Faulty powers

Fault management in distribution networks is one of the most challenging and at least the most visible task of the utilities. From the customer point of view the power cut means at least harm but in many cases also costs, which may be tens of times greater than the cost of delivered energy. Pekka Verho, Product Manager at ABB in Finland (part time professor at the Tampere University of Technology) and Pertti Järventausta a professor at the Tampere University of Technology look at the fault management process and an IT-based solution that provides support for this process.

Most faults are caused by different kinds of weather circumstances, such as lightning, wind and snow burden. However, technical defects may also cause faults. In responding to faults there are also many different traditions in system protection. In relay based and centralised philosophy, used for example in Finland, all MV faults are tripped with breakers, which are also connected to a SCADA system. Fuses are used mainly in the LV side. Another tradition is to use local automation, as well as fuses in the MV side. The former philosophy means larger power cut areas, but a better awareness of the faults and a readiness to improve the fault management process because of the connection of the protection devices to the SCADA system.

Traditional fault location is quite time consuming and cumbersome, which results in fairly low power quality levels. In the case of breaker protected and centralised systems, the fault location is based on trial and error switchings, where part of the network is disconnected and then the breaker is closed. Fault location can be completed whether the feeder is tripped or not. The process has been improved using remote controlled disconnectors. In a fuse-based system and in the case of using non-communication protection, fault location is based on customer calls. In addition to long outage times, traditional fault location means reduced power quality in regards to voltage sags/dips caused by a number of trial and error trips.

Intelligent solutions

The foundation of intelligent solutions for fault management lies with the integration of distribution automation and information systems. In Finland, automation is very strong in distribution networks and there is also a long tradition in the use of information systems in order to support the distribution process.

The protection relays and the other substation automation provides the connection between the process and the SCADA centralised control system. The extended distribution automation also covers feeder level functionality; remote controlled disconnectors and fault indicators.

Traditional information systems are customer information systems (CIS) and network information systems (NIS). CIS systems were originally developed for the billing process, but via system integration, customer information can also be used in network calculations and trouble call management. The concept of NIS originates more or less from Finland and means that a system with network calculations and planning is integrated to a network database.

The development of new applications based on the high level foundation was quite active in Finland in the 1990s and a total concept has arisen - distribution management system (DMS). This is a software application, which is based on the integration of distribution SCADA and network databases and in turn provides advanced functionality for network monitoring, fault management and operations planning.

In the case of faults in the distribution network the fault current data registered by modern microprocessor based relays and the indications of fault detectors is transferred from the substations to the SCADA system. This information is combined with the network data and fault currents in the DMS are calculated by applying fuzzy reasoning. As a result the possible fault locations are shown to the system operator together with instructions on how to isolate the fault and restore the supply to the non-faulted parts of the network. The remote controlled part of the sequence can even be automated, which is extremely useful in an unmanned control centre, for example at night. When the fault has been repaired, the DMS is used to support the outage reporting. The interruption time and amount of non-delivered energy for each customer as well as the total values are calculated and stored to a database. The detailed fault location and type are also stored on the database in order to be used in network development and maintenance planning.

Another important part of fault management is handling the calls of customers. In most of the cases (MV faults) there is just the need to estimate the outage time to the calling customer. In these cases the calls simply mean additional work and a waste of the operator’s time. A solution to save operator’s time, allowing them to concentrate on fault location and network restoration is to use automatic telephone answering machine for handling customer calls. The DMS informs the answering machine how to respond depending on the outage situation. The information includes the reason and the range of interruption, as well as the phase and expected time of restoration. If the customer has some important information, such as they know the fault location, they are then asked to dial another number, where the operator answers.
Another approach to trouble call management is applied if the operator is not aware of the fault until the customer calls. In Finnish circumstances it means a fault in LV network, but in fuse protected networks, MV faults also require alternative call management. In these cases the customer call is used in the fault location process. Based on the integrated customer data, the DMS provides a fast search of the calling customer and highlights its location in the network map.

