	*	*	*	*	*	T		Indication of sheets where branch is present
Sort	*	*	*	*	*	*	*	T		Type of Object (LINK, LINE, CABLE, etc)
MainSort	*	*	*	*	*	*	*	I	2/3	Integer designation of main object sort (branches:2; 3w-transf:3)
Group	*	*	*	*	*	*	*	I		Group number (Reliability)
FirstNode	*	*	*	*	*	*	*	T		Branch from-node name
SecNode	*	*	*	*	*	*	*	T		Branch to-node name
ThirdNode							*	T		Three windings transformer third node name

Object/ Attribute	lk	li	cb	tc	tf	st	3w	Type	Unit	Description
Serial	*	*	*	*	*	*	*	I		Serial number, based on trace
Parts			*					I		Number of cable parts
Length		*	*					R	m	Cable total length
R			*	*				R	Ohm	Total resistance
X			*	*				R	Ohm	Total reactance
C			*					R	μF	Total capacity
Ro			*					R	Ohm	Total zero sequence resistance
Xo			*					R	Ohm	Total zero sequence reactance
Co			*					R	μF	Total zero sequence capacity
Inom			*					R	A	Rated current inclusive derating factor
Ik1s			*					R	s	Admissible short circuit current for 1 second
Unom1					*		*	R	kV	Primary winding nominal voltage
Unom2					*		*	R	kV	Secondary winding nominal voltage
Unom3							*	R	kV	Tertiary winding nominal voltage
Snom1							*	R	4)	Primary winding rated apparent power
Snom2							*	R	4)	Secondary winding rated apparent power
Snom3							*	R	4)	Tertiary winding rated apparent power
TapSide					*	*	*	I	1/2	Tap changer side: primary/secondary
TapSize					*	*	*	R	kV	Tap changer voltage per single tap
TapMin					*	*	*	I		Tap changer minimum tap position
TapNom					*	*	*	I		Tap changer nominal tap position
TapMax					*	*	*	I		Tap changer minimum tap position
Result	*	*	*	*	*	*	*	T		Calculation result (LF/NO)
P1, Q1, S1, I1	*	*	*	*	*	*	*	R	4)	Active, reactive and apparent power and current, flowing into a branch at the node side corresponding to FirstNode
P2, Q2, S2, I2	*	*	*	*	*	*	*	R	4)	Active, reactive and apparent power and current, flowing into a branch at the node side corresponding to SecNode
P3, Q3, S3, I3							*	R	4)	Active, reactive and apparent power and current, flowing into a 3w-transformer at the node side corresponding to ThirdNode
Ploss	*	*	*	*	*	*	*	R	kW	Branch active power loss
Qloss	*	*	*	*	*	*	*	R	kvar	Branch reactive power loss
CosPhi								R		Element power factor
Loadrate	*	*	*	*	*	*	*	R	%	Branch or Element load rate
NewTap					*	*	*	I		New tap changer position
Tmax	*	*	*	*	*	*	*	R	s	Admissible short-circuit time
Kind						*		T		Sort of special transformer
Faulted	*	*	*	*	*	*	*	B		Indicates whether an IEC calculation has been carried out successfully or not
Ik1a, Ik1b, Ik1c	*	*	*	*	*	*	*	R	kA	Maximum short circuit current per phase at the node side corresponding to FirstNode
Ik2a, Ik2b, Ik2c	*	*	*	*	*	*	*	R	kA	Maximum short circuit current per phase at the node side corresponding to SecNode
Ik3a, Ik3b, Ik3c							*	R	kA	Maximum short circuit current per phase at the node side corresponding to ThirdNode
Sk1	*	*	*	*	*	*	*	R	MVA	Subtransient short circuit power at side corresponding FirstNode
Sk2	*	*	*	*	*	*	*	R	MVA	Subtransient short circuit power at side corresponding SecNode
Sk3							*	R	MVA	Subtransient short circuit power at side corresponding ThirdNode
Imax	*	*	*	*	*	*		R	kA	Maximum through going short-circuit current
Imax1							*	R	kA	Maximum through going short-circuit current
Imax2							*	R	kA	Maximum through going short-circuit current
Imax3							*	R	kA	Maximum through going short-circuit current
I1a, I1b, I1c	*	*	*	*	*	*	*	R	kA	Fault Analysis branch phase currents at FirstNode
I1a_ang, I1b_ang, I1c_ang	*	*	*	*	*	*	*	R	degr.	Fault Analysis branch phase currents angles at FirstNode
I2a, I2b, I2c	*	*	*	*	*	*	*	R	kA	Fault Analysis branch phase currents at SecNode
I2a_ang, I2b_ang, I2c_ang	*	*	*	*	*	*	*	R	degr.	Fault Analysis branch phase currents angles at SecNode
I3a, I3b, I3c							*	R	kA	Fault Analysis branch phase currents at ThirdNode
I3a_ang, I3b_ang, I3c_ang							*	R	degr.	Fault Analysis branch phase currents angles at ThirdNode
Selective		*	*					B		Selectively protected
F	*	*	*	*	*	*	*	R	/year	Outage frequency
D	*	*	*	*	*	*	*	R	min	Outage duration
P	*	*	*	*	*	*	*	R	%	Outage duration per year
Pmy	*	*	*	*	*	*	*	R	min/year	Outage probability

4) Respectively kW, kvar, kVA of MW, Mvar, MVA, to be defined with: SetPQS(k / M); default: MW, Mvar, MVA

Elements

so: Source
sg: SynGen
sm: SynMot
ag: AsynGen
am: AsynMot
amg: AsynMotGroup
ld: Load
tl: TransformerLoad
ca: Capacitor
co: Coil
zz: ZigZagCoil
wt: WindTurbine

Object/ Attribute	so	sg	sm	ag	am	amg	ld	tl	ca	co	zz	wt	Type	Unit	Description
Name	*	*	*	*	*	*	*	*	*	*	*	*	T		Object name
SubNr	*	*	*	*	*	*	*	*	*	*	*	*	I		internally generated serial number
Live	*	*	*	*	*	*	*	*	*	*	*	*	B		Element present on active sheet
Alive	*	*	*	*	*	*	*	*	*	*	*	*	B		Element present and visible on active sheet
Sheets	*	*	*	*	*	*	*	*	*	*	*	*	T		Indication of sheets where element is present
Sort	*	*	*	*	*	*	*	*	*	*	*	*	T		Type of Object (SOURCE, SYNGEN, LOAD,..)
MainSort	*	*	*	*	*	*	*	*	*	*	*	*	I	1	1 (integer designation of main object sort)
Group	*	*	*	*	*	*	*	*	*	*	*	*	I		Group number (Reliability)
Node	*	*	*	*	*	*	*	*	*	*	*	*	T		Element node name
Number						*							I		Number of asynchronous machines
TapMin								*					I		Tap changer minimum tap position
TapNom								*					I		Tap changer nominal tap position
TapMax								*					I		Tap changer minimum tap position
Behaviour							*	*					T		Load behaviour
Qmin		*											R	4)	Reactive power lower limit
Qmax		*											R	4)	Reactive power upper limit
Result	*	*	*	*	*	*	*	*	*	*	*	*	T		Calculation result (LF/NO)
U								*					R	kV	Calculated phase to phase voltage
Up								*					R	kV	Transformer load calculated phase voltage
P, Q, S, I	*	*	*	*	*	*	*	*	*	*	*	*	R	4)	Active, reactive and apparent power and current, flowing from a Source, Generator or Capacitor into the network or from the network into a Load, Motor or Coil at the node corresponding to Node
Ploss								*					R	kW	Branch active power loss
Qloss													R	kvar	Branch reactive power loss
CosPhi	*	*	*	*	*	*	*	*	*	*	*	*	R		Element power factor
Loadrate	*	*	*	*	*	*	*	*	*	*	*	*	R	%	Branch or Element load rate
Ia, Ib, Ic	*	*	*	*	*	*	*	*	*	*	*	*	R	kA	Subtransient short-circuit current per phase
Ia_ang, Ib_ang, Ic_ang	*	*	*	*	*	*	*	*	*	*	*	*	R	degr.	Subtransient short-circuit current angle per phase
Selective	*	*	*	*	*	*	*	*	*	*	*	*	B		Selectively protected
F	*	*	*	*	*	*	*	*	*	*	*	*	R	/year	Outage frequency
D	*	*	*	*	*	*	*	*	*	*	*	*	R	min	Outage duration
P	*	*	*	*	*	*	*	*	*	*	*	*	R	%	Outage probability
Pmy	*	*	*	*	*	*	*	*	*	*	*	*	R	min/year	Outage duration per year
NDE	*	*	*	*	*	*	*	*	*	*	*	*	R	kWh/yr	Expected energy not served
Lm							*	*					R	min/year	Large customers outage duration
Sm							*	*					R	min/year	Small customers outage duration

4) Respectively kW, kvar, kVA of MW, Mvar, MVA, to be defined with: SetPQS(k / M); default: MW, Mvar, MVA

Switches and protections

sw: Switch **fu**: Fuse **br**: Breaker **in**: Indicator
pr: Protection

Object/ Attribute	sw	fu	br	in	pr	Type	Unit	Description
Nr	*	*	*	*	*	I		Internally generated serial number
Name	*	*	*	*	*	T		Object name
Live	*	*	*	*	*	B		Switch present on active sheet
Alive	*	*	*	*	*	B		Switch present and visible on active sheet
Sheets	*	*	*	*	*	T		Indication of sheets where switch is present
Mainsort	*	*	*	*	*	I	4	4 (Integer designation main object type)
Sort	*	*	*	*	*	T		Object type (BREAKER, SWITCH, FUSE,..)
Group	*	*	*	*	*	I		Group number (reliability)
Node	*	*	*	*		T		Object corresponding node name
ToNode	*	*	*	*		T		To node name (opposite in branch)
In	*	*	*	*		T		Object corresponding branch or element name
NodeObject	*	*	*	*		O		Object corresponding node
ToNodeobject	*	*	*	*		O		To node (opposite in branch)
Inobject	*	*	*	*		O		Object corresponding branch or element
Side	*	*	*	*		I	1/2/3	Branch side where Object is located
Shorttype		*	*			T		Short type of circuit breaker / fuse
Unom		*	*			R	kV	Rated voltage
Inom		*	*			R	A	Rated current
Threephase		*				B		Fuse switches three phases simultaneously
Result	*	*	*	*	*	T	'NO'	Álways 'NO'

Load behaviour

Attribute	Type	Unit	Description
Nr	I		Internally generated serial number
Name	T		Object name
Mainsort	I		-1
Sort	T		LOADBEHAVIOUR

Load growth

Attribute	Type	Unit	Description
Nr	I		Internally generated serial number
Name	T		Object name
Mainsort	I		-1
Sort	T		LOADGROWTH

Selection

Attribute	Type	Unit	Description
Name	T		Object name
Mainsort	I		-1
Sort	T		SELECTION

Sheet

Attribute	Type	Unit	Description
Name	T		Object name
Nr	I		Sheet number
Mainsort	I	-1	-1 (Integer designation main object type)
Sort	T		Type of Object (SHEET)
Comment	T		Comment
Color	I		Background colour

There are also input data. See: all attributes that can be altered: input data. 371

7.4.5 Macro: table with attributes

Nodes: Node

Attribute	Type	Unit	Description
Simultaneousness	R		Simultaneity factor
Rail type	T		Rail type name
Specifics	T		Specifics
TF_Frequency	R	Hz	Tone frequency
TF_U	R	%	Tone frequency voltage
TF_Angle	R	°	Tone frequency voltage angle
GX	R	m	Geographical X coordinate
GY	R	m	Geographical Y coordinate
FailureFrequency	R	/yr	FailureFrequency
RepairDuration	R	min	Repair duration
MaintenanceFrequency	R	/yr	Maintenance frequency
MaintenanceDuration	R	min	Maintenance duration
MaintenanceCutOffDuration	R	min	Maintenance cut-off duration
RemoteStatus	B		Reminder
Selected	B		Selected
Deleted	B		Deleted
Bool, Bool1, Bool2	B		Free to use truth attribute
Real, Real1, Real2	R		Free to use number attribute
String, String1, String2	T		Free to use text attribute
Object, Object1, Object2	O		Free to use object attribute
Name	T		Name
No.	I		Internally generated sequence number
Live	B		Whether node is present on active leaf
Alive	B		Whether node is present and visible on active sheet
Sheets	T		Sheets on which the node occurs
Selections	T		Selections in which the node appears
Note	T		Note
Sort	T		NODE
MainSort	I		0
Group	I		Group number
Direction	I		Direction number
Feeding	I		Feeding group number
Short	T		Short name
ID	T		ID
Fields	T		Enumeration of field names
Unom	R	kV	Rated voltage
BusbarSystem	T		Name of busbar system
Function	T		Function
Serial	I		Serial number, based on track
Branches	I		Number of branches
ClosedBranches	I		Number of branches with closed switch
Elements	I		Number of elements
ClosedElements	I		Number of elements with closed switch
Inom	R	A	
Idynamic	R	kA	
Ikthermic	R	kA	
Tthermic	R	s	
VoltageChecking	I		VoltageChecking
OwnUmin	R	pu	Alternative Umin
OwnUmax	R	pu	Alternative Umax
OwnduMax	R	%	Alternative dUmax
Result	T		Result (NO / LF / IEC / FA / REL / PROT / SEL / RIP / NC)
U	R	kV	Calculated coupled voltage
dU	R	%	Deviation of the calculated voltage from the rated voltage
Uang	R	°	Angle of the calculated coupled voltage
Upu	R	p.u.	Calculated voltage
Umin	R	kV	Calculated minimum voltage
Umax	R	kV	Calculated maximum voltage
P	R	MVA	Summed real power of the elements according to generator convention
Ika, Ikb, Ikc	R	kA	Subtransient short-circuit current
Ika_ang, Ikb_ang, Ikc_ang	R	°	Angle of subtransient short-circuit current, after calculation Failure Sequential
Ike	R	kA	Subtransient short-circuit current to earth in case of failure Sequential
Ike_ang	R	°	Angle of subtransient short-circuit current to earth in case of failure sequentially
Ip	R	kA	Peak value of the short-circuit current
Sk	R	MVA	Short-circuit capacity
Ri	R	mOhm	Grid impedance (resistance) at the short-circuited node
Xi	R	mOhm	Line impedance (reactance) on the short-circuited node
RX	R		R/X ratio of mains impedance
Tmax	R	s	Maximum permitted short-circuit duration
Faulted	B		Indicates whether an IEC calculation has been performed for this node
I	R	kA	Stationary short-circuit current, after single-node short-circuit calculation
Selective	B		Selectively protected
Ua, Ub, Uc	R	kV	Node voltages at fault Sequential
Ua_ang, Ub_ang, Uc_ang	R	grad.	Angle of the node voltages at Failure Sequential
Freq1, Freq2	R	Hz	Frequency of tone frequency source (1 and 2)
Ufreq1, Ufreq2	R	kV	Coupled voltage of tone-frequency signal for Freq1 and Freq2
Ufreqproc1, Ufreqproc2	R	%	Percentage voltage of tone-frequency signal for Freq1 and Freq2
F	R	/year	Non-availability frequency

Branches

lk: Link	**cb**: Cable	**tf**: Transformer	**3w**: 3WTransformer
li: Line	**rc**: ReactanceCoil	**st**: SpecialTransformer	

