SECONDARY SUBSTATION MONITORING AND CONTROL – PRACTICAL BENEFITS THROUGH INTELLIGENT COMPONENTS AND SYSTEMS

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ABSTRACT

This paper reports the key features and practical experience gained so far of a unique secondary substation monitoring and control system. After a small pilot installation, an increasing number of urban MV/LV substations have been equipped with communication and automation. The functionality of the comprehensive system is evaluated, and examples of how the functions are utilized are given. As examples and highlights of the system, power quality monitoring and MV network fault indication are reported in detail. Putting various functions together, the system is a real example of changing the grid smarter and providing tools for network asset management.

INTRODUCTION

Traditionally distribution network protection, monitoring and control functions have been focused on primary substation (HV/MV) automation, except remote controlled disconnectors or reclosers. AMM systems extend some monitoring capability down to customer level. However, secondary substation is an ideal point for data acquisition, because both MV and LV networks as well as the secondary substation itself can be monitored, and the powering of the automation equipment can be arranged in a simple way. In addition to secondary substation level equipment, communication to control room and data management in SCADA, DMS and measurement data management systems are essential components of the comprehensive system.

The system provides a number of functions for various users. The most valuable functions are related to improved MV fault management enabled by MV fault indication and remote control of MV switching devices. On-line monitoring of the substation and the transformer significantly enhance network asset management, reliability and safety. On the LV side, recordings of the electrical quantities enable versatile measurement data monitoring and reporting, carried out by dedicated measurement data management system. Figure 1 presents a block diagram of the system.

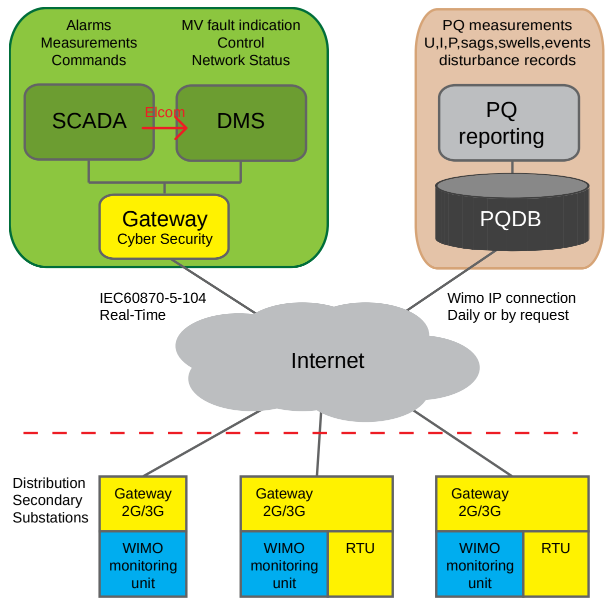

Figure 1. System diagram of the secondary substation monitoring and control system.

THE SECONDARY SUBSTATION MONITORING AND CONTROL SYSTEM

Measurements and recordings at secondary substations

For MV short-circuit fault indication, secondary substations are equipped with simple short-circuit sensors, transmitting the indication information to a digital input of the measuring and monitoring device, WIMO 6CP10. Indication of earth faults is more complicated. A cost effective solution is based on measurement of only the residual current via a straightforward current sensor, and intelligent processing of the measured information by the monitoring device or upper level systems. No MV VT's are needed. The integration of earth-fault indication into the system is one of the major achievements of the system, and it is reported more in detail in a separate paragraph below.

The key component at MV/LV substations is the measuring and monitoring device. It is connected to the LV side by normal CT's and VT's that enable measuring of electric quantities. Currents, voltages, load and power quality recordings can thus be registered. These values are kept in the memory of the device and transferred normally once an hour to the SCADA system. In case one of the monitored quantities passes its alarm level, immediate information is sent. Power quality related recordings (10 min average values) are sent to the measurement data management system daily or upon request e.g. in fault study. The connection of the multifunction measuring and monitoring unit is presented in Figure 2.

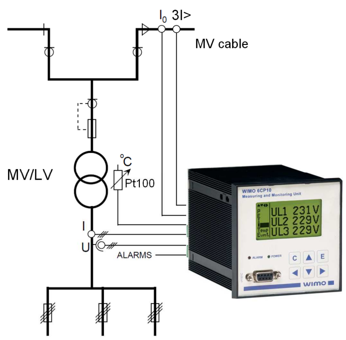

Figure 2. Connection of the measuring and monitoring device.

