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Fault localisation in an MV distribution network

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1 INTRODUCTION

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Why fault localisation?

- Largest number of interruptions originate in the MV network
- Average restoration time is 90 minutes
- Automatically locate the fault within:
  - 100 m accuracy for two and three phase faults
  - 1000 m accuracy for single phase faults
- Aim: maximum restoration time to 30 min.

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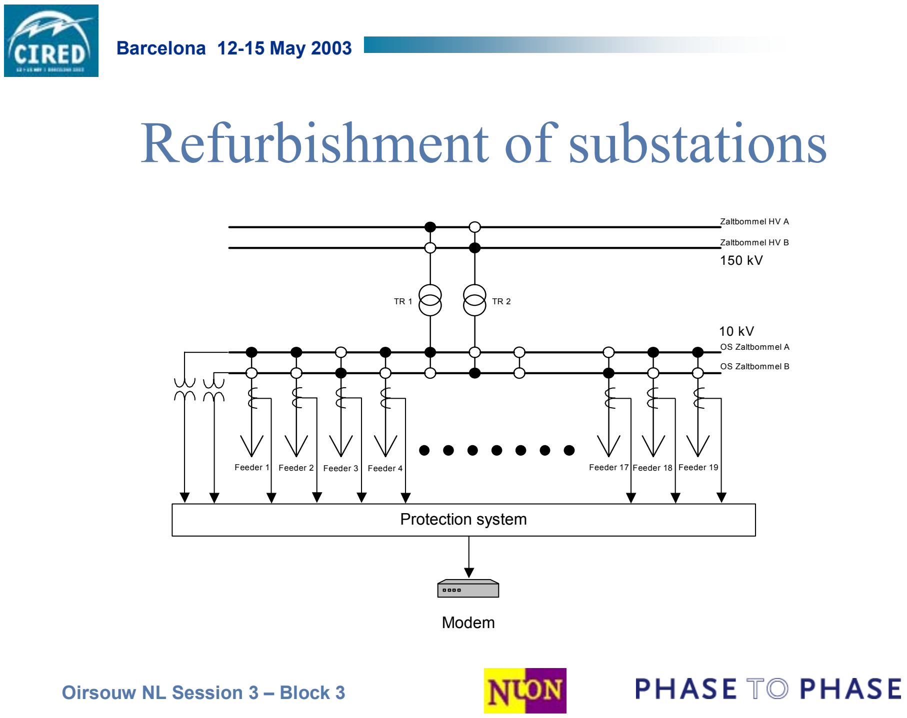
Why fault localisation?

According to the yearly Dutch National Fault Registration Enquiry the largest number of electricity delivery interruptions are caused by faults in the MV networks. Approximately 70 % of all delivery interruptions originate on this voltage level. The restoration time for fault localisation and switching takes averagely 90 minutes. In order to decrease the average electricity delivery outage time per customer, priority has to be given to the reduction of the restoration time in case of faults in the MV network. One of the main items hereby is the reduction of the fault localisation time.

The MV distribution systems in The Netherlands are constructed with buried cables. These networks are operated with radial feeders and there are switching possibilities to other feeders. Each feeder is protected in its outgoing feeder bay in the substation and has extra protections at splitting points.

It was decided to develop a system to pinpoint the fault location within a 100 metres accuracy for two and three phase faults and 1000 metres for single phase faults. Aim of the project was to reduce the average restoration time by one hour from 90 minutes to 30 minutes.

2 DESCRIPTION OF THE SYSTEM



Refurbishment of substations.

In the NUON electricity system the substations are being refurbished. In these substations new digital protection relays are installed. The pilot project substation consists of two HV bus bars, two HV/MV transformers, two grounding transformers, two MV bus bars and 19 outgoing feeders. The MV network consists of cables and is normally grounded by the grounding transformers.

Nowadays the digital protection equipment contains embedded functions for transient recording. Besides its normal function of protecting the electricity system, the protection system also captures the measurements in case of a fault. This capture consists of oscilloscopic time series measurements of bus phase voltage and faulted feeder phase currents. Also the pre fault values of bus voltage and all feeder currents are captured by the system. Directly after a fault, the captured data are transmitted to the dispatch centre.

The bus bar voltages, the transformer currents and the feeder currents only need to be processed in order to calculate the possible fault location directly after the fault has occurred. No other special transient recording devices are necessary. This cuts the cost of the system.