Attribute	lk	li	cb	rc	tf	st	3w	Type	Unit	Description
FirstSwitch	*	*	*	*	*	*	*	S		Switch position near from node
SecSwitch	*	*	*	*	*	*	*	S		Switch position near to node
ThirdSwitch							*	S		Switch state near third node
SwitchState	*	*	*	*	*	*	*	I		Binary representation switch positions of the 2 (3 in case of three-wire transformer) switches Combinations normal branch: 0, 1, 2, 3 Combination three-winding transformer: 0, 1, 2, 3, 4, 5, 6, 7 First/Sec/ThirdSwitch: 0=open; 1=closed; value = FirstSwitch + 2xSecSwitch + 4xThirdSwitch
FirstNodeObject	*	*	*	*	*	*	*	O		From node to which branch is connected
SecNodeObject	*	*	*	*	*	*	*	O		To node to which branch is connected
ThirdNodeObject							*	O		Third node to which branch is connected
Specifics	*	*	*	*	*	*	*	T		Details
R		*		*				R	Ohm	Total normal resistance
X		*		*				R	Ohm	Total normal reactance
C		*						R	μΦ	Total normal capacitance
Ro		*						R	Ohm	Total homopolar resistance
Xo		*						R	Ohm	Total homopolar reactance
Co		*						R	μΦ	Total homopolar capacitance
Ik1s		*						R	kA	Allowable short-circuit current for 1 second
Inom		*		*				R	A	Rated current
Snom					*	*		R	MVA/kVA	Nominal apparent power
uk					*			R	%	Relative short-circuit voltage
Pk					*			R	kW	Copper loss
Tap					*	*		I		Tap position
TapControl							*	I		Step position controlled winding
TapAdjust							*	I		Step position adjustable winding
Type				*	*	*	*	T		Component type
Type1 ... 9			*					T		Cable type of cable part
Length1 ... 9			*					R	m	Length of cable section
Gselect1 ... 9			*					I		Selected G (0/1/2/3) for cable section
Rating1 ... 9			*					R		Load factor Inom of cable section
Smax					*	*		R	MVA/kVA	Maximum power
Smax1							*	R	MVA/kVA	Maximum power in winding 1
Smax2							*	R	MVA/kVA	Maximum power in winding 2
Smax3							*	R	MVA/kVA	Maximum power in winding 3
PhaseShift					*	*		R	grad.	PhaseShift
Ucontrol					*	*	*	B		Voltage control in/out
Uset					*	*	*	R	kV	Regulated voltage
Uband					*	*	*	R	kV	Regulated voltage band
Rc					*	*	*	R	Ohm	Resistance Compounding
Xc					*	*	*	R	Ohm	Reactance Compounding
FailureFrequency	*	*	*	*	*	*	*	R	/yr	Failure rate
RepairDuration	*	*	*	*	*	*	*	R	min	Repair time
MaintenanceFrequency	*	*	*	*	*	*	*	R	/yr	Maintenance frequency
MaintenanceDuration	*	*	*	*	*	*	*	R	min	Maintenance duration
MaintenanceCutOffDuration	*	*	*	*	*	*	*	R	min	Maintenance degradation time
Sleeves			*					I		Number of sleeves
SleeveFailureFrequency			*					R	/yr	Failure frequency of sleeves
Selected	*	*	*	*	*	*	*	B		Selected
Deleted	*	*	*	*	*	*	*	B		Deleted
Bool, Bool1, Bool2	*	*	*	*	*	*	*	B		Free to use truth attribute
Real, Real1, Real2	*	*	*	*	*	*	*	R		Free to use number attribute
String, String1, String2	*	*	*	*	*	*	*	T		Free to use text attribute
Object, Object1, Object2	*	*	*	*	*	*	*	O		Free to use object attribute
Name	*	*	*	*	*	*	*	T		Branch name
ID	*	*	*	*	*	*	*	T		ID (via specific with attribute "ID")
No	*	*	*	*	*	*	*	I		Internally generated sequence number
Live	*	*	*	*	*	*	*	B		Indicates whether branch is present on active leaf
Alive	*	*	*	*	*	*	*	B		Indicates whether branch is present and visible on active sheet
Sheets	*	*	*	*	*	*	*	T		Indicates on which sheets the branch appears
Selections	*	*	*	*	*	*	*	T		Selections in which the branch appears
Note	*	*	*	*	*	*	*	T		Note
Sort	*	*	*	*	*	*	*	T		Object type (LINK, LINE, CABLE, etc)
MainSort	*	*	*	*	*	*	*	I		Indication for main object type (branches: 2; 3w transformer: 3)
Group	*	*	*	*	*	*	*	I		Group number
Direction	*	*	*	*	*	*	*	I		Direction number
Feeding	*	*	*	*	*	*	*	I		Supply group number
Subnetborder	*	*	*	*	*	*		B		Subnetborder
Mesh	*	*	*	*	*	*	*	B		Whether it is a mesh branch
Unom				*				R	kV	Rated voltage
FirstNode	*	*	*	*	*	*	*	T		From node name to which branch is connected
SecNode	*	*	*	*	*	*	*	T		To-node name to which branch is connected
ThirdNode							*	T		Third node name of a three-winding transformer
FirstField	*	*	*	*	*	*	*	T		Name of field near the from node

Elements

so: Source	**ag**: AsynGen	**ld**: Load	**co**: Coil	**ac**: Battery
sg: SynGen	**am**: AsynMot	**tl**: TransformerLoad	**zz**: ZigZagCoil	
sm: SynMot	**amg**: AsynMotGroup	**ca**: Capacitor	**wt**: Wind Turbine	

Attribute	so	sg	sm	ag	am	amg	ld	tl	ca	co	zz	wt	ac	pv	Type	Unit	Description
Switch	*	*	*	*	*	*	*	*	*	*	*	*	*	*	S		SwitchState
SwitchState	*	*	*	*	*	*	*	*	*	*	*	*	*	*	I		Binary representation switch- states of the switch Combinations: 0 (open), 1 (closed)
NodeObject	*	*	*	*	*	*	*	*	*	*	*	*	*	*	O		Node to which element is connected
Specifics	*	*	*	*	*	*	*	*	*	*	*	*	*	*	T		Details
Profile	*	*	*	*	*	*	*	*	*	*	*	*	*	*	T		Profile
Snom		*	*					*				*	*		R	MVA/kVA	Nominal apparent power
Tap								*							I		Taps
Uref	*	*													R	p.u.	Set voltage
UQStatic		*													R	%	Voltage/blind power statistic
Sk2nom	*														R	MVA	Rated short-circuit power
Sk2min	*														R	MVA	Minimum short-circuit power
Sk2max	*														R	MVA	Maximum short-circuit power
Angle	*														R	°	Tension angle
Z0_Z1	*														R		Ratio Z0/Z1
R_X	*														R		Ratio R/X
Pnom				*	*	*									R	MW/kW	Rated power
Pref		*	*	*								*	*		R	MW/kW	Set electric power
Qref													*		R	Mvar/kvar	Set reactive power
SoC													*		R	%	Load condition
Capacity													*		R	MWh	Loading capacity
FPStatic		*													R	%	Frequency/power statistic
Control		*													T		Voltage control (U) or cos-phi control (C)
CosRef		*	*									*		*	R		Set power factor
Qdirection		*	*												V		Set reactive power direction (supply/absorb)
Isochronous		*													B		Isochronous control
PmRef					*										R	MW/kW	Set mechanical power
IsInom					*										R		Ratio of starting current to rated current
InUse						*									I		Set number of motors in operation
Lref						*									R	%	Set load degree motors
Pl							*	*							R	MW/kW	Active power set (of load)
Ql							*	*							R	Mvar/kvar	Set reactive power (of load)
Pg								*							R	MW/kW	Set active power of generation
Qg								*							R	Mvar/kvar	Set reactive power of generation
Ppv								*							R	MWp/kWp	Nominal power of the PV
Growth							*	*							T		Name of load growth
Qc									*	*					R	Mvar/kvar	Set reactive power
Large							*	*							I		Number of large consumers
Generous							*	*							I		Number of generous consumers
Small							*	*							I		Number of small consumers
Windspeed												*			R	m/s	Set wind speed
Rg												*			R	p.u.	Stator resistance
Xd2												*			R	p.u.	Stator reactance
Type		*	*	*	*	*		*			*	*			T		Component type
N		*	*												B		Starpoint earthed yes/no
Re		*	*												R	Ohm	Earthing resistor
Xe		*	*												R	Ohm	Ground reactance
Scaling														*	R	‰	Scaling
Latitude														*	R	°NB	Latitude
Longitude														*	R	°OL	Longitude
Pnom1														*	R	MWp/kWp	Power of the first panel (inverter.Snom becomes sum of the three panels)
Tilt1														*	R	°	Inclination of the first panel
Orientation1														*	R	°	Orientation of the first panel
Pnom2														*	R	MWp/kWp	Power of the second panel (inverter.Snom becomes sum of the three panels)
Tilt2														*	R	°	Inclination of the second panel
Orientation2														*	R	°	Orientation of the second panel
Pnom3														*	R	MWp/kWp	Power of the third panel (inverter.Snom becomes sum of the three panels)
Tilt3														*	R	°	Inclination of the third panel
Orientation3														*	R	°	Orientation of the third panel
Pcontrol														*	I		P-control (0,1)
Qcontrol														*	I		Q-control (0,1,2)
InverterSnom														*	R	MVA/kVA	Inverter.Snom
FailureFrequency	*	*	*	*	*	*	*	*	*	*	*	*	*	*	R	/yr	Failure rate
RepairDuration	*	*	*	*	*	*	*	*	*	*	*	*	*	*	R	min	Repair time
MaintenanceFrequency	*	*	*	*	*	*	*	*	*	*	*	*	*	*	R	/yr	Maintenance frequency
MaintenanceDuration	*	*	*	*	*	*	*	*	*	*	*	*	*	*	R	min	Maintenance duration
MaintenanceCutOffDuration	*	*	*	*	*	*	*	*	*	*	*	*	*	*	R	min	Maintenance interruption duration
Selected	*	*	*	*	*	*	*	*	*	*	*	*	*	*	B		Selected
Deleted	*	*	*	*	*	*	*	*	*	*	*	*	*	*	B		Deleted
Bool, Bool1, Bool2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	B		Free to use truth attribute

Switches and protections

sw: Switch **fu**: Fuse **br**: Breaker **in**: Indicator **mf**: MeasureField

Attribute	sw	fu	br	in	mf	Type	Unit	Description
Specifics	*	*	*	*	*	T		Details
Failurefrequency	*		*			R	/year	Failure frequency
Repairduration	*		*			R	min	Repair time
Remotestatus			*			B		Brake notification
Remotecontrol	*		*			B		Remotecontrol
Refusechance			*			R		Refusechance
Refusing			*			B		Refusing
Current1					*	B		First current measuring transformer present
Current_present			*			B		First current protection present
Current_active			*			B		First current protection active
Current1_direction			*			I		Directionality (0: none; 1: branch in; -1: branch out)
Current1_RCA			*			R	°	Relay characteristic angle
Current1_info			*			T		
Current2					*	B		Second current measuring transformer present
Current2_present			*			B		Second current protection present
Current2_active			*			B		Second current protection active
Current2_direction			*			I		Directionality (0: none; 1: branch in; -1: branch out)
Current2_RCA			*			R	°	Relay characteristic angle
Current2_info			*			T		
Earth1_present			*			B		First earth fault protection present
Earth1_active			*			B		First earth fault protection active
Earth1_direction			*			I		Directionality
Earth1_RCA			*			R	°	Relay characteristic angle
Earth1_info			*			T		
Earth2_present			*			B		Second earth fault protection present
Earth2_active			*			B		Second earth fault protection active
Earth2_direction			*			I		Directionality
Earth2_RCA			*			R	°	Relay characteristic angle
Earth2_info			*			T		
Voltage					*	B		Voltage measurement transformer present
Voltage_present			*			B		Voltage protection present
Voltage_active			*			B		Voltage protection active
Voltage_direction			*			I		
Voltage_RCA			*			R		
Voltage_info			*			T		
Distance_present			*			B		Distance_present
Distance_active			*			B		Distance_security active
Distance_info			*			T		
Differential_present			*			B		Differential protection present
Differential_active			*			B		Differential protection active
Differential_info			*			T		
Type	*	*	*			T		Type
PhaseCurrent				*		R	A	Phase current trigger value
EarthCurrent				*		R	A	Earth current trigger value
ResponseTime				*		R	s	Phase response time
RemoteStatus				*		B		Remote status notification
Current1_Function					*	T		Function of the first current measuring transformer
Current1_type			*			T		Current protection type 1
Current1_short type			*			T		Short type name
Current1_Inom			*		*	R	A	Rated current (read only at measuring field)
Current1_Sort			*			I		Type of tripping characteristic: 0: curve; 1: fixed time; 11: normal inverse; 12: very inverse; 13: extreme inverse; 14: long time inverse; 15: RI inverse; 21: special; 31: HV fuse; 32: FR fuse; 41: LSI
Current1_I>			*			R	A	Current for slow disconnection
Current1_t>			*			R	s	Time of slow trip
Current1_I>>			*			R	A	Current for medium cut-off
Current1_t>>			*			R	s	Time of medium cut-off
Current1_I>>			*			R	A	Current for rapid shutdown
Current1_t>>			*			R	s	Time of rapid shutdown
Current1_m			*			R		
Current1_alpha			*			R		
Current1_beta			*			R		
Current1_c			*			R		
Current1_d			*			R		
Current1_e			*			R	s	
Current1_Tinput			*			R	s	Pick-up time
Current1_Toutput			*			R	s	
Current2_Function					*	T		Function of the second current measuring transformer
Current2_????			*					20 above for the second current transformer
Earth1_????			*					20 above for the first earth fault protection
Earth2_????			*					20 above for the second earth fault protection
Voltage_Function					*	T		Function of voltage measuring transformer
Voltage_type			*			T		Voltage protection type
Voltage_short type			*			T		
Voltage_Tinput			*			R	s	
Voltage_Toutput			*			R	s	
Voltage_U<			*			R	kV	
Voltage_U<<			*			R	kV	
Voltage_U>			*			R	kV	

LoadBehaviour

Attribute	Type	Unit	Description
ConstantP	R	%	Percentage constant active power
ConstantQ	R	%	Percentage of constant reactive power
No.	I		Internally generated sequence number
Name	T		Name
Mainsort	I		-1
Sort	T		LOADBEHAVIOUR

LoadGrowth

Attribute	Type	Unit	Description
Scaling0 ... Scaling30	R		Scaling factor in relevant year
Growth1 ... Growth30	R	%/year	Growth in relevant year
No.	I		Internally generated sequence number
Name	T		Name
Mainsort	I		-1
Sort	T		LOADGROWTH
GrowthSort	I		Exponential (0) or linear (1)

Variant

Attribute	Type	Unit	Description
Name	T		Variant name
Mainsort	I		-1
Sort	T		VARIANT
Description	T		Description
Message	T		Message
Scenarios	T		Coupled scenario's
Active	B		Active

Scenario

Attribute	Type	Unit	Description
Name	T		Name of the scenario
Mainsort	I		-1
Sort	T		SCENARIO
Description	T		Description
Message	T		Message
Variants	T		Coupled variants
Active	B		Active

Selection

Attribute	Type	Unit	Description
Name	T		Name of selection
Mainsort	I		-1
Sort	T		SELECTION
#Objects	I		Number of objects in the selection

Sheet

Attribute	Type	Unit	Description
Name	T		Sheet name
No.	I		Serial number of the sheet
Mainsort	I		-1
Sort	T		SHEET
Comment	T		Comment
Colour	I		Background colour

Profile

Attribuut	Type	Eenheid	Omschrijving
Name	T		Profile name
Nr	I		Sequence number of the profile
Mainsort	I		-1
Sort	T		PROFILE
Type	T		Type name
Typesort	I		Sort of type

7.5 Macro commands and parameters

Each command requires a certain number of parameters. Parameters are given between brackets at the end of a command, separated by commas. A parameter may be a value, an attribute or a collation character.

- A value may be text, a number, a logical value (true/false), a switch position (open/closed), a power direction (supply/absorb) or an object. A value may be stored within in a variable or within an attribute associated with an object (e.g. the voltage at a node).
- An attribute is an item of input or output data concerning a component within the network. Input data items may be altered and printed in the macro language. Output data items may only be printed.
- A collation character is required for logical functions. The following are available in the macro language: = (equals), <> (does not equal), < (less than), <= (less than or equal to), > (more than), >= (more than or equal to). These collation characters may be used in the commands If, While and Until.

Commands are available for:

- Alteration 393: changing the network or variables
- Arithmetic functions 400: functions for rounding, square, logarithm an goniometry
- Procedures 402: user defined procedures
- Conditional actions 403: executing or skipping parts of a macro, depending on a value
- Loops 404: repeatedly executing or skipping parts of a macro, depending on a value
- Calculation 408: determining results
- Reporting 415: entering data into Excel cells or formatting them
- Input 429: reading from spreadsheets for a macro execution
- Network actions 433: saving networks modified by the macro
- Topological 436
- Python

7.5.1 Macro alteration commands

Using an alteration command, it is possible to:

- Assign a value to a variable
- Assign a value to an attribute associated with a particular object
- Assign a value to an attribute, as associated with all selected objects of a particular type

Alteration commands are used with the most common attributes: switch positions, tap positions and powers. A list of the attributes of the various components that may be altered 372 using the macro language is given in a table.