In addition to electrical quantities, the temperature of the transformer is monitored by Pt100 sensor. This is very valuable e.g. in case the load is moderate but the ventilation of the substation is not working. Temperature monitoring has proven especially important with dry type transformers, because they are sensitive to overload.
The substation can be equipped with door alarm, smoke sensors and water (flood) sensors. SF_6 switchgear can be equipped with SF_6 pressure alarm. The alarms are collected and sent on by the monitoring device.

Communication between secondary substations and the control centre – Gateways from Netcontrol

Because the system is geographically spread with a number of nodes, communication plays a major role. Inside the secondary substations, the communication between the monitoring unit, RTU and the communication unit is unbalanced IEC60870-5-101.
Remote controlled disconnectors have been used in rural networks since 1980, but traditionally there has been no remote control of disconnectors in urban MV lines. Because the monitoring system brings the communication channel to secondary substations, it is natural to use this channel also for remote control. Remote control significantly improves alarming and fault management resulting in reduced outage time. In many cases the secondary substation disconnectors are equipped with DC motors and a Netcon RTU including batteries.

The secondary substations SCADA communication is arranged using IEC60870-5-104 protocol and the measurement data management service communication is using the specific WIMO protocol. Both are tunnelled using secured virtual private network (VPN) provided by the Netcon Gateways from Netcontrol. As communication media 2G, 3G, ADSL or WAN connections through Internet are used. Figure 3 illustrates the communication options between the secondary substations and the control centre.

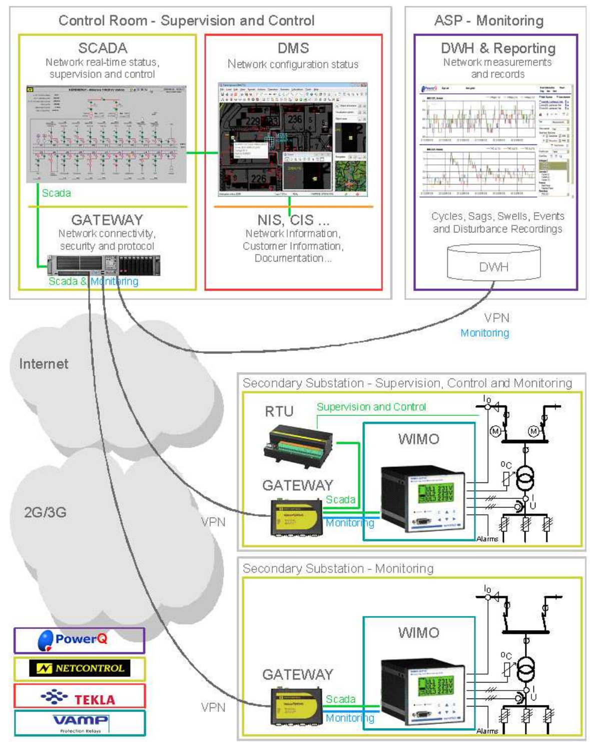

Figure 3. Communication options between the secondary substations and the control centre

Originally the SCADA system has not been built for the increased information the secondary substation monitoring produces. To avoid overloading of the SCADA system, the Netcon Gateway consolidates one hundred single secondary substations into one large virtual substation presented to SCADA. Only selected information is transferred to the SCADA system. Most of the measurement data is stored in the database of the measurement data management system, enabling versatile reporting.
The secondary substations communication is monitored by the Gateway in real time. In case of communication failure the gateway rebuilds the connection or gives an alarm, in case the fault is permanent.
The remote configuration and maintenance of Gateway and WIMO devices is enabled in the communication implementation thus saving time and effort in service work of the monitoring system.

Functions in SCADA, DMS and measurement data management systems

The introduction of secondary substation monitoring and control system did not require new SCADA or DMS systems to the control centre. The existing systems were just enhanced by a few new functions. Remote control of MV switchgear at secondary substations is the most important control function, improving fault management. The DMS system is used for remote control along with the SCADA system. In addition to the position information of the switches, the load current of the MV/LV transformers, and the magnitude of the residual current are continuously monitored.

The most critical alarms are the following:

- Temperature of the transformer
- Earth-fault indication and the magnitude of the earth-fault current
- Short-circuit fault indication
- SF_6 pressure alarm
- Open door alarm
- Combined power quality of the following quantities:
    - o Under or over voltage
    - o Voltage unbalance
    - o Voltage THD

Some of the alarms are shown in the SCADA system, and some are presented in the DMS system. Queries of the status of the secondary substations are available. An example of the user interface of to the system, built in the SCADA system, is presented in Figure 4.