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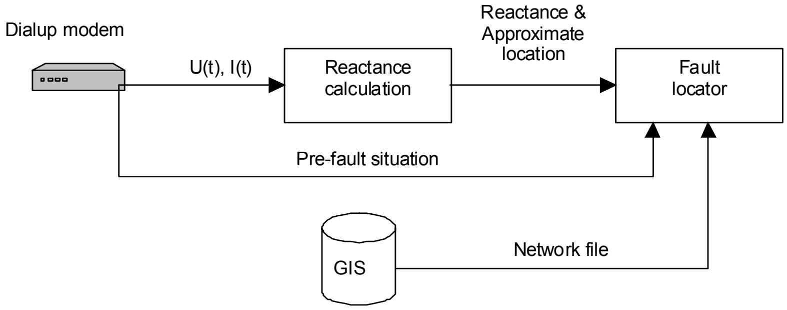
Data flows in the dispatch centre



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Data flows in the dispatch centre

In the dispatch centre the measurements are numerically analysed and the impedance from the substation to the fault location is calculated.

The result is fed into a network model where an automatic fault analysis is performed in order to find the exact location. In the simulation process the calculated short circuit currents, voltages and reactances are compared with the available measured values. The best match reveals the location of the fault.

The network model must reflect the actual situation at all times. The model uses the pre-fault values for the load and switches adjustment. All other network data are stored in an actual Geographic Information System (GIS). Not only all network nodes and cables are stored in the GIS, but also the actual switch positions in the MV network. Every time a single setting is changed, a new network model is generated automatically by the GIS.

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The fault locator method

- Fault situation measurement received
- Signal analysis
- Fault type detection
- Global fault location
- Network model simulation
- Comparison calculated with measured values

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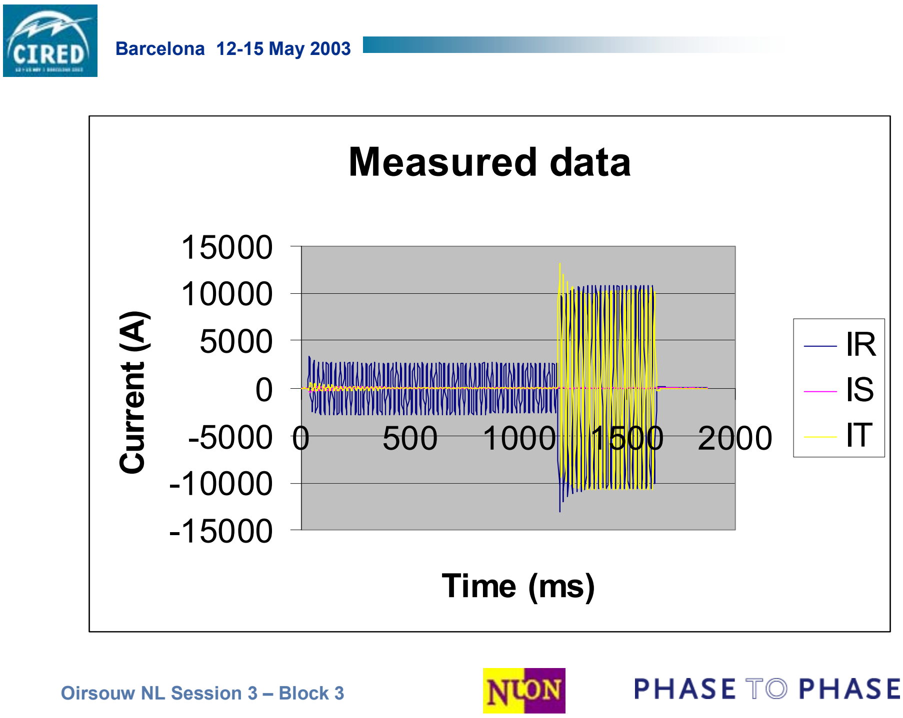
The fault locator method

Directly after a fault the protection system transmits the measured data to the dispatch centre using a standard Comtrade format. Once the data is received by the fault locator program, it starts the signal analysis. Using the analysed signal, the program automatically detects the fault type. The global fault location in main feeder, sub feeder or dead end feeder is determined by comparing the actual switching time with the protection scheme.
The result of the previous stage is fed into a network model where the fault is simulated in order to find the exact location. In the simulation process the calculated short circuit currents and voltages are compared with the available measured values. The model uses the pre-fault values for the load and switches adjustment.
The result is presented in a one-line schematic diagram.