The alteration options are:
- SetPQS 394: define whether the power attributes are respresented in kW/kvar/kVA or in MW/Mvar/MVA
- Set 394: set a variable or an attribute to a particular value
- Add 395: increase the value of a variable or an attribute by a certain amount
- Subtract 396: decrease the value of a variable or an attribute by a certain amount
- Multiply 396: multiply the value of a variable or an attribute by a value
- Divide 397: divide the value of a variable or an attribute by a value

It is also possible to use a command to alter a parameter, as associated with all components of a Selection. The alteration options are then:
- SetSelection 395: set an attribute of all components within a Selection to a particular value
- AddSelection 395: increase the value of an attribute of all components within a Selection by a certain amount
- SubtractSelection 396: decrease the value of an attribute of all components within a Selection by a certain amount
- MultiplySelection 397: multiply the value of an attribute of all components within a Selection by a value
- DivideSelection 397: divide the value of an attribute of all components within a Selection by a value

- Arrays 398: defined to store a large amount of calculated values

- Trace 399: select objects in a trace, starting at Node, in direction of Branch.

7.5.1.1 Macro command SetPQS

Using SetPQS(k) and SetPQS(M) the unity of power can be set to kW/kvar/kVA, respectievely to MW/Mvar/MVA. (No load)losses are always in kW. Default is MW/Mvar/MVA.

Purpose:
    Defines the power attributes in kW/kvar/kVA or in MW/Mvar/MVA.

General notation:
    SetPQS (k / M)
or:
    SetPQS (‘k’ / ‘M’)

7.5.1.2 Macro command Set

Purpose:
    Assigns a value to an attribute or a variable.

General notation:
    Set(**Object** (ObjectName).Attribute , value)
or
    Set(Variable , value)

Examples:
    Change transformer 'MyTransformer' tap changer into 4:
```
Set( Transformer( 'MyTransformer' ).Tap , 4 )
```
    Open cable 'MyCable' first (from-node) switch:
```
Set( Cable( 'MyCable' ).FirstSwitch , Open )
```
    Close cable 'YourCable', between nodes 'Station 1' and 'Station 2' second (to-node) switch:
```
Set( Cable( 'YourCable:Station 1-Station 2' ).SecSwitch , Closed )
```
    Change synchronous motor 'MyMachine' reactive power direction into "flowing into the network":

```
Set( SynMot( 'MyMachine' ).Qdirection , Supply )
```
Change load behaviour 'MyLoadBehaviour' scaling factor into 1.1:
```
Set( LoadBehaviour( 'MyLoadBehaviour' ).Scaling , 1.1 )
```
Initiate variable with name 'MyVoltage' at 10.5:
```
Set( MyVoltage , 10.5 )
```
Save node 'MyNode' p.u. voltage into variable HelpVoltage:
```
Set( HelpVoltage , Node( 'MyNode' ).Upu )
```
Save the node with name 'MyNode' into variable MonitoredNode:
```
Set( MonitoredNode , Node( 'MyNode' ) )
```
Creating or changing a Characteristic with the identifier 'Maintenance' and its Value with the text: 'Do Not Switch':
```
Set( Node('MyNode').Specifics , 'Maintenance=Do Not Switch' )
```
Deleting a Characteristic with the identifier 'Maintenance':
```
Set( Node('MyNode').Specifics , 'Maintenance=' )
```

7.5.1.3 Macro command SetSelection

Purpose:
Assigns a value to an attribute of all components within a Selection.

General notation:
SetSelection (Object(SelectionName).Attribute , value)

Examples:
Turn all generators within selection 'MySelection' off:
```
SetSelection( SynGen( 'MySelection' ).Switch , Open )
SetSelection( AsynGen( 'MySelection' ).Switch , Open )
```
Change for all nodes within selection 'MySelection' the simultaneousness for loads into 1:
```
SetSelection( Node( 'MySelection' ).Simultaneousness , 1 )
```

7.5.1.4 Macro command Add

Purpose:
Adds a value to an attribute or a variable.

General notation:
Add (Object(ObjectName).Attribute , value)
or
Add (Variable , value)

Examples:
Increase transformer with name 'MyTransformer' tap changer position with 1 step:
```
Add( Transformer( 'MyTransformer' ).Tap , 1 )
```
Lower load with name 'MyLoad' with 0.1 MW:
```
Add( Load ( 'MyLoad' ).Pl , -0.1 )
```
Increase load behaviour with name 'MyLoadBehaviour' scaling factor with 0.1:
```
Add( LoadBehaviour( 'MyLoadBehaviour' ).Scaling , 0.1 )
```
Lower variable with name 'MyVoltage' with 0.5:
```
Add( MyVoltage , -0.5 )
```
Compose a name dependent text for a node voltage warning:
```
Set( BranchName, 'Node with short name ' )
Add(BranchName, Node( 'MyNode' ).Short )
Add(BranchName, ' voltage is low. ' )
```

7.5.1.5 Macro command AddSelection

Purpose:
Adds a value to an attribute of all components within a Selection.

General notation:

AddSelection (Object(SelectionName).Attribute , value)

Examples:

Increase all transformer tap changers within selection with name 'MySelection' with 1 position:

```
AddSelection( Transformer( 'MySelection' ).Tap , 1 )
AddSelection( SpecialTransformer( 'MySelection' ).Tap , 1 )
AddSelection( 3WTransformer( 'MySelection' ).TapControl , 1 )
```

Increase all loads within selection with name 'MySelection' with 100 kW:

```
AddSelection( Load( 'MySelection' ).Pl , 0.1 )
```

7.5.1.6 Macro command Subtract

Purpose:

Subtracts a value from an attribute or a variable.

General notation:

Subtract(Object(ObjectName).Attribute , value)

or

Subtract (Variable , value)

Examples:

Lower load with name 'MyLoad' with 0.1 MW:

```
Subtract( Load ( 'MyLoad' ).Pl , 0.1 )
```

Lower variable with name 'MyVoltage' with 0.5:

```
Subtract( MyVoltage , 0.5 )
```

7.5.1.7 Macro command SubtractSelection

Purpose:

Subtracts a value from an attribute of all components within a Selection.

General notation:

SubtractSelection (Object(SelectionName).Attribute , value)

Examples:

Lower all transformer tap changers within selection with name 'MySelection' with 1 position:

```
SubtractSelection( Transformer( 'MySelection' ).Tap , 1 )
SubtractSelection( SpecialTransformer( 'MySelection' ).Tap , 1 )
SubtractSelection( 3WTransformer( 'MySelection' ).TapControl , 1 )
```

Lower all loads within selection with name 'MySelection' with 100 kW:

```
SubtractSelection( Load( 'MySelection' ).Pl , 0.1 )
```

7.5.1.8 Macro command Multiply

Purpose:

Multiplies an attribute or a variable with a value.

General notation:

Multiply (Object(ObjectName).Attribute , value)

or

Multiply (Variable , value)

Examples:

Lower load with name 'MyLoad' with 10%:

```
Multiply( Load ( 'MyLoad' ).Pl , 0.9 )
```

Increase load behaviour with name 'MyLoadBehaviour' scaling factor with 5%:

```
Multiply( LoadBehaviour( 'MyLoadBehaviour' ).Scaling , 1.05 )
```

Increase variable with name 'MyVoltage' with 10%:

```
Multiply( MyVoltage , 1.1 )
```

Increase load (P and Q) with name 'MyLoad' at node 'MyNode' with the value of the scaling factor of load behaviour with name 'MyLoadBehaviour':

```
Multiply( Load( 'MyLoad:MyNode' ).Pl ) , LoadBehaviour( 'MyLoadbehaviour' ).Scaling )
Multiply( Load( 'MyLoad:MyNode' ).Ql ) , LoadBehaviour( 'MyLoadbehaviour' ).Scaling )
```

7.5.1.9 Macro command MultiplySelection

Purpose:

Multiplies an attribute of all components within a Selection with a value.

General notation:

MultiplySelection (Object(SelectionName).Attribute , value)

Examples:

Increase all voltage controlled generators within selection with name 'MySelection' reference voltage with 10%:

```
MultiplySelection( SynGen( 'MySelection' ).Uref , 1.1 )
```

Increase all loads within selection with name 'MySelection' with 5%:

```
MultiplySelection( Load( 'MySelection' ).Pl , 1.05 )
MultiplySelection( Load( 'MySelection' ).Ql , 1.05 )
```

7.5.1.10 Macro command Divide

Purpose:

Divides an attribute or a variable by a value.

General notation:

Divide (Object(ObjectName).Attribute , value)

of

Divide (Variable , value)

Examples:

Lower load with name 'MyLoad' with 10%:

```
Divide( Load ( 'MyLoad' ).Pl , 1.1 )
```

Divide load (P and Q) with name 'MyLoad' at node 'MyNode' by the value of the growth of load behaviour with name 'MyLoadBehaviour':

```
Divide( Load( 'MyLoad:MyNode' ).Pl ) , LoadBehaviour( 'MyLoadBehaviour' ).Growth )
Divide( Load( 'MyLoad:MyNode' ).Ql ) , LoadBehaviour( 'MyLoadBehaviour' ).Growth )
```

7.5.1.11 Macro command DivideSelection

Purpose:

Divides an attribute of all components within a Selection by a value.

General notation:

DivideSelection (Object(SelectionName).Attribute , value)

Examples:

Lower all voltage controlled generators within selection with name 'MySelection' reference voltage with 10%:

```
DivideSelection( SynGen( 'MySelection' ).Uref , 1.1 )
```

Lower all loads within selection with name 'MySelection' with 5%:

```
DivideSelection( Load( 'MySelection' ).Pl , 1.05 )
DivideSelection( Load( 'MySelection' ).Ql , 1.05 )
```

Divide all nodes within selection with name 'MySelection' simultaneousness by 2:

```
DivideSelection( Node( 'MySelection' ).Simultaneousness , 2 )
```

7.5.1.12 Macro arrays

Arrays have been defined to store a large number of calculated values. Maximum 9 two-dimensional arrays are available of maximum 10000 rows and 1000 columns. A value can be stored using the command **Store**. Using the command **Restore** a value can be recalled.

General notation:

Store (index , row , column , value)
Restore (index , row , column , value)

The parameter Index (1..9) points to the arrays.

Example:

```
procedure(calculate_deviation)
// calculate (U-Uref) / Uref * 100%
   set(x,U)
   subtract(x,Uref)
   divide(x,Uref)
   multiply(x,100)
end

procedure(store_voltages_in_matrix_1)
   set(U,MyNode.U)
   call(calculate_deviation)
   add(i,1)
   store(1,i,1,U)
   store(1,i,2,Uref)
   store(1,i,3,x)
end

procedure(print_voltages_matrix_1)
   loop(j,1,i,1)
      restore(1,j,1,A)
      restore(1,j,2,B)
      restore(1,j,3,C)
      text(A:6:2,' kV   ',B:6:2,' kV   ',C:6:2,' %')
   end
end

loadflow(0,,true)
if(Network.Result,=,'LF')
   text('Voltage     Reference   Deviation')
   text('=======     =========   =========')
   set(Uref,node('MS-Station').U)
   set(i,0)
   forselection(node('MS-net'),MyNode)
      call(store_voltages_in_matrix_1)
   end
   call(print_voltages_matrix_1)
else
   text('no loadflow')
end
```

On the demo network this macro results in:

```
Voltage     Reference   Deviation
=======     =========   =========
 10,36 kV    10,36 kV     0,00 %
 10,08 kV    10,36 kV    -2,75 %
 10,31 kV    10,36 kV    -0,48 %
  9,93 kV    10,36 kV    -4,16 %
 10,37 kV    10,36 kV     0,09 %
  9,93 kV    10,36 kV    -4,16 %
```

7.5.2 Macro selecting

There are commands to edit the Selected attribute. See:

- Trace399: select all objects in a trace,

- Route 399: select all objects in a route,
- Feeding 399: select all objects to the source,
- Direction 399: select all objects in a direction.

There are commands to use and set the Selected attribute. See:
- AddSelectedToSelection 400: add all selected objects to a selection,
- DeselectAll 400: deselect all objects.

7.5.2.1 Macro command Trace

Purpose:
Select objects in a trace, starting at Node, in direction of Branch.

General notation:
Trace(Node(NodeName), Branch(BranchName))

The internal macro network will be deselected firstly. The trace will be selected consecutively. The selected objects can be detected by their boolean attribute Object.Selected.

7.5.2.2 Macro command Route

Purpose:
Selects all objects in a route, between two nodes or elements.

General notation:
Route(Node(NodeName), Node(NodeName))
Route(Node(NodeName), Element(ElementName))
Route(Element(ElementName), Node(NodeName))
Route(Element(ElementName), Element(ElementName))

The internal macro network is deselected first and then the corresponding route is selected.
The selected objects are detectable by consulting the attribute Object.Selected.

7.5.2.3 Macro command Direction

Purpose:
Selects all objects in a direction in which the specified object is located.

General notation:
Direction (Object(ObjectName) , [Ancillary direction level])

The internal macro network is deselected first and then the corresponding direction is selected.
The selected objects are detectable by consulting the attribute Object.Selected.

The optional second parameter Ancillary directions level, a 0, 1 or 2, ensures that ancillary directions are also selected if necessary. With 1 also all secondary directions. With 2 also all secondary directions and secondary directions.
If none is selected, this value is 0.

7.5.2.4 Macro command Feeding

Purpose:
Selects all objects in a route, between a node or element and the nearest source.

General notation:

Feeding (Node(NodeName))
Feeding (Element(ElementName))

The internal macro network is deselected first and then the corresponding route is selected. The selected objects are detectable by consulting the attribute Object.Selected.

7.5.2.5 Macro command AddSelectedToSelection

Purpose:
Add the selected objects to a new or existing selection.

General notation:
AddSelectedToSelection (SelectionName)

7.5.2.6 Macro command DeselectAll

Purpose:
Deselect all objects.

General notation:
DeselectAll

7.5.3 Macro functions

In the macro language many arithmetician functions have been defined. These functions are not case sensitive. The functions can be used on direct values 369 and variables 369 only. If an attribute 370 is to be consulted, it should be saved into a variable firstly.

See:

- General functions 401
- Calculating functions 401
- Power and logarithm functions 401
- Goniometric functions 401
- Logical functions 402
- Text functions 402
- Excel functions 402

Example:
Output the absolute value of a transmitted power:

```
Set(Pconnection,Line('MyLine').P1)
Set(Pconnection,ABS(Pconnection))
Text('Power=',Pconnection)
```

7.5.3.1 General functions

Function	Purpose	Example	Result
ABS	Absolute value	Text(ABS(1))	1
		Text(ABS(-1))	1
CEIL	Round up	Text(CEIL(1.1))	2
		Text(CEIL(-1.1))	-1
FLOOR	Round down	Text(FLOOR(1.1))	1
		Text(FLOOR(-1.1))	-2
FRAC	The fraction behind the decimal point	Text(FRAC(1.1))	0.1
ROUND	Round	Text(ROUND(1.4))	1
		Text(ROUND(1.5))	2
		Text(ROUND(-1.4))	-1
		Text(ROUND(-1.5))	-2
SIGN	Sign of the number	Text(SIGN(2))	1
		Text(SIGN(0))	0
		Text(SIGN(-2))	-1
TRUNC	Truncation of the decimals	Text(TRUNC(1.4))	1
		Text(TRUNC(1.5))	1
		Text(TRUNC(-1.4))	-1
		Text(TRUNC(-1.5))	-1
NEG	Negative value	Text(NEG(5))	-5
		Text(NEG(-5))	5
MAX	The maximum of two values	Text(MAX(1,2))	2
MIN	The minimum of two values	Text(MIN(1,-2))	-2
MID	The mean of two values	Text(MID(1,2))	1.5
RANDOM	A random number between 0 and Max (integer number)	Set(Max,1e8)	76523821
		Text(RANDOM(Max))	
ISREAL	Checks if a value is a number or not	Text(ISREAL('abc'))	FALSE
		Text(ISREAL(123))	TRUE
FILEEXISTS	Checks if a file exists	Text(FILEEXISTS('Test.xls'))	TRUE

7.5.3.2 Calculations functions

Function	Purpose	Example	Result
SUM	Sum of two values	Text(SUM(2,3))	5
DIFFERENCE	Difference of two values	Text(DIFFERENCE(2,3))	-1
DIF	The absolute difference of two values	Text(DIF(1,-2))	3
PRODUCT	Product of two values	Text(PRODUCT(2,3))	6
PIF	Multiply with Pi	Text(PIF(2))	6.28318531
QUOTIENT	Quotient of two values	Text(QUOTIENT(2,3))	0.66666667
DIV	Division of two values, rounded towards zero	Text(DIV(11,4))	2
MOD	Remainder after the division of two values	Text(MOD(11,4))	3

