BRINGING GRID INFORMATION INTO THE OFFICE

Walter VAN BUIJTENEN
Phase to Phase – The Netherlands
w.m.vanbuijtenen@phasetophase.nl

Frank BALDINGER
Locamation – The Netherlands
baldinger@locamation.nl

Frans VOLBERDA
Nuon Tecno – The Netherlands
frans.volberda@nuon.com

ABSTRACT

Regulatory and market forces are directing the utilities to automate and enhance the operations of their distribution networks. It is now inevitable that the kind of automation so common to transmission and generation operations has to be developed for the distribution network.

With new modern substation automation systems a significant amount of measured data is available from the MV networks. With the right processing, presentation and access of this data the grid is coming under control. This paper describes the importance and the development of the right applications for typical end-users such as: grid operators, asset managers and engineers. Two developed applications: Power Quality and Fault Location are described.

Another import issue when bringing information across the utility is the so called cyber security. In this paper a practical solution is described.

INTRODUCTION

Distribution operations are becoming increasingly automated in response to demands for higher reliability, improved power quality, lower costs, regulation, and the rapid increase in connected small distributed generation, along with the new enabling technologies.

Although, the HV grid was always given privilege to, most of the assets to be managed and operated are located in the MV and LV grid. Therefore, providing users of the MV grid, other than the traditional protection and substation operation groups, with data and information is a new task.
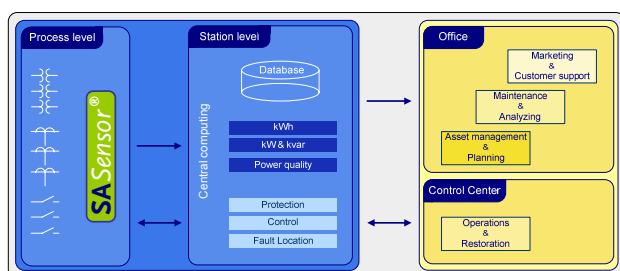

Figure 1: SA*Sensor*® system

With new modern substation automation systems such as the low cost SA*Sensor*® system [1] (figure 1) a significant amount of measured data is available from the MV network. In the SA*Sensor* system the data is collected in the central Control Unit in the substation. The unit is a multiprocessor computer connected by fibre optics to current and voltage sensors, to circuit breakers. All functionality – control,

over-current protection, fault location, revenue metering, power quality, etc. – is implemented in simple maintainable and upgradeable software.

THE RIGHT APPLICATIONS

With the right processing, presentation and access of the measured data in the MV substations the grid is coming under control: users behind their desk can "log on" to grid information.

At the beginning of the development, it has been recognized that the user interfaces and the related visualization techniques are equally important as the underlying data acquisition and processing algorithms. Therefore, from scratch much effort has been put to the development of the interfaces. This has been achieved by good communication between end-users, utility engineers and the developers of the application.

This methodology resulted in applications that have a so called "layered" graphical user interface. The top layer represents the overview at a global level; a high level of aggregation is performed here. On detail level explanation should be possible (on request); the end-user should be provided with relevant, context dependent information to make the aggregation transparent. On more detailed level the end-user can access the "raw" data for making specific calculations for example in Excel.

Another advantage of the above approach is the minor load on the information channels/network. Data collection and aggregation can be done regional or even per substation.

POWER QUALITY

Our modern society is more and more sensitive to power quality problems. Therefore, a kind of PQ regulation is needed. Such regulation asks for reliable and transparent tools for monitoring and reporting the PQ levels.

Besides using these levels for regulatory issues, they can be used for coordination between the manufacturers of electrical equipment, the customers and the transmission and distribution companies.

Classification

Nuon and Phase to Phase developed a PQ classification application based on the classification methodology introduced by J.F.G. Cobben from Continuon [2]. This classification is analogue to the one already in use to classify the energy efficiency of household appliances such as washing machines. This ABC classification uses letters combined with colours to label the various levels of quality.

The same format is adapted for voltage quality. The voltage quality is split into six aspects: voltage and frequency variations, dips, THD, flicker and unbalance.

The classification method for this voltage quality is based on the STAV (Standard Deviation, Average Value) [2] method. This means that for a week of measurements the average and standard deviation are calculated for every aspect. So each aspect is represented by a single point on the (U_m, σ) plane. Dips are handled in a separate way [1], which will not be discussed in this paper.