In addition to fault management, DMS provides a number of other functions to support the network operation, including network monitoring and network analysis, which also provides the foundation for fault management. Network monitoring means topology management and real time network analysis. Topology management is based on static network data and dynamic status information of the switches of which the ‘remote readable’ are obtained from SCADA. The function provides connectivity analysis and geographic topology representation via feeder coloring. Network analysis allows real time calculations of load flow and fault current, as well as the protection analysis. In addition to static load modeling the function uses the real time load measurements available from the process in order to provide the best possible calculation results. Network analysis can also be run in simulative mode in order to support the operations planning function of the DMS. The function provides an advanced sequence creation tool for scheduled outages and efficient searching for optimal open points.

Distribution automation as core strategy

In the middle of 1980s the level of automation was rather low and old-fashioned in a pilot utility in Finland. However, the situation was favorable for change. The construction manager and the operation managers were open to new ideas and the organisation was small enough for flexible changes. The situation was analysed and a long-term development plan for the network operation was made. According to the plan, the investments should be focused on distribution automation instead of the primary network. This decision can be seen as a strategic move, together with the broad-minded use of the latest technology and intensive cooperation with a number of partners, such as the system suppliers and a university.

A new NIS was acquired already in 1987 - a PC-based offering inexpensive solutions for data management and network calculations. The old-fashioned SCADA system was replaced in 1988 with a modern and inexpensive PC-based system. In this context the revolutionary selection was the remote terminal technology. Instead of traditional remote terminal units (RTU) a new concept was chosen - integrated secondary technology. This means using new feeder terminals for both relay protection and remote control. The shift to the new technology was made step-by-step between 1988 and 1992 so that eventually all relays (feeder terminals) in all substations were identical. In addition to the substation control, the building of remote controlled disconnector stations was intensive during this period and the process has been continued throughout the years. There is about 600 line disconnectors of which today 100 are remote controlled.

One of the results achieved by the implementation of distribution automation was the development of the mean outage time (in hours) per fault, which is a good measure for the operational efficiency. This value decreased by half between 1988 and 1998. At the same time remarkable labor cost saving were achieved. The full time duty in control centres was changed to home duty outside office hours by applying a remote SCADA workstation. Meanwhile, along with the higher automation level (especially because of remote controlled disconnectors and fault location applications) the number of duty crew needed was halved.

Future directions?

So what does the future look like for network management? At first, it may be said the for many parts of the world the future has already been described, because the development of DMS in Finland has such a long history. However, the future also needs to be looked at from the present situation with advanced distribution management.

IT will play an important role in future distribution management systems. It is developing faster and faster providing more openness, more capacity, more information and as a consequence more possibilities. The Internet and especially mobile IT technology also offer new possibilities. However, IT is not a driving force in the development of electricity distribution, but an instrument. The most important driving force is market requirement.

Along with deregulation, the awareness of power quality and the effectiveness of network operation are becoming increasingly important. Ultimately, the development of new IT applications is also based on a third factor - innovation.

Looking to the future some new directions can be found. In the field of faults, the main focus for new development is on fault prevention instead of fault location. Future applications will be able to highlight faults before they cause a trip and consequently an interruption to the customer. Another part of preventive fault indication is overall condition monitoring and optimisation of maintenance. Today most of the maintenance is time based and the present practices can be compared with calendar based car maintenance instead of using the mileage recorder.

A natural future direction is the extension of distribution automation to LV side. At first it means secondary substation automation, such as the automation of ring main units and other distribution transformer stations. In addition to fault location the LV distribution automation may provide advanced functions for power quality management and condition monitoring.

The huge development of mobile communication technology also brings some new possibilities to be applied in distribution network management. At first it provides advanced communication for field crews and may even lead to a mobile control centre. There is still centralised processing requirement, but at least part of the control centre operations can become mobile. Together with the preventive fault indication there is a vision that some faults can be cleared without disturbing the customers and even the control centre.

In addition to technology development the utility business itself is changing to be more business driven. This means that instead of power quality maximisation, the objective is profit maximisation with adequate power quality. The business transformation means lower marginal rating, bigger utilities, outsourcing and - as a natural consequence - even more advanced information systems and system integration.