7.5.3.3 Power and logarithm functions

Function	Purpose	Example	Result
SQR	Square	Text(SQRT(3))	9
SQRT	Square root	Text(SQRT(3))	1.73205081
POWER	Power of a value	Text(POWER(2,5))	32
EXP	Power of e	Text(EXP(1))	2.71828183
LN	Natural logarithm	Text(LN(2.7))	0.99325177
LOG10	Logarithm of 10	Text(LOG10(1000))	3
LOG2	Logarithm of 2	Text(LOG2(64))	6

7.5.3.4 Goniometric functions

Function	Purpose	Example	Result
RAD	Conversion of degrees to radians	Text(RAD(45))	0,785398163397
GRAD	Conversion of radians to degrees	Text(GRAD(0,785398163397))	45
ARCCOS	Inverse cosine (radians)	Text(ARCCOS(1))	0
ARCSIN	Inverse sine (radians)	Text(ARCSIN(1))	1.57079633
ARCTAN	Inverse tangent	Text(ARCTAN(1))	0,785398163397
COS	Cosine (radians)	Text(COS(3.14))	-0.9999987
SIN	Sine (radians)	Text(SIN(3.14))	0.00159265
TAN	Tangent (radians)	Text(TAN(1.57))	1255.76559

7.5.3.5 Logical functions

Function	Purpose	Example	Result
AND	AND-function of 2 booleans (boolean)	Text(AND(TRUE,FALSE))	FALSE
OR	OR-function of 2 booleans (boolean)	Text(OR(TRUE,FALSE))	TRUE
XOR	XOR-function of 2 booleans (boolean)	Text(XOR(TRUE,TRUE))	FALSE
NOT	NOT-function	Text(NOT(TRUE))	FALSE
LT	less than	Text(LT(2,3))	TRUE
LE	less than or equal	Text(LE(3,3))	TRUE
GT	larger than	Text(GT(3,3))	FALSE
GE	larger than or equal	Text(GE(3,3))	TRUE
EQ	equal	Text(EQ(2,3))	FALSE
NE	not equal	Text(NE(2,3))	TRUE

7.5.3.6 Text functions

Function	Purpose	Example	Result
UPPERCASE	Conversion to uppercase	Text(UPPERCASE('abc'))	ABC
LOWERCASE	Conversion to lowercase	Text(LOWERCASE('ABC'))	abc
TRIM	Deletion of leading and trailing spaces	Text(TRIM(' abc '))	abc
LEFTSTR	First characters of a string	Text(LEFTSTR('abc',2))	ab
RIGHTSTR	Last characters of a string	Text(RIGHTSTR('abc',2))	bc
MIDSTR	Middle characters of a string	Text(MIDSTR('abcde',2,3))	bcd
LENGTH	Number of characters of a string	Text(LENGT('abc'))	3
POS	Position of a text in a string	Text(POS('bc','abcde'))	2
CHR	Character corresponding to an Ascii value	Text(CHR(66))	B
ASC	Ascii value of a character	Text(ASC('A'))	65
REPLACESTR	Replaces OldPattern with NewPattern in a text string	Set(S,'abcde')	
		Text(REPLACESTR(S,'cd','12')	ab12e
REALTOSTR	Conversion of a real number to a string	Text(RealToStr(1.23))	1.23
STRTOREAL	Conversion of string to real number		
SAMETEXT	Checks equality of two strings, case insensitive	Text(SameText('Vision','VISION'))	TRUE

7.5.3.7 Excel functions

Function	Purpose	Example	Result
CELL	Excel-designation of a cell (row, column)	Text(CELL(3,27))	AA3
RANGE	Excel-designation of a range (row1, column1,row2, column2)	Text(RANGE(1,1,99,256))	A1:IV99

7.5.3.8 Date functions

Function	Purpose	Example	Result
WEEKDAY	The weekday of a date number	Text (WeekDay(44694))	6
YEARDAY	The year day of a date number	Text (YearDay(44694))	133
YEARWEEK	The week of a date number	Text (Yearweek(44694))	19
DAY	The day of a date number	Text (Day(44694))	13
MONTH	The month of a date number	Text (Month(44694))	5
YEAR	The year of a date number	Text (Year(44694))	2022
REALTODATE	The textual notation of a date number	Text (RealToDate(44694))	13-5-2022
REALTODATETIME	The textual notation of a date number	Text (RealToDateTime(44694.345))	13-5-2022 08:16:48
DATETOREAL	The date number of a textual date	Text (DateToReal('13-5-2022'))	44694
DATETIMETOREAL	The date time number of a textual date	Text (DateTimeToReal('13-5-2022 9:34'))	44694.3986111111

7.5.4 Macro procedures

User defined procedures enable the execution of frequently used sets of macro commands, for example calculations or reporting actions.

Definition of a procedure:

Procedure (*procedure_name*)
...
...
End

Using a procedure:

Call (*procedure_name*)

The procedures do not have parameters and use only global variables. The definitions may not be nested. However, a previously defined procedure may be called in a next procedure definition. It is allowed to recursively call procedures.

Example:

```
procedure(calculate_deviation)
// calculate (U-Uref) / Uref * 100%
set(x,U)
subtract(x,Uref)
divide(x,Uref)
multiply(x,100)
end

procedure(print_voltages)
text(U:6:2,' kV   ',Uref:6:2,' kV   ',x:6:2,' %')
end

loadflow(0,,true)
if(Network.Result,=,'LF')
   text('Voltage     Reference   Deviation')
   text('=======     =========   =========')
   set(Uref,node('MS-Station').U)
   forselection(node('MS-net'),MyNode)
      set(U,MyNode.U)
      call(calculate_deviation)
      call(print_voltages)
   end
else
   text('no loadflow')
end
```

On the demo network this macro results in:

```
Voltage     Reference   Deviation
=======     =========   =========
 10,36 kV    10,36 kV     0,00 %
 10,08 kV    10,36 kV    -2,75 %
 10,31 kV    10,36 kV    -0,48 %
  9,93 kV    10,36 kV    -4,16 %
 10,37 kV    10,36 kV     0,09 %
  9,93 kV    10,36 kV    -4,16 %
```

7.5.5 Macro conditional commands

A conditional is used to perform an action if a particular condition is met. So, for example, you can automatically reduce the load by a certain value if one or more cables is/are overloaded, or arrange for a particular warning text to be printed in the event of an overload.

A conditional occupies several lines of a macro. Two values are compared and, depending on the outcome, the relevant part of the macro is executed, repeatedly executed or skipped.

See:
- If 403

7.5.5.1 Macro command if

If ... [Else] ... End

Purpose:

Executes a number of macro commands dependent on the result of a comparison between two values.

The If command is always used together with an End command. There is also an Else available for the case the outcome of the comparison is not true. The If and End lines enclose the part of the macro whose execution depends on fulfilment of the condition. General notation:

If (value1 , collation character , value2)
[**Else**]
End

The collation character may be:

= (equals),
<> (does not equal),
< (less than),
<= (less than or equal to),
> (more than),
>= (more than or equal to).

Examples:

If the current through cable with name 'MyCable' is larger than 80% of the maximum cable ampacity, lower the load with name 'MyLoad' with 10%:

```
If( Cable( 'MyCable' ).Load, >, 80 )
       Multiply( Load( 'MyLoad' ).Pl, 0.9 )
       Multiply( Load( 'MyLoad' ).Ql, 0.9 )
End
```

Write a text if the transformer with name 'MyTransformer' load is 90% or more:

```
If( Transformer( 'MyTransformer' ).Load, >= , 90 )
       Text( 'Transformer nearly overloaded.' )
Else
       Text( 'Transformer not overloaded' )
End
```

Change the tap changer of transformer with name 'MyTransformer' if not to its limit and if the voltage at node with name 'MyNode' is lower than 95% of its nominal value:

```
If( Node( 'MyNode' ).Upu, < , 0.95 )
       If( Transformer( 'MyTransformer' ).Tap, > , 1 )
              Subtract( Transformer( 'MyTransformer' ).Tap, 1 )
       Else
              Text( ‘Transformer tap changer reached limit’)
       End
End
```

Test the logical function **and**. The text function prints FALSE and the if-command prints *no* . Also applicable on **or** and **xor**.

```
set( a, true )
set( b, false )
text( and( a, b ) )

if( xor( a, b ), = , true )
       text( 'yes' )
else
       text( 'no' )
end
```

7.5.6 Macro loop commands

A loop command is used to perform an action repeatedly, as long as a particular condition is met. A loop occupies several lines of a macro. Two values are compared and, depending on the outcome, the relevant part of the macro is executed, repeatedly executed or skipped. Using a loop, it is possible, for example, to perform an action in connection with all selected components or to keep on performing as long as two specified values are equal.

The following loop commands may be used:

- While ... End 405: keep executing the relevant part of the macro as long as a particular condition is met

- Repeat ... Until 405: execute the relevant part of the macro repeatedly until a particular condition is met
- Loop ... End 406: execute the relevant part of the macro for a variable, stepping from start value to end value
- For ... End 406: execute the relevant part of the macro for all objects of a particular type
- ForSelection ... End 407: execute the relevant part of the macro for all objects of a particular type within a Selection

To prevent a macro accidentally getting stuck in an endless loop, it is possible to assign two types of protective value. One is the maximum number of loop iterations; the other is the maximum time for which execution should be continued. These protective values are set in th***Options*** , using **Calculation | Macro**.

7.5.6.1 Macro command While

Purpose:

To keep executing part of a macro as long as a particular condition is met. First, fulfilment of the condition is determined; depending on the outcome, the relevant part of the macro is executed or skipped. Following execution, fulfilment of the condition is determined again.

The While command is always used together with an End command. The While and End lines enclose the part of the macro whose execution depends on fulfilment of the condition. General notation:

While (value1 , collation character , value2)
End

The collation character may be:

= (equals),
<> (does not equal),
< (less than),
<= (less than or equal to),
> (more than),
>= (more than or equal to).

Example:

The next macro commands are executed for a simultaneousness varying from 1 through 0.2:

```
Set( MySimultaneousness, 1 )
While(MySimultaneousness, > , 0.1 )
       SetSelection( Node( 'MV-network' ).Simultaneousness, MySimultaneousness )
       Loadflow( 0, , true )
       Subtract(MySimultaneousness, 0.1 )
End
```

7.5.6.2 Macro command Repeat

Purpose:

Repeat a number of macro commands until a condition is met. Firstly, the macro commands are executed; secondly the condition is checked. Dependent on the condition the macro execution jumps back to the begin of the conditional macro commands.

The Repeat command is always used together with an Until command. The Repeat and Until lines enclose the part of the macro whose execution depends on fulfilment of the condition. General notation:

Repeat
Until (value1 , collation character , value2)

The collation character may be:

= (equals),
<> (does not equal),
< (less than),
<= (less than or equal to),
> (more than),

>= (more than or equal to).

Example:

The next macro commands are executed for a simultaneousness varying from 1 through 0.2:

```
Set( MySimultaneousness, 1 )
Repeat
        SetSelection( Node( 'MV-network' ).Simultaneousness, MySimultaneousness )
        Loadflow( 0, , true )
        Subtract(MySimultaneousness, 0.1 )
Until(MySimultaneousness, <= , 0.1 )
```

7.5.6.3 Macro command Loop

Purpose:

Executes a part of the macro for a variable, stepping from a start value to an end value. The end value is also executed.

The Loop command is always used together with an End. Between Loop and End are the repeatedly executable commands. General notation:

Loop(variable, start, end, step)
End

Example:

Next macro presents the losses of a cable connection in a period of 30 years.

```
Loop( year, 0, 30, 1 )
        Loadflow( year, , true )
        Text( 'Year: ', year, ' Losses: ', Cable('MyCable:FromNode-ToNode').Ploss, ' kW' )
End
```

7.5.6.4 Macro command For

Purpose:

Execute a number of macro commands for all objects of a specified type. The objects are one by one temporary stored into a variable.

The For-command always occurs together with an End. Between For and End are the repeatedly executable commands. General notation:

For (ExtendedObject , ObjectVariableName)
End

An ExtendedObject can be:

- an object (Node, Link, Cable, Line, ...), as defined in paragraph 4.1
- ***Branch*** : general indication of a branch between two nodes (Link, Cable, ...)
- ***Element*** : general indication of an element on a node (Source, SynGen, ...)
- ***Object*** : general indication of a component in the network.
- ***Loadbehaviour*** : load behaviour
- ***Selection*** : selection

Examples:

Perform an N-1 contingency analyse for all branches:

```
Set( sheet, 1 );
Set( column, 1 );
Set( row , 1 );
For( Branch, failingbranch )
        Write( sheet, row , column, failingbranch )
        Set( failingbranch.FirstSwitch, open )
        Loadflow( 0, , true )
        Write( sheet, row, 2, Node('MyNode').upu)
        Set( failingbranch.FirstSwitch, closed )
        Add( row , 1 )
```

```
End
```

Report for all components the name:

```
Set( sheet, 1 )
Set( column, 1 )
Set( row , 0 )
For( Object, Component )
       Add( row , 1 )
       Write( sheet, row , column, Component.Name )
End
```

Other examples:

```
For( Loadbehaviour, MyLoadBehaviour )
For( Selection, MySelection )
```

7.5.6.5 Macro command ForSelection

Purpose:

Execute a number of macro commands for all objects of a specified type within a selection. The objects are one by one temporary stored into a variable.

The ForSelection-command always occurs together with an End. Between ForSelection and End are the repeatedly executable commands. General notation:

ForSelection (ExtendedObject(SelectionName) , ObjectVariableName)
End

An ExtendedObject can be:

- an object (Node, Link, Cable, Line, ...), as defined in paragraph 4.1
- ***Branch*** : general indication of a branch between two nodes (Link, Cable, ...)
- ***Element*** : general indication of an element on a node (Source, SynGen, ...)
- ***Object*** : general indication of a component in the network.

Examples:

Perform an N-1 contingency analyse for all branches in the selection with name 'MV-network':

```
Set( sheet, 1 );
Set( column, 1 );
Set( row , 1 );
ForSelection( Branch( 'MV-Network' ), failingbranch )
       Write( sheet, row , column, failingbranch )
       Set( failingbranch.FirstSwitch, open )
       Loadflow( 0, , true )
       Write( sheet, row, 2, Node('MyNode').upu)
       Set( failingbranch.FirstSwitch, closed )
       Add( row , 1 )
End
```

Report for all components in the selection with name 'MySelection' the name:

```
Set( sheet, 1 )
Set( column, 1 )
Set( row , 0 )
ForSelection( Object( 'MySelection' ), Component )
       Add( row , 1 )
       Write( sheet, row , column, Component.Name )
End
```

7.5.6.6 Macro command Break

Purpose:

Jump out of a for, loop, while or repeat.

General notation:

Break

7.5.6.7 Macro command Exit

Purpose:
Terminate the macro immediately.

General notation:
Exit

7.5.6.8 Macro command Pause

Purpose:
Pause the execution of the macro.

General notation:
Pause (Time)

The time is in s.

7.5.6.9 Macro command ForSelected

Purpose:
Execute a piece of macro for selected objects of a specified type. The objects are available one by one in a variable.

The ForSelected command always occurs together with an End. Between ForSelected and End are the commands to be executed repeatedly. General notation:
ForSelected (ExtendedObject, ObjectVariableName)
End

7.5.7 Macro calculating commands

A calculation command is used to perform a particular calculation on the network. Parameters are used to indicate the settings.

See:

- Load flow 409
- IEC 60909 410
- Fault analysis 410
- Selectivity 411
- Ripple 412
- Reliability 412

Almost all objects have the attribute *'**Result**'* . This is a text, containing the value *'NO'* if no calculation results are available. After successful completion of a calculation this attribute contains the values:
'LF' : loadflow result available
'IEC' : IEC 60909 result available
'FA' : Fault Analysis result available
'REL' : Reliability analysis results available

This is used to test if a calculation has been carried out successfully. E.g.:

```
if( Node('MyNode').Result, =, 'LF' )
        ...
end
```

7.5.7.1 Load flow

Purpose:

Calculation of the load flow 250 of a network. Parameters are the number of years for the load growth, load pattern, motor start, automatic transformer tap changers control and percentages.

General notation:

Loadflow ([year] , [extra] , [transformercontrol] , [shuntcontrol], [generation], [load], [PV], [wind] , [suntime], [transformer control tactics], [profile files])

The parameters may be omitted from the last to the front. The parameters may also left blank. When omitted or left blank, the default value counts.