The different classes are set as lines in the (U_m, σ) plane which represents a fixed probability of (not) exceeding a certain U_m, as illustrated in figure 3.

The limits sets by the Dutch national regulator (mainly based on the European standard, EN50160) are incorporated in the classification. These limits are set as the boundary between the classes C and D.

Visualisation

The developed application presents the information in different accessible layers to its users. In the main screen (see figure 2) the PQ levels of each aspect for the measurements locations are shown for the selected week. In the left part of the main screen, the names of the measurements are shown in a tree. This tree allows for grouping different voltage levels, for instance MV and LV measurements. User can navigate into the tree: accordingly to the selected node the aggregation and visualisation is performed over all underlying nodes. From figure 1 it is seen that the quality level is mostly of class A and B except for flicker (4th bar from the left) in a certain location where only class F is met.
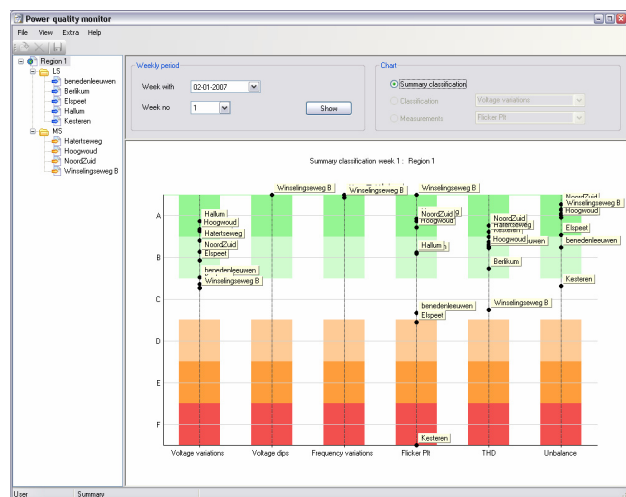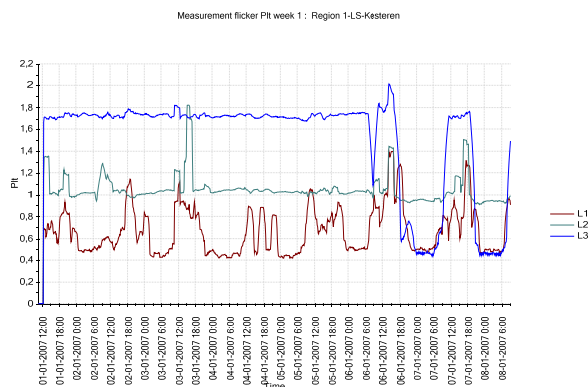

Figure 2: PQ classification application: overview

User can now decide to go in more detail, and look only to the aspect flicker. In figure 3, the graph of the classification results are shown for the aspect flicker. It is shown that the PQ level (of phase L3) is located outside the F class boundary.
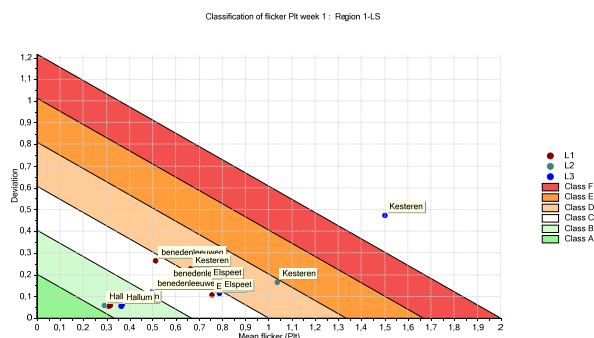
Figure 3: Classification of flicker Plt

If the user still wants more detail the 10-minute average measurements of the selected week for a single measurement location can be plotted into a graph. In figure 4 the graph for the aspect flicker is shown. From this graph it is clearly seen that for the L3 phase the limit set by the Dutch national regulator of 1% Plt is exceeded for most time of the week.

Figure 4: 10-min average values of flicker Plt

Implementation

Every substation where the SA*Sensor* system is installed the PQ classification application can be configured to connect to it. At the substation the measured data is stored in so called "week files" on a web server. These files can directly be accessed by a secure mechanism (see also chapter Cyber Security).