Signal analysis.

The picture shows the time series for the three measured phase currents during a single phase fault, migrating into a two phase fault. In the signal analysis step all measured oscilloscopic data are Fourier Transformed in order to find the three phase voltages and currents. Hereafter the voltage and current phase signals are transformed into the normal, inverse and zero sequence signals for the fault type detection and for the comparison with the simulation.

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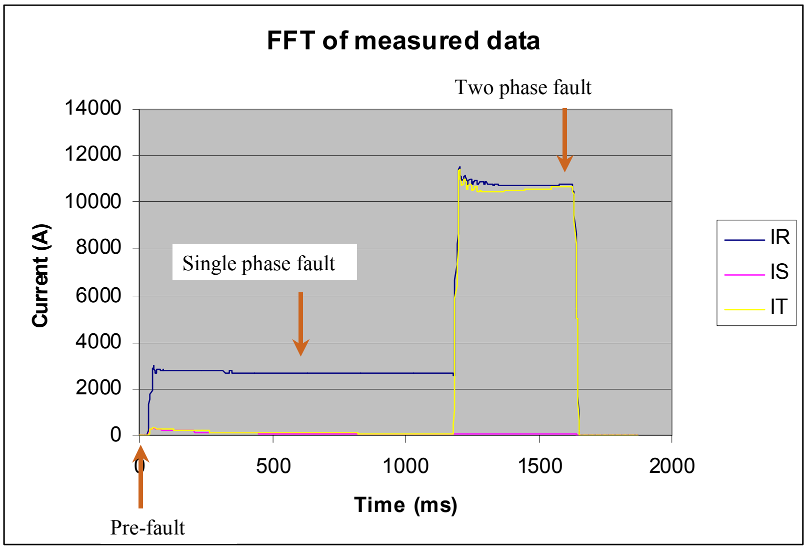

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Determination of appropriate values.

After the measured time series are Fourier transformed, the program must automatically detect the appropriate moment in the signal to obtain the correct values for the calculations. Since the fault analysis method calculates quasi stationary values, the program must detect the moment that the oscillations and transients are faded. In the case of a changing fault type the program uses the most severe type. In the picture it is the two phase fault. The arrow points at the moment that the transients are gone.

3 TESTING THE SYSTEM

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Testing the system

- Measurements since 1997
- 9 faults

Fault type	Number of faults	Found correct section	Found neighbouring section	Average section length (m)	Maximum deviation (m)
Phase - Earth	5	3	2	1480	499
Two Phase	2	2	-	3164	< 100
Three Phase	2	2	-	833	< 100

- Feedback to the network model

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Testing the system

Transient recorders were installed for a feasibility study since 1997. The network consists of approximately 200 nodes. During 6 years only 9 faults were recorded. The system turned out to work good for any three and two phase faults and for single phase faults in a grounded network. Two of five single phase faults were found in a neighbouring cable section. Therefore the maximum deviation was less than 499 metres. All two phase and three phase faults were found in the correct cable sections. Even a calculation of the exact distance in a long cable section revealed that the maximum deviation did not exceed 100 metres. The accuracy depends upon:

- the measuring system,
- the correct point of time selection for the impedance calculation and
- the correct modelling of the normal and zero sequence impedances.

The normal impedances are well known. The tests on single phase to ground faults revealed that the correct modelling of the zero sequence impedances is of major importance. These impedances firstly were estimated by experts, using their knowledge from other projects. Later, when transient recordings became available, these estimated values were corrected in the network model.

4 RESULTS

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Results

- The fault locating system needs no special transient recording devices
- The system accuracy meets the technical requirements; the accuracy is:
  - less than 100 m for phase to phase faults
  - less than 1000 m for single phase to ground faults
- Expectation that the reduction of restoration time is feasible

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Results

A fault locating system is developed and tested. The system is able to identify the fault location using the measured voltage and current during the fault sequence. The measurements are provided by extra functions in the existing digital protection system. Therefore no other special transient recording devices are necessary. This cuts the cost of the system.

The system turned out to be able to identify the fault location well within the required accuracy of 100 metres for two and three phase faults and 1000 metres for single phase to ground faults. Therefore we may conclude that the fault locator meets the technical requirements.

With these results the NUON electricity company expects that the aimed reduction of restoration time from 90 to 30 minutes will be feasible.