The parameters correspond with the load flow settings form.

year : number of years from present in order to establish load growth (default 0)
extra : text value for extended loadflow calculation (default ''; possible: '', 'ms', 'n-1', 'n-2', 'pf', 'prd')
transformercontrol *true/false* for adapting tap changers (default true)
shuntcontrol *true/false* for condensor en coil control (default true)
generation : generation scaling percentage (default 100)
load : load scaling percentage (default 100)
PV : PV scaling percentage (default 100)
wind : wind scaling percentage (default 100)
sun time : date time as a broken number (around 44000; default 0/n.a.)
transformer control tactics : 0:nothing special; -1:control to low voltage; 1:control to high voltage
profile files : path+file name, possibly with wildcards to select multiple files

After a successful execution the standard objects Network.Result and Object.Result will be equal to *'LF'* , otherwise *'NO'* .

The results of the load flow with profiles and the load flow over a period are available only as an export file, with the ExportResult command.

Load flow calculation with motor start:

Loadflow(year , 'ms' , transformercontrol)

The asynchronous motors which are 'selected' will start. The attribute Selected can be changed by the macro. Initially the 'selected' attributes have the value true if they are selected in the network; false otherwise. Calculated voltage and current are the values during the motorstart.

Examples:

Perform a load flow for year 3 and with automatic transformer tap changer control turned on:

```
Loadflow ( 3 , , true )
```

Perform a load flow with variables for year 5 and with automatic transformer tap changer control disabled:

```
Set( year, 5 )
Set( transformercontrol, false )
Loadflow ( year , , transformercontrol )
```

Perform a load flow with with motor start:

```
Set( AsynMot( 'MyMotor' ).Selected , true )
Set( transformercontrol, false )
Loadflow ( 0 , 'ms' , transformercontrol )
```

7.5.7.2 IEC 60909

Purpose:
Calculation of a short circuit according to IEC 60909 262, for only one node or for the whole network.

If the command is used for only one node, the short circuit is evaluated for that node and the currents of the other branches in the network are available for that situation.
If the command is used for the whole network, only the maximum short circuit currents on the nodes are available.

General notation:
IEC60909 (Node(ObjectName), Fault, Ik", Tap)
or
IEC60909 (NIL, Fault, Ik", Tap)

On the position of Fault a tekst or a text variable must be inserted. The options are:
'ppp' : symmetrical fault
'pe' : phase-earth fault
'pp' : phase-phase fault
'ppe' : phase-phase-earth fault

On the position of Ik" a tekst or a text variable must be inserted. The options are:
'max' : Ik"max (with asynchronous machines)
'min' : Ik"min (without asynchronous machines)

On the position of Tap a boolean or a boolean variable must be inserted. The options are:
true : nominal taps
false : actual taps

After a successful execution the standard objects **Network**.Result and **Object**.Result will be equal to *'IEC'* , otherwise *'NO'* .

Examples:
Perform a symmetric IEC calculation with asynchronous machines, with transformer tap changers nominal:
```
IEC60909 ( Node('MyNode'), 'ppp' , 'max' , true )
```

Perform a single phase IEC calculation without asynchronous machines for all nodes, with transformer tap changers actual:
```
Set( fault, 'pe' )
Set( ik, 'min' )
Set( taps, false )
IEC60909 ( NIL, fault, ik, taps )
```

7.5.7.3 Fault analysis

Purpose:
Calculation of a Sequential Fault Analysis 273 on a node, in a cable or in a line.

If the calculation is called for one node, for that node the short circuit is calculated. Of all other nodes and branches the voltages and currents in that situation are available. The transformer tap changers are in this calculation not adapted to the loadflow situation.
If the calculation is called with NIL (without specification of node, cable or line), only the initial situation (the loadflow situation) will be calculated.

General notation:
Fault (Node(NodeName) , , FaultType, Rf, Xf)
Fault (Cable(CableName), Distance, FaultType, Rf, Xf)
Fault (Line(LineName) , Distance, FaultType, Rf, Xf)

or

Fault (NIL, , , ,)

For Distance the distance from the FirstNode to the fault location in the cable or line will be specified, in percent (1 up to 99).

For FaultType a textvalue or a textvariable indicates the type of fault. The possible values are:
'abc' : symmetrical short circuit
'abco' : symmetrical short circuit to ground
'ao' : single phase short circuit to ground
'bo' : single phase short circuit to ground
'co' : single phase short circuit to ground
'ab' : two phase short circuit
'ac' : two phase short circuit
'bc' : two phase short circuit
'abo' : two phase short circuit to ground
'aco' : two phase short circuit to ground
'bco' : two phase short circuit to ground

For Rf:
The fault resistance, in Ohm

For Xf:
The fault reactance, in Ohm

After a successful execution the standard objects **Network**.Result and **Object**.Result will be equal to *'FA'* , otherwise *'NO'* .

Example:
Calculation of a symmetrical fault analysis with a zero-impedance short circuit:
```
Fault ( Node ('MyNode') ,  , 'abc' , 0, 0 )
```
Calculation of a single phase fault analysis with fault impedance 0.1+j0.1 Ohm:
```
Set( FaultType, 'a0' )
Set( Rf, 0.1 )
Set( Xf, 0.1 )
Fault ( Node ('MyNode') ,  , FaultType, Rf, Xf )
```

7.5.7.4 Selectivity

Purpose:
Calculation of the Selectivity of the protection 294 of a node, in a cable or a line or in an element.

If the calculation is called for one node, for that node the selectivity is calculated. The transformer tap changers are in this calculation not adapted to the loadflow situation.

General notation:
Selectivity (Node(NodeName) , FaultType)
Selectivity (Cable(CableName), FaultType)
Selectivity (Line(LineName) , FaultType)

or

Selectivity (NIL,)

For FaultType a textvalue or a textvariable indicates the type of fault. The possible values are:
'abc' : symmetrical short circuit
'abco' : symmetrical short circuit to ground
'ao' : single phase short circuit to ground
'bo' : single phase short circuit to ground
'co' : single phase short circuit to ground

'ab' : two phase short circuit
'ac' : two phase short circuit
'bc' : two phase short circuit
'abo' : two phase short circuit to ground
'aco' : two phase short circuit to ground
'bco' : two phase short circuit to ground

After a successful execution the standard objects **Network**.Result and **Object**.Result will be equal to *'SEL'* , otherwise *'NO'* .

Example:
Calculation of the selectivity for a symmetrical fault:
```
Fault ( Node ('MyNode') ,  , 'abc' , 0, 0 )
```

7.5.7.5 Ripple

Purpose:
Calculation of the Ripple control 282 signals propagation in a network.

General notation:
Ripple

No parameters are needed.

After a successful execution the standard objects Network.Result and Node.Result are *'RIP'* .

7.5.7.6 Reliability

Purpose:
Calculation of the reliability 289 of a network.

General notation:
Reliability (Refusing switches, Common cause faults, Maintenance)

After a successful execution the standard objects **Network**.Result and **Object**.Result will be equal to *'REL'* , otherwise *'NO'* .

Example:
Perform a reliability analysis with default parameters:
```
Reliability( false, false, false )
```

7.5.7.7 Macro command Protection

Purpose:
To perform security-one-failure calculation 294 optionally on a single node, in a cable or in a link or in an element.

General notation:
Protection (Node(NodeName), Distance, Closure, Rf, Xf, [Generation], [Load], [PV], [Wind], [Solar Time])
Protection (Cable(CableName) , Distance, Closure, Rf, Xf, [Generation], [Load], [PV], [Wind], [Solar Time])
Protection (Line(CableName) , Distance, Closure, Rf, Xf, [Generation], [Load], [PV], [Wind], [Solar Time])

Distance in percent. Not applicable at node.

At the location of Closure, a text value should be entered or a text variable. The possibilities are:
'abc' : symmetric closure
'abco' : symmetrical closure with earth contact

'ao' : phase-to-earth closure
'bo' : phase-to-earth closure
'co' : phase-to-earth closure
'ab' : phase-earth connection
'ac' : phase-terminal closure
'bc' : phase-terminal closure
'abo' : phase-ground closure
'aco' : phase-phase ground closure
'bco' : phase-phase-earth closure

After successful execution, the default Network.Result and Object.Result objects are equal to *'PROT'* and *'NO'* otherwise

Examples:
Execute symmetric single-error calculation:
```
Protection ( Node ('MyNode') ,0 , 'abc', 0, 0 )
```

7.5.7.8 Macro command Simulation

Purpose:
Execute the security simulation calculation 294 optionally on a single node, cable or connection or element.

If the calculation is called with NIL (without specification of node, cable, connection or element), the simulation is performed for all objects.

General notation:
Simulation (Node(NodeName), Closure, Rf, Xf)
Simulation (Cable(CableName) , Closure, Rf, Xf)
Simulation (Line(ConnectionName) , Closure, Rf, Xf)
or
Simulation (NIL, Closure, Rf, Xf)

In the place of Closure, a text value must be entered or a text variable. The possibilities are:
'abc' : symmetric closure
'abco' : symmetrical closure with earth contact
'ao' : phase-to-earth closure
'bo' : phase-to-earth closure
'co' : phase-to-earth closure
'ab' : phase-earth connection
'ac' : phase-terminal closure
'bc' : phase-terminal closure
'abo' : phase-ground closure
'aco' : phase-phase ground closure
'bco' : phase-phase-earth closure

After successful execution, the default objects Network.Result and Object.Result are equal to *'SIM'* and otherwise *'NO'*.

Examples:
Execute symmetric simulation calculation:
```
Simulation ( Node ('MyNode') , 'abc', 0, 0 )
```

7.5.7.9 Macro command FailureAnalysis

Purpose:
Calculation of fault analysis 319 for selected nodes and branches. Parameters include transformer arrangements, shunt arrangements and percentages.

General notation:

FailureAnalysis ([transformer controls] , [shunt controls], [generation], [load], [PV], [wind], [solar time], [transformer control tactics])

The parameters may be omitted from the last one forward. If omitted, the default value below applies.

The parameters correspond to the fault analysis settings 319:

transformer controls *true/false* for yes/no automatic adjustment of transformer report switches (default true)
shunt controls *true/false* for yes/no application of capacitor and coil controls (default true)
generation : generation scaling percentage (default 100)
Load : load scaling percentage (default 100)
PV : PV scaling percentage (default 100)
wind : wind scaling percentage (default 100)
solar time : date time as a broken number (around 44000; default 0/n/a)
trafo control tactic : 0:nothing special; -1:control to low voltage; 1:control to high voltage

After successful execution, Network.Result and Object.Result are equal to *'FAILA'*.

The Selected attribute is modifiable within the macro. Initially, the 'selected' attributes have the value as selected in the network.

Example:

```
failureanalysis(TRUE,TRUE,100,100,100,100,0)
for(node,onenode)
 if (onenode.result,=,'FAILA')
       text(onenode)
       if (onenode.switchedbranch1,<>,NIL)
              text(anode.switchedbranch1)
       end
 if (anode.switchedbranch2,<>,NIL)
       text(anode.switchedbranch2)
 end
 text()
 end
end
```

7.5.7.10 Macro command NetCheck

Purpose:

Calculation of net sets of wholesale consumption.

General notation:

Netcheck(Node(ObjectName), S, Application, Name)

The first parameter is the node to which the new element is to be applied.
The second parameter is the apparent power of the new element in MVA.
The third parameter is a textual notation of the type of element. Possible values are: "load", "PV", "wind turbine" and "generation".
The fourth parameter is the name of the new element.

The results are available via the "Problem" attribute at all objects.

7.5.7.11 Macro command Pseudomonitor

Purpose:

Calculation of pseudomonitoring.

General notation:
Pseudomonitor(Phase, Measurement files folder, Profile files folder, [Start date], [End date])

Leave the profile files folder empty ('') if there are no profile files.
The start date and end date are optional. If not specified, the entire time span of the measurement files will be calculated.
Phase can be 1 or 2.

The results can only be output with the ExportResult429 command.

7.5.7.12 Macro command DataDrivenLoadflow

Purpose:
Calculation of data driven loadflow.

General notation:
DataDrivenLoadflow(Measurement files, [Profile files], Preprocessor, Calculation interval, Method)

Leave the profile files folder empty ('') if there are no profile files. Measurement file(s) is/are mandatory.
Preprocessor is a boolean. If preprocessor is enabled, Calculation interval and Method should be set.
Calculation interval sets the number of minutes between calculated time samples.
Method is a string with preprocessor method for filling in missing data. Possible values are: 'Previous_week', 'Previous_day', 'Previous_time_stamp', 'Average', 'Reference_profile'.

The results can only be output with the ExportResult429 command.

7.5.8 Macro reporting commands

There are four ways to report data from within a macro:
- Write to an object in the one-line editor
- Write to a text
- Write to a text file
- Write to an Excel workbook

Write to an object in the one-line editor
Macro resulting text can be printed next to each object in the one-line network diagram. Also the colour of each object can be changed. See:
- View417
- Viewcolor418

Write to a text
Besides reporting to a file it is also possible to output to a text on screen. See:
- Text418: write a value as line to a text
- Debug419: write a value as line to a text, in a separate window

Write to a text file
A reporting command is used to print the results of a calculation to a text file. The file has to be opened and a separator has to be defined. Data can be written to one line or to multiple lines of text. Afterwards the file has to be closed. An opened file can not be read at the same time. See:
- TfOpenForWrite419: Open a text file for writing
- TfWrite420: Write to one line of a text file
- TfWriteLn420: Write to one line of a text file and include a linefeed
- TfClose420: Close a text file

Write to an Excel workbook

A reporting command is used to print the results of a calculation in the form of an Excel workbook (spreadsheet). Using the commands, one can increase the number of sheets in the workbook and assign a title to each sheet. The workbook can be formatted by using a command to have the content of a particular cell printed in bold type. It is also possible to have the width of a column adjusted to accommodate its content. Read and write operations may be executed in the same session. See:

- Create 421: create a new spreadsheet
- Open 421: opening an existing spreadsheet
- Close 421: closing a spreadsheet
- Addsheets 421: expands the number of worksheets in aan Excel workbook
- Getsheets 422: retrieve the number of worksheets in aan Excel workbook
- Title 422: definition of a name for a worksheet in the workbook. The worksheet can be accessed by the number only
- GetTitle 422: retrieve the name of a worksheet in the workbook
- Write 422: write a value in a cel of a worksheet into the workbook
- Copy 424: to copy a range of cells of a worksheet into a worksheet of the output workbook
- Bold 424: boldface the contents of a range of cells in the worksheet
- Border 425: create a border around the contents of a range of cells in the worksheet
- Merge 425: merge a range of cells in the worksheet
- Fit 425: to fit the column width to the contents of a range of cells in the worksheet
- Align 425: to align the text of a range of cells in the worksheet horizontally and vertically
- Fontcolor 426: to colour a range of cells in a spreadsheet
- Backcolor 426: to colour the background of a range of cells in a spreadsheet

- Format 416: to format the presentation of a number or a text value

7.5.8.1 Macro format

There is no command for defining a format for printing the numbers and texts. The format is indicated directly behind a value or variable at a write or text command.

Aim:

Format of a value to a fixed presentation format in order to be printed of presented in a table.

General notation:

NumericalValue:MinLength

or:

NumericalValue:MinLength:Decimals

or:

TextValue:MinLength

or:

Textvalue:MinLength:MinLengthBehind

The use of a format is optional.

It is possible to influence the presentation of values by defining a format. For a numerical value is possible to define the length and the number of decimals by writing these immediately behind the value, preceded by colon: NumericalValue:MinLength or NumericalValue:MinLengt:Decimals. NumericalValue is a numerical value. MinLength is an integer value, indicating the minimum length of the numerical presentation. If without format the normal numerical presentation would be shorter, spaces would have been added to the front. In that case the presentation is no longer numerical, but alphanumerical.
For alphanumeric values the length can be given up similarly: TextValue:MinLength or TextValue:MinLength:MinLengthBehind. In the first case spaces are added to the front until the total length amounts to MinLength. In the second case spaces to MinLengthBehind are added to the back firstly and afterwards spaces to the front to MinLength.

Formatting with length is mainly useful when reporting column-oriented in text values.