Nuon has also installed standard PQ measuring devices in some locations. This data is centrally managed in a SQL database. The plan is to make this data also available for the PQ classification application. In this way Nuon is able to assess the power quality issue in a uniform way across the utility.

FAULT LOCATION

Most of the outage time for Dutch utilities is caused by faults in the MV network. The usual way of manually finding the fault location by checking short circuit indicators is time consuming. Nuon wants to improve the network performance and one of its goals is to decrease the time to locate the faults. Since 2003 a fault location system [3] has been matured and used within Nuon.

Fault analysis

The fault location system uses the sinusoidal measurement of current and voltage during the fault that is provided by the substation digital protection system. The measured signals are transformed into momentary amplitude and phase angle values, using Fourier and symmetrical components transforms. From these transformed signals the samples that are representative for the system state during the fault are detected automatically. The fault type is detected using Fuzzy Logic rules. The method is designed to calculate the impedance (see figure 5) from the measured point to the fault location for all three phase and two phase faults and for single phase faults in grounded networks.

The fault location process is based on the reactance from the measuring point to the fault location. This information is combined with the settings of the protection schemes to detect the approximate location in the main feeder, a sub feeder or a dead end.
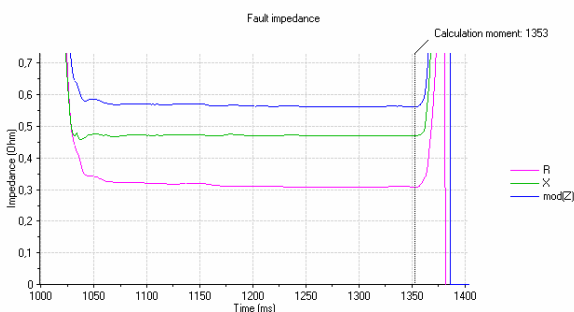

Figure 5: Calculated fault impedance

Visualisation

The result of this first step is fed into a network model where the fault is simulated at several selected points in the faulted feeder in order to find the exact location. This part is based on the existing load flow and short circuit analysis software from Phase to Phase (Vision). 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 actual loads and feeder configuration. Finally the location is visualized in the network model and geographically to the operators, see figure 6.
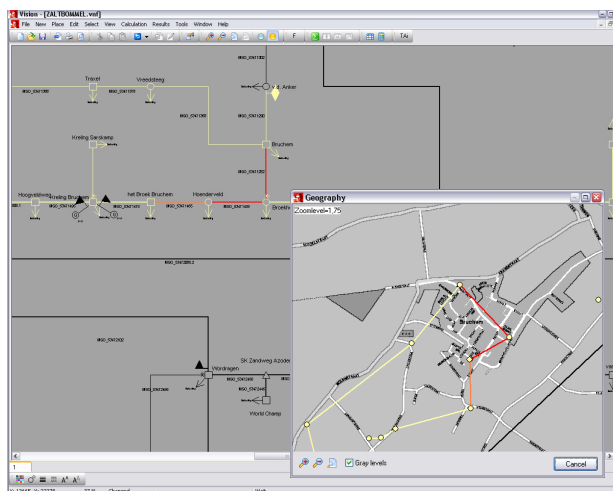

Figure 6: Visualisation of the fault location

Implementation

Until now this fault location system could only be installed in substations with modern (digital) protection devices. Because only these devices can deliver DFR (Digital Fault Recording) files which form the basis of the fault location system. With the new SA*Sensor* system the triggering mechanism and DFR functionality was easily implemented in software in the central processing unit. When a fault occurs the DFR files are automatically transferred via a secure connection (see also cyber security) to the control centre.

CYBER SECURITY

A traditional way of computer networking is from a hardware perspective in terms of servers, bridges, routers, etc. But since the various systems are more integrated and interconnected, the concept of security domain is used to address and support analysis of the total integrated system. A domain is a specific area, wherein specific activities and operations are going on and they can be grouped together. Domains may be different from one electric utility to another, depending on the utility's operation and tasks. Figure 7 shows an example of domains that are introduced in the substation automation environment.
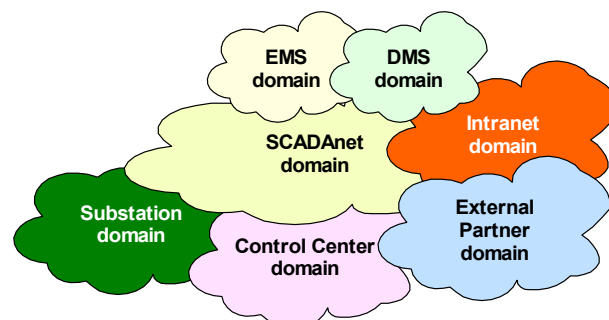

Figure 7: Security Domains

The purpose of the domain concept is to emphasize the

importance and handling of information security issues.
It is evident that an incident or event that takes place in one domain could, if not properly managed, spill over to impact the other domains. Such a spill over is in situations where different cyber security practices apply in different domain.