Example:

```
Loadflow(0,,true,false)
Set(NNN,Node('Station 1'))
Text('>',NNN.Name:20,'<')
Text('<',NNN.Name:20:10,'<')
Text('<',NNN.Name:20:20,'<')
Text('<',NNN.Upu:8:2,'<')
```

yields:

```
>            Station 1<
>           Station 1 <
>Station 1            <
>    1,01<
```

A table can be created using the format. For example, see next macro, applied on the demonstration network 'demo.vnf':

```
Loadflow(0,,true,false)
Text('Node name             Voltage')
Text('                         [pu]')
Text('============================')
For(Node,NNN)
  Text(NNN.Name:20:20,NNN.Upu:8:2)
End
```

Yields the next table:

```
Node name             Voltage
                         [pu]
============================
HS-Station               1,05
MS-Station               1,04
Station 1                1,01
Station 4                1,03
Station 3, rail A        0,99
Hoofdrail                1,04
TS                       1,02
Station 3, rail B        0,99
Hoofdrail                1,04
Molen 2                  1,04
Molen 1                  1,02
```

7.5.8.2 Macro write to an object

7.5.8.2.1 Macro command View

Purpose:

Write macro resulting text next to an object in the one-line network diagram

General notation:

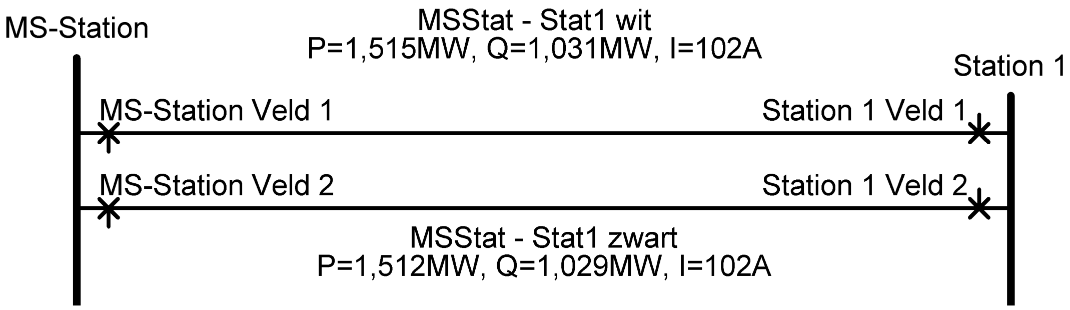
View (Object, value1 [, value2 [, value3 ...]])

Example:

Write P1, Q1 and I1 on one line next to each branch:

```
loadflow ( 0 , , true , false )
for(branch,a)
   view(a,'P=',a.P1,'MW, Q=',a.Q1,'MW, I=',a.I1,'A')
end
```

The example prints text variable b next to each branch. In the next example for two branches of the demo-network:



7.5.8.2.2 Macro command Viewcolor

Purpose:
Colour an object in the one-line network diagram depending on macro result

General notation:
Viewcolor (Object, Colour)

Colour is an integer value between 0 and 14, representing the colours: black, gray, lightgray, navy, blue, aqua, purple, fuchsia, green, lime, teal, maroon, red, yellow and white.

Example:
Colour cables red (12) and lines blue (4):

```
for(branch,a)
   if(a.Sort,=,'CABLE')
      viewcolor(a,12)
   end
   if(a.Sort,=,'LINE')
      viewcolor(a,4)
   end
end
```

7.5.8.3 Macro write to a text

7.5.8.3.1 Macro command text

Purpose:
Write one or more values as line to a text.

General notation:
Text (value1 [, value2 [, value3 ...]])

The format 416 can be specified together with the value.

It is possible to write more than one value. In that case all values are delimited with a comma. In the case that the value is an object, the commands writes to the worksheet cell: the object type, directly followed by the object name.

The text is shown on the screen after the macro has finished. The user may save the text by giving it a filename. There are no formatting commands.

Example:
Perform an n-1 contingency analysis for all branches in selection 'MV-Network' and present the voltage of node 'MyNode':

```
Set( year, 2006 )
Set( textline, 'Results N-1 contingency analysis year: ' )
```

```
        Add( textline , year )
        Text( textline )
        Text( 'Failing branch:      Voltage (p.u.):' )
        For( Branch( 'MS-net' ), failingbranch )
               Set( textline, failingbranch )
               Add( textline, '      ' )
               Set( failingbranch.FirstSwitch, open )
               Loadflow( 0, , true )
               Add(textline, Node( 'MyNode' ).Upu )
               Text( textline )
               Set( failingbranch.FirstSwitch, closed )
        End
```

The example yields the next ASCII text:

```
Results N-1 contingency analysis year: 2006
Failing branch:     Voltage (p.u.):
Link     1.0199
Cable MSStat - Stat1 circuit 1     0.9798
Cable MSStat - Stat1 circuit 2     0.9798
Cable MSStat - Stat4 circuit 2     0.9906
Cable MSStat - Stat4 circuit 1     0.9906
Cable Stat4 - Stat3     0.9505
Cable Stat4 - Main bus bar     0.9833
Cable Stat1 - Stat3 circuit 1     0.966
```

7.5.8.3.2 Macro command debug

Purpose:
Write one or more values as line to a text, in a separate output window.

General notation:
Debug (value1 [, value2 [, value3 ...]])

The working of this command is similar to that of the command Text 418, but the output will be directed to a separate window. This window appears before the normal Text window.

7.5.8.3.3 Macro command SetDecimalSeparator

With SetDecimalSeparator, numbers are forcibly output with a decimal point or comma.

Notation:
SetDecimalSeparator('.')
or:
SetDecimalSeparator(',')

7.5.8.4 Macro write to a text file

7.5.8.4.1 Macro command TfOpenForWrite

Purpose:
Open a text file for writing

General notation:
TfopenForWrite(FileIndex, FileName, Separator)

An opened file can not be read at the same time.

Example:
Opening a text file with a semicolon as a separator:

```
TfOpenForWrite( 1, 'output.txt', ';' )
```

7.5.8.4.2 Macro command TfWrite

Purpose:
Write to one line of a text file

General notation:
TfWrite(FileIndex, value1 [, value2 [, value3 ...]])

The separator has been defined by TfOpenForWrite 419 and will be written between the values.
Text values will be written as text.
Text values with additional quotation marks will be written between quotation marks.
The command TfWrite generates no line feed.

Example:
```
TfOpenForWrite( 1, 'output.txt' )
Set( a, 1.2345 )
TfWrite( 1, ''one'', 2, 3, 4, 'five', 6, a:6:2 )
TfWrite( 1, ''one'', 2, 3, 4, 'five', 6, a:6:2 )
TfClose(1)
```

Results in:
```
'one';2;3;4;five;6;  1.23;'one';2;3;4;five;6;  1.23
```

7.5.8.4.3 Macro command TfWriteLn

Purpose:
Write to one line of a text file and include a linefeed

General notation:
TfWriteLn(FileIndex, value1 [, value2 [, value3 ...]])

The separator has been defined by TfOpenForWrite 419 and will be written between the values.
Text values will be written as text.
Text values with additional quotation marks will be written between quotation marks.
The command TfWriteLn generates one line feed.

Example:
```
TfOpenForWrite( 1, 'output.txt' )
Set( a, 1.2345 )
TfWriteLn( 1, ''one'', 2, 3, 4, 'five', 6, a:6:2 )
TfWriteLn( 1, ''one'', 2, 3, 4, 'five', 6, a:6:2 )
TfClose(1)
```

Results in:
```
'one';2;3;4;five;6;  1.23
'one';2;3;4;five;6;  1.23
```

7.5.8.4.4 Macro command TfClose

Purpose:
Close a text file

General notation:
TfClose(FileIndex)

Example:
```
TfClose( 1 )
```

7.5.8.5 Macro write to Excel

7.5.8.5.1 Macro command create

Purpose:
Generate a new spreadsheet.

General notation:
Create (FileIndex , FileName)

Using the Create command a spreadsheet file is assigned to a FileIndex for Read and Write commands. The FileIndex is an integer number between 1 and 9. This means that a maximum of nine spreadsheet files can be opened simultaneously. If more files have to be opened, firstly other files have to be closed using the Close command.

7.5.8.5.2 Macro command open_2

Purpose:
Opening an existing spreadsheet.

General notation:
Open (FileIndex , FileName)

Using the Open command a spreadsheet file is assigned to a FileIndex for Read and Write commands. The FileIndex is an integer number between 1 and 9. This means that a maximum of nine spreadsheet files can be opened simultaneously. If more files have to be opened, firstly other files have to be closed using the Close command.
Writing to FileIndex 0 creates a new runtime Excel-file. It opens automatically and remains open in Excel after execution of the macro. The result has to be saved manually.

Example:
Open nine spreadsheet files for reading metered data in files File1, File2, ... File9:

```
Loop ( Index , 1 , 9 , 1 )
       Set ( FileName , 'D:\MyDir\File' )
       Add ( FileName , Index )
       Add ( FileName , '.xls' )
       Open ( Index , FileName )
End
```

7.5.8.5.3 Macro command close_2

Purpose:
Closing a spreadsheet.

General notation:
Close (FileIndex)

Example:
Close nine spreadsheet files:

```
Loop ( Index , 1 , 9 , 1 )
       Close ( Index )
End
```

7.5.8.5.4 Macro command addsheets

Purpose:
Expands the number of worksheets in an Excel workbook.

General notation:

Addsheets (FileIndex, number)

Example:

Add 3 worksheets to the Excel workbook 1.

```
Addsheets ( 1, 3 )
```

7.5.8.5.5 Macro command getsheets

Purpose:

To retrieve the number of worksheets in aan Excel workbook.

General notation:

Getsheets (FileIndex, number)

FileIndex is the same index used by the Open command. Using the Open command a spreadsheet file is assigned to a FileIndex for later Read commands. The FileIndex is an integer number between 1 and 9. If a value of 0 is assigned to the FileIndex, this corresponds to the currently opened output spreadsheet.

Example to retrieve the number of worksheets in the standard output workbook (FileIndex 0):

```
GetSheets ( 0, N )
Text( 'The number of worksheets is: ', N)
```

7.5.8.5.6 Macro command title

Purpose:

Definition of a name for a worksheet in the workbook. The worksheet can be accessed by the number only.

General notation:

Title (FileIndex, worksheetnumber, title)

Example:

```
Title ( 1, 'N-1 contingency analysis' )
```

7.5.8.5.7 Macro command gettitle

Purpose:

Retrieve the name of a worksheet in the workbook. The worksheet can be accessed by the number only.

General notation:

GetTitle (FileIndex, worksheetnumber, title)

FileIndex is the same index used by the Open command. Using the Open command a spreadsheet file is assigned to a FileIndex for later Read commands. The FileIndex is an integer number between 1 and 9. If a value of 0 is assigned to the FileIndex, this corresponds to the currently opened output spreadsheet.

Example:

```
GetTitle ( 0, 1, S)
Text( 'Title = ', S)
```

7.5.8.5.8 Macro command write

Purpose:

Write a value in a cel of a worksheet.

General notation:

Write (FileIndex, sheet , row , column , value)

FileIndex 0: standaard output to Excel on your computer.
FileIndex 1..9: index pointing to the opened spreadsheet file.
Using the Open command a spreadsheet file is assigned to a FileIndex for Read and Write commands. The FileIndex is an integer number between 1 and 9. This means that a maximum of nine spreadsheet files can be opened simultaneously. If more files have to be read, firstly other files have to be closed using the Close command.
Writing to FileIndex 0 creates a new runtime Excel-file. It opens automatically and remains open in Excel after execution of the macro. The results has to be saved manually.
A new Excel file can also be created with FileIndex 1 to 9 by using Create 421.

The format 416 can be specified together with the value.

In the case that the value is an object, the commands writes to the worksheet cell: the object type, directly followed by the object name.

The worksheet cell can be accessed by its row and colum number. The normal Excel notation (identification of a cell by means of a combination of letters and numbers) is not possible because the macro language works on a numeric basis.

Example:

Execute an n-1 contingency analysis for all branches in selection ‘MV-network’ and present the voltage of node ‘MyNode’:

```
Set( year, 2006 )
Write ( 0 , 1 , 1 , 1 , 'Results N-1 contingency analysis year: ' )
Write ( 0 , 1 , 1 , 2 , year )
Set( row, 3)
Write ( 0 , 1 , row , 1 , 'Failing branch:' )
Write ( 0 , 1 , row , 2 , 'Voltage (p.u.):' )
ForSelection( Branch( 'MV-network' ), failingbranch )
       Add( row, 1 )
       Write( 0 , 1, row, 1, failingbranch )
       Set( failingbranch.FirstSwitch, open )
       Loadflow( 0, , true )
       Write( 0 , 1, row, 2, Node( 'MyNode' ).Upu)
       Set( failingbranch.FirstSwitch, closed )
End
```

This example yields the following Excel worksheet:

Results N-1 contingency analysis year:	2006
Failing branch:	Voltage (p.u.):
Link	1.0199
Cable MSStat - Stat1 circuit 1	0.9798
Cable MSStat - Stat1 circuit 2	0.9798
Cable MSStat - Stat4 circuit 2	0.9906
Cable MSStat - Stat4 circuit 1	0.9906
Cable Stat4 - Stat3	0.9505
Cable Stat4 - Main bus bar	0.9833
Cable Stat1 - Stat3 circuit 1	0.966

Formulas

Formulas can be written by starting the value with an "=" sign. Use English function names and commas instead of semicolons.

Html
Formatting tags can be used in an html-oriented value, by starting the value with <html>. This works for FileIndex 1 to 9.
For example: ..... for bold, <i>.....</i> for italic, <u>.....</u> for underlined,
 for a new line.

7.5.8.5.9 Macro command copy

Purpose:
to copy a range of cells of a worksheet into a worksheet of the output workbook

General notation:
Copy(FileIndex, SheetA, Row1, Column1, Row2, Column2, SheetB, Row3, Column3)

FileIndex is the same index used by the Open command. Using the Open command a spreadsheet file is assigned to a FileIndex for later Read commands. The FileIndex is an integer number between 1 and 9. If a value of 0 is assigned to the FileIndex, this corresponds to the currently opened output spreadsheet.
The result will always be copied into the output spreadsheet (with FileIndex number 0).

The worksheet cell can be accessed by its row and colum number. The normal Excel notation (identification of a cell by means of a combination of letters and numbers) is not possible because the macro language works on a numeric basis.

SheetA	: the worksheet where has to be copied from
Row1	: 'from' cells range upper left corner row number
Column1	: 'from' cells range upper left corner column number
Row2	: 'from' cells range lower right corner row number
Column2	: 'from' cells range lower right corner column number
SheetB	: the worksheet in the output spreadsheet where has to be copied to
Row3	: 'to' cells range upper left corner row number
Column3	: 'to' cells range upper left corner column number

Example:
Copy the cells range A2 .. C9 on Sheet1 of spreadsheet with FileIndex 1 to the output spreadsheet, Sheet2 on position G6:

```
Set( FileIndex, 1 )
Set( SheetA, 1 )
Set( Row1, 2 )
Set( Column1, 1 )
Set( Row2, 9 )
Set( Column2, 3 )
Set( SheetB, 2 )
Set( Row3, 6 )
Set( Column3, 7 )
Copy( FileIndex, SheetA, Row1, Column1, Row2, Column2, SheetB, Row3, Column3 )
```

Or simply:

```
Copy( 1, 1, 2, 1, 9, 3, 2, 6, 7 )
```

7.5.8.5.10 Macro command bold

Purpose:
Boldface the contents of a range of cells in the worksheet.

General notation:
Bold (FileIndex, sheet , row1 , column1 , row2 , column2)

Series of cells can be addressed using row and column numbers. The values row1 and column1 refer to the top left-hand corner of a series, while row2 and column2 refer to the bottom right-hand corner. The normal Excel notation (identification of a cell by means of a combination of letters and numbers) is not possible because the macro language works on a numeric basis.

7.5.8.5.11 Macro command border

Purpose:
Create a border around the contents of a range of cells in the worksheet.

General notation:
Border (FileIndex, sheet , row1 , column1 , row2 , column2)

Series of cells can be addressed using row and column numbers. The values row1 and column1 refer to the top left-hand corner of a series, while row2 and column2 refer to the bottom right-hand corner. The normal Excel notation (identification of a cell by means of a combination of letters and numbers) is not possible because the macro language works on a numeric basis.

7.5.8.5.12 Macro command merge

Purpose:
Merge a range of cells in the worksheet.

General notation:
Merge (FileIndex, sheet , row1 , column1 , row2 , column2)

Series of cells can be addressed using row and column numbers. The values row1 and column1 refer to the top left-hand corner of a series, while row2 and column2 refer to the bottom right-hand corner. The normal Excel notation (identification of a cell by means of a combination of letters and numbers) is not possible because the macro language works on a numeric basis.

7.5.8.5.13 Macro command fit

Purpose:
To fit the column width to the contents of a range of cells in the worksheet.

General notation:
Fit (FileIndex, sheet , row1 , column1 , row2 , column2)

Series of cells can be addressed using row and column numbers. The values row1 and column1 refer to the top left-hand corner of a series, while row2 and column2 refer to the bottom right-hand corner. The normal Excel notation (identification of a cell by means of a combination of letters and numbers) is not possible because the macro language works on a numeric basis.

7.5.8.5.14 Macro command align

Purpose:
To align the text of a range of cells in a spreadsheet horizontally and vertically.

General notation:
Align (FileIndex, sheet , row1 , column1 , row2 , column2 , Alignment)

Series of cells can be addressed using row and column numbers. The values row1 and column1 refer to the top left-hand corner of a series, while row2 and column2 refer to the bottom right-hand corner. The normal Excel notation (identification of a cell by means of a combination of letters and numbers) is not possible because the macro language works on a numeric basis.

Alignment is an integer number of value: 00, 01, 02, 03, 10, 11, 12, 13, 20, 21, 22, 23, 30, 31, 32, 33.
The left digit indicates the vertical alignment: 0=none, 1=top, 2=center, 3=bottom.
The right digit indicates the horizontal alignment: 0=none, 1=left, 2=center, 3=right.

7.5.8.5.15 Macro command fontcolor

Purpose:
To colour the font of a range of cells in a spreadsheet.

General notation:
Fontcolor (FileIndex, sheet, row1, column1, row2, column2, colour)

Series of cells can be addressed using row and column numbers. The values row1 and column1 refer to the top left-hand corner of a series, while row2 and column2 refer to the bottom right-hand corner. The normal Excel notation (identification of a cell by means of a combination of letters and numbers) is not possible because the macro language works on a numeric basis.

All parameters are integer values***Colour*** is an integer value between 0 and 14, representing the colours: black, gray, lightgray, navy, blue, aqua, purple, fuchsia, green, lime, teal, maroon, red, yellow and white.

7.5.8.5.16 Macro command backcolor

Purpose:
To colour the background of a range of cells in a spreadsheet.

General notation:
Backcolor (FileIndex, sheet, row1, column1, row2, column2, colour)

Series of cells can be addressed using row and column numbers. The values row1 and column1 refer to the top left-hand corner of a series, while row2 and column2 refer to the bottom right-hand corner. The normal Excel notation (identification of a cell by means of a combination of letters and numbers) is not possible because the macro language works on a numeric basis.

All parameters are integer values***Colour*** is an integer value between 0 and 14, representing the colours: black, gray, lightgray, navy, blue, aqua, purple, fuchsia, green, lime, teal, maroon, red, yellow and white.

7.5.8.5.17 Macro command SetScreenUpdating

Purpose:
Do not show edits of the workbook on screen (saves time).

General notation:
SetScreenUpdating (Update)

Update is a boolean.

Example:

```
SetScreenUpdating ( FALSE )
```

7.5.8.5.18 Macro command ClearSheet

Purpose:
To clear a worksheet.

General notation:
ClearSheet (FileIndex , sheet)

7.5.8.5.19 Macro command Get

Purpose:
Copying an array of cells from a workbook worksheet to an internal array.

General notation:
Get (FileIndex , Sheet , Row1 , Column1 , Row2 , Column2 , ToArrayIndex, Row , Column)

FileIndex is the index that refers to the Excel file opened using Open 421.
If FileIndex is assigned the value 0, it can be copied from the workbook file described by the Macro with Write 422.

Sheet : the worksheet to be copied from.
Row1 : row number of the top left corner of the range to be copied
Column1 : column number of the top left corner of the series to be copied.
Row2 : row number of the bottom right corner of the series to be copied
Column2 : column number of the bottom right corner of the series to be copied
ToArrayIndex : the number of the internal array
Row : row number of the top left corner of destination
Column : column number of the top left corner of destination

7.5.8.5.20 Macro command Put

Purpose:
Copying an array of cells from one of the two-dimensional arrays to a worksheet.

General notation:
Put (ArrayIndex , Row1 , Column1 , Row2 , Column2 , ToFileIndex, ToSheet , Row , Column)

ToFileIndex is the index that refers to the Excel file opened using Open 421.
If ToFileIndex is assigned the value 0, it can be copied to the workbook file described by the Macro with Write 422.

ArrayIndex: the array to be copied from
Row1 : row number of the top left corner of the array to be copied
Column1 : column number of the top left corner of the array to be copied
Row 2 : row number of the bottom right-hand corner of the series to be copied
Column2 : column number of the bottom right corner of the series to be copied
ToFileIndex: the workbook to copy to
ToSheet: the destination worksheet in the output workbook
Row : row number of the top left corner of destination
Column : column number of the top left corner of destination

7.5.8.5.21 Macro command SaveAs

Purpose:
Saving a workbook.

General notation:
SaveAs (FileIndex , FileName)

In this, FileIndex is an integer value between 0 and 9.

7.5.8.5.22 Macro command AddFormatCondition

Purpose:

Set conditional formatting of some cells of a worksheet of a workbook with FileIndex. Only FileIndex 0 is supported.

General notation:

AddFormatCondition (FileIndex , sheet , row1 , column1 , row2 , column2 , ConditionType, Operator, Formula, FontColour, CellColour)

The range of cells can be accessed through the row and column numbers. The values row1 and column1 indicate the top-left corner of the array and row2 and column2 the bottom-right corner.

ConditionType is an integer with the following meaning:

1	Cell value
2	Expression
3	Colour scale
4	Databar
5	Top 10 values
6	Icon set
8	Unique values
9	Text string
10	Blanks condition
11	Time period
12	Above average condition
13	No blanks condition
16	Errors condition
17	No errors condition

Operator is an integer with the following meaning:

1	between
2	not between
3	equal
4	not equal
5	greater than
6	less than
7	greater than or equal to
8	less than or equal to

The value FontColour and CellColour is an integer value is between 0 and 14, corresponding to the colours:

0	no special colour
1	grey
2	light grey
3	navy blue
4	blue
5	aquamarine
6	purple
7	pink
8	green
9l	ichth green
10	blue-green
11	red-brown
12	red
13	yellow
14	white

Example:

```
AddFormatCondition(0,1,1,1,20,20,1,5,'100',0,12)
```

7.5.8.5.23 Macro command CreateDir

Purpose:
To create a subdirectory.

Common notation:
CreateDir (FolderName)

The directory name is the complete path.
A maximum of one sublevel per call is possible.

7.5.8.5.24 Macro command ExportResult

Purpose:
Export calculation results to an Excel file.

General notation:
ExportResult (Filename, [Selected Only])

Filename is a text value. The filename can be enclosed in single quotes or passed via a variable.
OnlySelected is an optional truth value to export only selected objects.
The command exports the results of the last calculation performed, provided an export function is available for it.

7.5.8.5.25 Macro command FreezePanes

Purpose:
Block titles on a workbook worksheet with FileIndex.

General notation:
FreezePanes (FileIndex , sheet , row , column)

7.5.8.5.26 Macro command GetUsedRange

Purpose:
Retrieve the range of a worksheet in the workbook under FileIndex, via four variables.

General notation:
GetUsedRange (FileIndex, sheet number, first row variable, first column variable, late row variable, late column variable)

FileIndex is the index that refers to the workbook file opened using Open421.
FileIndex 0 is the default output workbook.

7.5.9 Macro input commands

There are three ways to import data into a macro:
- Read from a dialog
- Read from a text file
- Read from an Excel workbook

Read from a dialog
See:
- Input 430: prompting the user for a value

Read from a text file
Using these commands, data can be input from a text file. The file has to be opened and a separator has to be defined. Data can be read from one line or from multiple lines of text. Afterwards the file has to be closed. An opened file can not be written to at the same time. See:
- TfOpenForRead 430: Open a text file for reading
- TfRead 431: Read from one line of a text file
- TfReadLn 431: Read from one line of a text file and go to the next line
- TfEOF 432: Test end of file
- TfClose 420: Close a text file

Read from an Excel workbook
Similar to reporting to a Spreadsheet using Write, Read inputs data from a Spreadsheet into the Macro. Firstly the data files have to be opened and assigned. A maximum of nine data files can be opened simultaneously. After the reading operations the data files can be closed so that other data files may be opened. After execution of the Macro, all opened files will be closed automatically. Read and write operations may be executed in the same session. See:
- Open 421: opening a spreadsheet for Read
- Read 432: reading a value from a cell on the worksheet of a spreadsheet
- Close 421: closing a spreadsheet

7.5.9.1 Macro read from input dialog

7.5.9.1.1 Macro command input

Purpose:
Prompting the user for a value.

General notation:
Input (Object(ObjectName).Attribute , Label)
or
Input (Variable , Label)

A small input form appears which prompt the user for a value.
The attribute or the variable must be declared before. Its value is presented as default value.

The prompting text is contained in the text variable or text value, called ***Label*** .

7.5.9.2 Macro read from a text file

7.5.9.2.1 Macro command TfOpenForRead

Purpose:
Open a text file for reading

General notation:
TfOpenForRead (FileIndex, FileName, Separator)

Example:
Opening a text file with a semicolon as a separator:

```
TfOpenForRead( 1, 'output.txt', ';' )
```

7.5.9.2.2 Macro command TfRead

Purpose:
Read from one line of a text file

General notation:
TfRead (FileIndex, value1 [, value2 [, value3 ...]])

The separator has been defined by TfOpenForRead 430 and will be assumed present between the values.
The command TfRead reads the current line.
If there are no data left to be read, the numerical variables will be filled with 0 and the text variables with an empty string.

Example:
```
TfOpenForRead( 1, 'output.txt' )
TfRead( 1, Textvariable )
text( Textvariable )
TfRead( 1, Numericalvariable1, Numericalvariable2, Numericalvariable3 )
text( Numericalvariable1, ',', Numericalvariable2, ',', Numericalvariable3 )
TfRead( 1, Textvariable )
text( Textvariable )
TfRead( 1, Numericalvariable1, Numericalvariable2, Numericalvariable3 )
text( Numericalvariable1, ',', Numericalvariable2, ',', Numericalvariable3 )
TfClose(1)
```

Using the data:
```
'one';2;3;4;five;6;  1.23
```

Results in:
```
'one'
2,3,4
five
6,  1.23,0
```

7.5.9.2.3 Macro command TfReadLn

Purpose:
Read from one line of a text file and go to the next line

General notation:
TfReadLn (FileIndex, value1 [, value2 [, value3 ...]])

The separator has been defined by TfOpenForRead 430 and will be assumed present between the values.
The command TfReadLn reads the current line and jumps to the next input line.
If there are no data left to be read, the numerical variables will be filled with 0 and the text variables with an empty string.

Example:
```
TfOpenForRead( 1, 'output.txt' )
TfRead( 1, Textvariable )
text( Textvariable )
TfReadLn( 1, Numericalvariable1, Numericalvariable2, Numericalvariable3 )
//     At this point the reading process continues on the next input line
text( Numericalvariable1, ',', Numericalvariable2, ',', Numericalvariable3 )
TfRead( 1, Textvariable )
text( Textvariable )
TfRead( 1, Numericalvariable1, Numericalvariable2, Numericalvariable3 )
text( Numericalvariable1, ',', Numericalvariable2, ',', Numericalvariable3 )
TfClose(1)
```

Using the data:
```
'one';2;3;4;five;6;  1.23
'one';2;3;4;five;6;  1.23
```

Results in:

```
'one'
2,3,4
'one'
2,3,4
```

7.5.9.2.4 Macro function TfEOF

Purpose:

Function to test the end of a text file

General notation:

TfEOF(FileIndex)

Example:

```
TfOpenForRead( 1, 'output.txt' )
While( TfEOF(1) , = , FALSE )
   TfReadln(1,a,b)
   Text('a=',a,' b=',b)
end
TfClose(1)
```

7.5.9.3 Macro read from an Excel file

7.5.9.3.1 Macro command read

Purpose:

Reading a value from a cell on the worksheet of a spreadsheet.

General notation:

Read (FileIndex , sheet , row , column , Object(ObjectName).Attribute)

or

Read (FileIndex , sheet , row , column , Variable)

FileIndex is an index pointing to the opened spreadsheet file.

In the case that a value of 0 has been assigned to FileIndex, the Read command reads from the spreadsheet file that has been currently written by the Macro Write command.

The worksheet cell can be accessed by its row and colum number. The normal Excel notation (identification of a cell by means of a combination of letters and numbers) is not possible because the macro language works on a numeric basis.

Example:

Read the results of an n-1 contingency analysis for all branches in sheet 1 of a spreadsheet assigned to FileIndex 1 and present as text:

```
Set( row, 3 )
Loop ( Index , 1 , 8 , 1 )
       Add( row, 1 )
       Read ( 1 , 1 , row, 1, failingbranch )
       Read ( 1 , 1 , row, 2, nodevoltage )
       Text ( 'Branch: ', failingbranch, ' voltage: ', nodevoltage, ' p.u.' )
End
```

The example above uses the next Excel spreadsheet data :

Results N-1 contingency analysis year:	2006
Failing branch:	Voltage (p.u.):
Link	1.0199
Cable MSStat - Stat1 circuit 1	0.9798
Cable MSStat - Stat1 circuit 2	0.9798
Cable MSStat - Stat4 circuit 2	0.9906
Cable MSStat - Stat4 circuit 1	0.9906
Cable Stat4 - Stat3	0.9505
Cable Stat4 - Main bus bar	0.9833
Cable Stat1 - Stat3 circuit 1	0.966

7.5.10 Macro network commands

To perform a macro, the whole of the network concerned is copied to the computer's RAM, so that the macro commands cannot affect the original network. However, once a macro command has been executed, it is possible to save the modified network for subsequent analysis outside the macro or for further use within the context of the macro. The network may either be saved to the disk or stored in the computer's RAM:

- SaveNetwork 433: save network on the disk
- StoreNetwork 434: store network in the RAM
- RestoreNetwork 434: retrieve network from the RAM

7.5.10.1 Macro command savenetwork

Purpose:

To save the network on the hard disk for subsequent analyse outside the macro.

General notation:

SaveNetwork (Filename)

Filename is a value. The name of a file may be given between single inverted commas, or in the form of a variable.

Examples:

Save the network using the name MyNetworkfile.vnf in directory D:\MyDir\:

```
SaveNetwork( 'D:\MyDir\MyNetworkfile.vnf' )
```

Save the network using the generated name *'Result5'* :

```
Set( networkfilename, 'D:\MyDir\Result' )
Set( networkcount, 5 )
Add( networkfilename, networkcount )
Add( networkfilename, '.vnf' )
SaveNetwork( networkfilename )
```

7.5.10.2 Macro command SavenetworkAsIs

Purpose:

To save the network, as set via variants and scenario's.

General notation:

SaveNetworkAsIs (Filename)

Filename is a value. The name of a file may be given between single inverted commas, or in the form of a variable.

7.5.10.3 Macro command storenetwork

Purpose:
To temporarily store the network in the computer's memory so that it may be retrieved for further use in the context of the same macro.

Only the network itself is stored. If the results of calculations performed on the network are required, the calculations will have to be performed again once the network has been retrieved.

A temporarily saved network cannot be retrieved after a macro has finished running.

General notation:
StoreNetwork(StoredNetworkIndex)

The current macro network is copied in the memory to a location indicated by the index StoredNetworkIndex. This has to be an integer value between 0 and 9.

If this command is used in a loop (e.q. a For ... End loop), in the course of which the index is automatically increased each time, the programmer needs to be confident that the counter will not rise above 9.

Examples:
Store the network data at memory index 3:

```
StoreNetwork( 3 )
```

Store the network data during an N-1 contingency analysis:

```
Set( Index, 0 )
ForSelection( Branch( 'MV-network' ), failingbranch )
       Set( failingbranch.FirstSwitch, open )
       Loadflow( 0, , true )
       If( Index, < , 10 )
              StoreNetwork( Index )
              Add( Index, 1 )
       End
       Set( failingbranch.FirstSwitch, closed )
End
```

7.5.10.4 Macro command restorenetwork

Purpose:
To retrieve a temporarily stored network from the computer's memory so that it may be put to further use in the context of the same macro.

Only the network itself is retrieved. If the results of calculations performed on the network are required, the calculations will have to be performed again once the network has been retrieved.

General notation:
RestoreNetwork(StoredNetworkIndex)

The current macro network is stored in the memory at a location indicated by the index StoredNetworkIndex. This has to be an integer value between 0 and 9.