SA*Sensor* collects a lot of data and information intended for different user groups within the utility. Depending on the organizational structure of the utility the users of the information reside in different departments or even companies as earlier called Domains. Aspects like integrity, confidentiality arise out of the different nature of the users of information. The process and system information is nevertheless originating from one source so the interest of the users must be secured. The geographical decentralization of the users and the application of wide area networks require a high level of information security. Firewalls are required for inter domain and external communication.

VPNs (Virtual Private Networks) are used to provide cost-effective mechanisms for private IP services over a public infrastructure. VPN methods used are e.g. filtering, tunnelling and cryptography. In SA*Tunnel* (see figure 8) of SA*Sensor* the mentioned security aspects are implemented. Essential for a good security in a VPN is that the communicating computers are able to do authentication. This happens by means of exchanging of digital signatures with the SA*Key* mechanism. Only when both computers agree that they can trust the other, a virtual tunnel is created
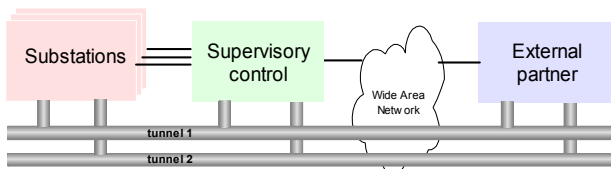
Figure 8: SA*Tunnel*

A tunnel is just a special type of connection across a network. It is done in a way to make the tunnel resemble a direct wire connecting between two computers.
Tunnelling enables remote users and distributed private networks to communicate with a relatively high degree of security over public networks. Simply, tunnelling is the ability to create circuit-like connections across a packet-oriented WAN (Wide Area Network). In a communication tunnel, a private point-to-point connection is established between endpoints in an IP network. Tunnels work in a similar fashion to virtual circuits. End-users can put any type of traffic, even non-IP traffic, into the tunnel.
Additional security measure such as cryptography is used in conjunction with tunnelling to further bolster VPN security.

The SA*Tunnel* system separates different types of information streams. For example, diagnostic data is

separated from on operational data stream like accountable meter readings.

The SA*Key* enables the user to securely and privately exchange data through the use of a public and a private key pair that is obtained and shared through a trusted authority. Once the message has been encrypted using the recipient's public key, even the sender will no longer be able to decrypt the resultant message. Only the receiver, using his private key only, is able to decrypt the message, thus making this impossible to read by anybody else.

CONCLUSION

Today's electricity market and regulating body are placing demands on the way distribution systems are operated and managed as never before. There is a need to shift focus from the state of the art transmission solutions to the "fallen behind" distribution systems.

With new MV substation automation systems such as the low cost SA*Sensor* system the poorly measured MV grid is catching up with the HV grid. With the right distribution automation applications utilities can improve the efficiency of system operation, reconfigure the system after disturbances, improve both reliability and power quality, and identify and resolve system problems.

In this paper the first two developed applications Power Quality and Fault Location are described. These applications transform data into information by means of smart processing and visualisation. The bulk of data is kept local and made centrally accessible.
Finally an elegant method to deal with cyber security involved in these information systems is developed and described.

REFERENCES

[1] M.J.M. van Riet, F. L. Baldinger, W.M. van Buijtenen, F.J.T. van Erp, F. Volberda, F. Provoost, 2005, "Alternative approach for a total integrated secondary installation in MV substations covering all possible and required functions", *CIRED 2005*.

[2] J.F.G. Cobben, J.F.L. van Casteren, 2006, "Classification Methodologies for Power Quality", *Electrical Power Quality and Utilisation, Magazine Vol II, No. 1, 2006*.

[3] P.M. van Oirsouw, F. Provoost, 2003, "Fault localisation in an MV distribution network", *CIRED 2003*.