If this command is used in a loop (e.g a For ... End loop), in the course of which the index is automatically increased each time, the programmer needs to be confident that the counter will not rise above 9.

Examples:
Recollect the network data that were stored at memory index 3:

```
RestoreNetwork( 3 )
```

Recollect the network data after a previous set of commands, where the network was stored 5 times:

```
Set( Index, 1 )
```

```
Repeat
        RestoreNetwork( Index )
        Loadflow( 0, , true )
        Write( 1, 1, Index, Transformer( 'MyTransformer' ).Load )
        Add( Index, 1 )
Until( Index, >= , 5 )
```

7.5.10.5 Macro command ShowNetwork

Purpose:
To display a network in the state after it has been altered by a macro.

Using this command, a network that has been altered by a macro will be displayed in de graphical editor for later analysis and evaluation.

General notation:
ShowNetwork(Name)

Name is a text value. It can be placed between quotation marks and it can be passed by a text variable.

Example:
Open a switch and display the altered network in the graphical editor:

```
Set(Cable('Stat4-Stat3').FirstSwitch,open)
ShowNetwork( 'MacroExample' )
```

7.5.10.6 Macro command OpenNetwork

Purpose:
To open network from a network file.

General notation:
OpenNetwork (Filename)

Filename is a text value. The name of a file can be enclosed in single quotes, or it can be passed through a variable.

Example:
OpenNetwork MyNetworkfile.vnf in folder D:\MyDir:

```
OpenNetwork( 'D:\MyDir\MyNetworkfile.vnf' )
```

7.5.10.7 Macro command ExportNetwork

Purpose:
To export network to an Excel file.

General notation:
ExportNetwork (Filename, [OnlySelected])

Filename is a text value. It can be enclosed in single quotes, or it can be passed through a variable.
OnlySelected is an optional truth value to export only selected objects.

7.5.10.8 Macro command ExportGeo

Purpose:
To export network geography to an Excel file.

General notation:
ExportGeo (Filename)

Filename is a text value. The name of a file can be placed in single quotes, or it can be passed through a variable.

7.5.10.9 Macro command Import

Purpose:
To import an Excel file into a network using the standard import functionality.

General notation:
Import (Filename)

Filename is a text value. The name of a file can be enclosed in single quotes, or it can be passed through a variable.

7.5.11 Macro topological commands

Certain attributes of objects are already set at the start of the macro based on the topology of the network. By changing switch positions in the macro, it may be desirable to reset these attributes. Four commands are available for this purpose:

- SetSerialsAndFeedings 436
- SetDirections 436
- SetMeshes 436
- SetGroups 436

7.5.11.1 Macro command SetSerialsAndFeedings

Purpose:
To reset the sequence number "serial" and the feeding group number "feeding" of all objects.

Common notation:
SetSerialsAndFeedings

7.5.11.2 Macro command SetDirections

Purpose:
To reset the direction number "direction" of all objects.

General notation:
SetDirections

7.5.11.3 Macro command SetMeshes

Purpose:
Re-setting the mesh-boolean "mesh" of all branches.

General notation:
SetMeshes

7.5.11.4 Macro command SetGroups

Purpose:
To reset the group number "group" of all objects.

General notation:
SetGroups (ActiveProtectionNeeded)

ActiveProtectionNeedful is a truth value indicating that a circuit breaker must have at least one active protection to serve as a group boundary.
Thus, if false, each circuit breaker is a group boundary.

7.5.12 Macro Python commands

Call a Python command or Python script.
First, enter the location of WinPython in the options, if necessary.

- RunPythonString 437
- RunPythonScript 437

7.5.12.1 Macro command RunPythonString

Purpose:
To execute a Python command.

General notation:
RunPythonString (Pythoncommand **)**

Created macro variables beginning with "Python" can be used to pass values to Python and to receive values from Python.

7.5.12.2 Macro command RunPythonScript

Purpose:
To execute a Python script.

General notation:
RunPythonScript (Pythonscriptfilename **)**

Created macro variables beginning with "Python" can be used to pass values to Python and to receive values from Python.

8 Appendix

8.1 Vision: info calculations

Load flow 250
- Newton Rapson method
- calculation of:
  - o network load and voltage management
  - o transformer tap setting
  - o starting current and voltage dip on motor starting
  - o n-1 analysis
  - o residual capacity
  - o voltage dips
  - o network losses.

IEC 60909 262
- superposition method in accordance with IEC 60909
- passive network model
- symmetrical and asymmetrical short-circuit calculations
- calculation of:
  - o subtransient short-circuit current and short-circuit power
  - o peak short-circuit current
  - o admissible short-circuit duration
  - o R/X ratio of the network at the fault location
  - o all network currents per phase.

Fault analysis 273
- active network model
- symmetrical and asymmetrical fault analysis
- fault impedances
- opening switches
- cross-country fault analysis
- calculation of:
  - o subtransient short-circuit current
  - o all currents and voltages (per phase or per symmetrical component, both absolute and complex).

Reliability 289
- failure modes:
  - o single mode failure
  - o single mode failure plus protection failure
  - o common cause failure
  - o maintenance plus single mode failure
- restoration process:
  - o signal a failure
  - o activate recovery and repair crew
  - o locate faulted component
  - o isolate faulted component
  - o recover energy service
- calculation of:
  - o F, Outage Frequency
  - o D, Outage Duration
  - o P, Outage Duration per year
  - o P, Outage Probability
  - o ENS, Energy Not Served
  - o P*BC: large customers outage duration

o P*SC: small customers outage duration

Protection 294
- modelling:
  o fuse
  o circuit breaker
  o current protection
  o earth fault protection
  o voltage protection
  o distance protection
  o differential protection
- calculation of:
  o coordination
  o simulation
  o selectivity

Harmonics 277
- calculation of:
  o harmonic load flow
  o frequency spectrum

Network analysis
- analysis of:
  o voltage dips 316
  o protections 304
  o failures 319

Macro's 365
- powerful programming language
- sensitivity analyses
- repetitive operations and calculations

8.2 Vision: info components

Components 63
- two- and three-winding transformers
- voltage regulation with current compounding for transformers
- synchronous generators with cos phi control or voltage regulation with static
- synchronous motors
- asynchronous generators and motors
- cables and cable sections
- lines
- reactance coils
- shunts (coils and capacitors)
- loads (constant power and constant admittance)
- busbar systems
- protections devices.

8.3 Vision: info user interface

User interface 63
- very fast drawing algorithm
- maximum number of nodes: 10,000
- work with several networks at a time (multi-document)
- copy and paste, including to other programs (Enhanced Meta File)
- component data and calculation results shown on screen can be user-defined (create Views)
- new, extended selection possibilities (create Selections)
- column layout of tables user-definable (create Reports)
- ASCII format for network files, component type files and communication files
- pop-up menu for frequently-occurring edit functions
- standard menu layout and options (Microsoft)
- "multi-form" display of nodes (busbar and junction)
- colour coding for selections and results
- graphics for results
- sort facilities for nodes and branches
- on-line help.

The user interface facilitates the network modeling and presents the calculation results. Menu and mouse control all actions, see: Menu and mouse control 38. A number of Shortcut-keys 39 have been defined for frequently used actions.

8.4 Vision: info subscriber

A service system is available for Vision users. A Vision subscription guarantees the user the latest upgrades, plus information on relevant developments via the Vision Periodical. New developments are presented and experiences with Vision are exchanged at the annual users' day, to which all subscribers are invited. A Vision subscription also entitles the user to front-line support.

The subscription year runs from 1 January to 31 December and subscriptions are renewed automatically.
A subscriber who does not wish to renew should give written notice at least two months before the end of the current subscription period.

Basic subscription package
Basic subscription, plus a PC hardware key or a network hardware key for 1 to 3 users, covers:
- support
- updates and upgrades
- Periodical

Support
Support by e-mail consists of expert advise on matters relating to the use or the application of Vision and Gaia. During office hours on working days, immediate advice is given in most cases; otherwise a response is given within three working days. The application of the software is such that a 24-hour service is not necessary.

Upgrades
An upgrade is a modified version of the software that provides increased functionality compared with an existing version. A new version is indicated by a higher version number, using the format X.X. New versions are sent to the user's software application manager. The latest version is always available on the Internet website, www.phasetophase.com.

Updates
An update is a new version of the software to which minor improvements or supplements have been made. A new update is indicated by a higher version number, using the format X.X.X, where the last digit is the update number. The latest version is always available on the Internet website, www.phasetophase.com.

Periodical
The periodical comes out twice a year and provides information about new developments. General technical information is also published on the Internet website, www.phasetophase.com.

8.5 Software installation and hardware key

VISION *NETWORK ANALYSIS* INSTALLATION

Vision *Network analysis* will be installed on a computer as follows:

- browse to www.phasetophase.nl/downloads
- start Visionxyz.exe, where xyz is the version number
- install Vision *Network analysis*
- next, install either the PC key software or the network key software, as described in the next chapter
- plug the PC key into the computer's USB port.

SOFTWARE INSTALLATION FOR PC-KEY OR NETWORK KEY

The right to use Vision is provided by the hardware key supplied with the software. Without a PC key or network key, Vision can only be used in demonstration mode. In this mode, Vision does not allow the user to save network files, and calculations can only be made for networks of a limited size.

Driver for SuperPro PC key

When using Vision with the SuperPro PC key, installation of the Sentinel driver is mandatory. This driver looks after communication between the computer and the key.

Installation of the Sentinel driver:

- go to www.phasetophase.nl/downloads
- start: **Sentinel System Driver Installer 7.6.0.exe**

Unikey PC key

The Unikey PC key does not require installation of any driver software.

Protection server (spnsrvnt.exe) for SuperProNet Network key

When using Vision with the SuperProNet network key, the Sentinel driver and the Sentinel Protection Server must be installed on the computer where the network key is to be found. The driver looks after communication between the computer and the network key; the server looks after communication between the computer and the clients, using the UDP protocol and port 6001. Nothing needs to be installed on the clients.

Installation of the Sentinel driver and the Sentinel Protection Server:
- place the CD in the computer
- using the Windows Explorer, browse to directory: **Sentinel**
- or: go to www.phasetophase.nl/downloads
- start: **Sentinel Protection Installer 7.7.0.exe**
- install: **Custom**
- unselect: **Sentinel Keys Server**
- unselect: **Sentinel Security Runtime**.

The driver and the server are both installed.

Options in Vision
With **Application menu | Options | Key** the options for use of the network key can be defined.

SuperProNet network key
By checking this item Vision assumes use of a Sentinel SuperProNet network key. However, Vision always checks first whether a PC key is present, and uses it if valid.

Server
The name or IP number of the server containing the SuperProNet must be entered.

8.6 Network file format

A Vision network file can be recognised by the .vnf (Vision Network File) extension. This network file is a plain text file and can also be edited using a standard text editor like Windows Notepad. A detailed description of the network file can be found at: www.phasetophase.nl/downloads

Index

- A -

Adding components 85
Alias 78
Align 97
Ampacity 118
Application menu 37, 78
Arc flash 119
Area, definition 74
Asymmetric load flow 257
Asynchronous generator 180
Asynchronous motor 182
Asynchronous motor group 186
Attributes 370

- B -

Bay 236
Bend 97
Breaker 201, 203
Busbar system 143

- C -

Cable 150
Cable rating 118
Calculations settings 131
Capacitor 192
Change individual 91
Circuit breaker 203
Coil 194
Coincidence factor 92, 235
Collective change 91
Compare networks 100
Component type database 76
Convergence load flow 252
Copy 88
Costs 287
Current measuring transformer 222
Current protection 205
Customers outage duration 289

- D -

Derating factor 118
Differential Protection 213
Direction, definition 73
Directional overcurrent 205
Distance protection 214
Diversity factor 92, 235
Drag 96

- E -

Earth fault protection 211
Earth point 138
Edit collective 91
Edit components 91
Edit individual 91
Edit special 92, 93
Editor settings 127
E-mail network 79
Energy Not Served 289
ENS 289
Excel 415, 429
Export type data 115
External earth point 138
External ground point 138

- F -

Failure analysis 319
Failure frequency 289
Fault analysis 273
Field 236
File 78
File locations 130
Find 81, 82
Frame 225
Functions, macro 400
Fuse 202

- G -

Generated power not sufficient 250
Generator 174, 180
Geography 113
Geography settings 135
Getting started 36
Goniometric functions 400
Grid 65
Ground point 138
Group 289
Group, definition 73

- H -

Hardware key 443
Hedrware key settings 136
Hyperlink 246

- I -

IEC 60909 262, 270
Import from another network 100
Information 11
Insert 85
Installation 36, 443
Island mode 250
Isolated networks 250
Iterations 252

- J -

Join 96

- L -

Legend 226
Lengthen 96
Line 145
Line impedance calculation 122
Link 149
Load 188, 190
Load behaviour 227
Load breaker 201
Load flow 250
Load profile 230
Load switch 201
Logarithmic functions 400

- M -

Macro
  Arrays 398
  Procedure 402
  Restore 398
  Store 398
  Trace 399
Macro editor 125
Macros
  Add 395
  AddSheets 421
  Align 425
  Alteration 393, 394, 395, 396, 397
  Attribute 370, 371, 372, 376, 377
  Backgroundcolor 426
  Bold 424
  Border 425
  Calculation 366, 408
  Close 421
  Color 426
  Command 393, 403, 404, 408, 415, 429, 433
  Conditional 403
  Copy 424
  Debug 419
  Divide 397
  Editor 365
  Fit 425
  For 406, 407
  Format 416
  GetSheets 422
  GetTitle 422
  If 403
  Input 421, 429, 430, 432
  Loop 404, 405, 406, 407
  Merge 425
  Multiply 397
  Object 367, 369
  Open 421
  Parameter 393
  Read 432
  Repeat 405
  Reporting 415, 416, 418, 419, 421, 422, 424, 425, 426
  RestoreNetwork 434
  SaveNetwork 433
  Set 394, 395
  SetPQS 394
  StoreNetwork 433, 434
  Structure 367, 369, 370
  Subtract 396
  Syntax 367, 369, 370
  Text 418
  Title 422
  Value 369
  Variable 369
  View 417
  Viewcolor 418
  While 405
  Write 422
Maintenance cut-off duration 289
Maintenance duration 289
Maintenance frequency 289

Mapping grid 65
Maximum current time protection 205
Maximum iterations 252
Measure field 222
Measuring transformer 222
Memory selection 85
Motor 178, 182
Motor group 186
Move 96
Mutual coupling 147

- N -

Network file 78
Network file handling 78
Network key 443
Network presentation 63
Network source 172
New 85
New in Vision 12
No operation probability 289
Node 138
Normal Open Point optimisation 323

- O -

Object types 75
Objects 63, 367
Options 127
Options file 116
Outage Duration 289
Outage Frequency 289
Outage Probability 289
Overhead lines 122

- P -

Paste 88
PC key 443
Power Station Unit 270
Power switch 203
Presentation Components 248
Print settings 134
Profile 230
Profile situation 93
Protection 294
Protection analysis 304
Protections 101

- R -

Rating factor 118
Reactance coil 154
Recovery of delivery 319
Redo 96
Reliability 289
Repair duration 289
Replace 97
Reports definitions 116
Represent 67, 89
Revisie 247
Route 82

- S -

Scale 97
Scenario 243
Select 81, 82, 235
Select special 82
Selection 82, 235
Selectivity 294
Send network 79
Sentinel 443
Separator 201
Sheet 65
Shift 96
Short circuit 262, 273
Short circuit indicator 221
Shorten 96
ShowNetwork 435
Simultaneity 92
Simultaneousness 92, 235
Software installation 443
Source 172
Special select 82
Special transformer 161
Special views 69
Specifics 246
Split 94
Spreadsheet 415, 429
Square functions 400
Store 90
storingsanalyse 413
Structure 37
Subnet border 93
SuperPro 443
Synchronous generator with cos phi control 174
Synchronous generator with U control 174
Synchronous motor 178

- T -

Text 224
Threewinding transformer 166
Tools 99
Trace 82
Transfer 94
Transformer 155, 161, 166
Transformer load 190
Transformer phase 117
Type 76
Type data export 115
Type data read in again 115
Type viewer 115

- U -

Unbalanced load flow 257
Undo 96
Unikey 443
User interface 63

- V -

Values 369
Variables 369
Variant 237
View 69, 72
Views definitions 115
Voltage dip analysis 316
Voltage measuring transformer 222
Voltage protection 212

- W -

Wind turbine 196

- Z -

Zigzag coil 195
Zoom 69
Zoomwindow 69