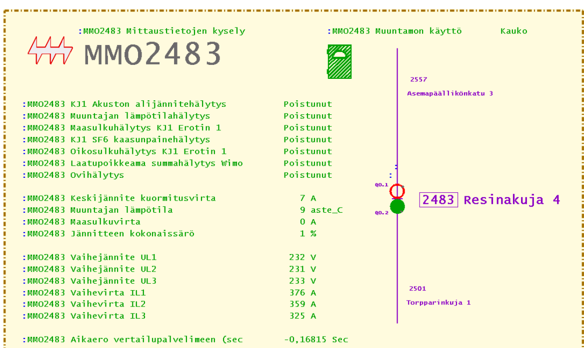

Figure 4. An example of the user interface: Query of one secondary substation.

The measurement data management system PQNet, designed by PowerQ Oy, stores a number of measurements in the PQ database for every secondary substation. From the user interface, a number of trend analyses from the database can be requested using web browser and enhanced graphical presentations. These reporting capabilities are reported in a separate paragraph below.

MV FAULT INDICATION

Rapid fault location is one of the ways to minimize outage time. In the case of cable network with open loop configuration, the target is to identify the faulty section between two disconnectors. When the secondary substations are equipped with fault indicators, this is possible.

In the developed system, short-circuit fault indication is simply based on traditional short-circuit indicators, giving the indication signal to the monitoring unit. Cost effective earth-fault indication is more challenging. It is based on analyzing only the residual current, measured by a current sensor designed for retrofit install. In earth-isolated networks earth-fault indication is simply based on threshold value of the residual current. The secondary substation monitoring unit sends the indication information to the control centre where the information is visualized to the operator. The magnitude of the residual current is continuously sent to the SCADA system.

For resonant grounded networks (Petersen coil) a new indication method has been developed. It is based on the fact that in case of low impedance faults the residual current between the substation and the fault the transient and initial current include harmonic components [2], [3]. The indication functions for earth-isolated network and the method for resonant-grounded network must be able to work simultaneously, without any change of parameter setting. The method has been successfully tested by using data from field experiments.

MEASUREMENT HISTORY DATA AND ANALYSIS – PQNet SYSTEM

Empowering the measurement data is one of the features that provide benefits to the entire system described in this paper. Measurements at LV level provide accurate information of electricity supply and can be used in making analysis needed by different utility processes.

The PQNet system is provided as service. The system is using web interface and customer can access it with web browser. Technology also provides easy integration as each measurement location can be saved as a URL address.

Measurements collected and saved into PQNet database in 10 rms values are:

- Phase currents
- Phase voltages
- Phase voltage THD
- Phase current THD
- Active, reactive and apparent power
- Temperature of the transformer
- Voltage sags and swells
- Voltage interruptions
- Load level (% of nominal power)

Additionally the following data is collected:

- Disturbance recordings (e.g. of power quality abnormality) in standard COMTRADE format.

Out of the measurement database the following reports and analysis can be formed:

- Measurement graphs/tables and their comparisons
- Automatic monitoring and comparison to limits
- Power quality reports
- Interruption and voltage sags/swells reports and analysis such as ITIC
- Statistical analysis such as Cumulative distribution function (CDF)

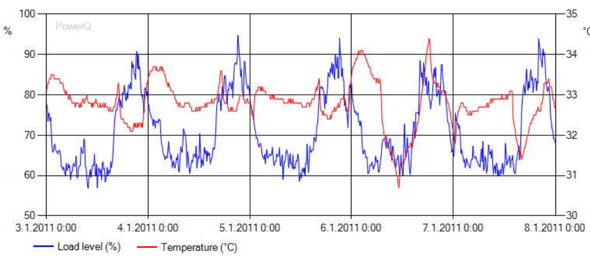

Figure 5. An example of the PQNet user interface: Comparison of load level and temperature.

EXPERIENCE AND DEVELOPMENT NEEDS

At the end of 2010, approximately 65 secondary substations have been connected to the system of Helen Electricity Network Ltd (Helsinki). The experience gained so far has been positive, encouraging to rapid expansion of the system. In the future annually approximately 145 MV/LV substations will be connected to the monitoring and control system in Helsinki. Pilot projects are currently planned by other urban network companies.

The key feature is that system is based on one monitoring unit and adequate communication capabilities. One system provides a number of functions instead of several separate systems. Utilizing the full range of benefits of makes the system cost effective.

Although there is only limited experience, the most significant benefits are expected to come from the functions for MV fault management: fault indication and remote control.

Transformer load management has proven useful, and the measurement data management system has already revealed several high THD levels, leading to further studies. The PQNet system is utilized daily, and in addition to internal use, external users have been able to use the system through a web based user interface. This usage has also been made attractive by integrating PQNet system into the existing maintenance system.

As the quality of supply requirement is increasingly high, the usage of LV feeding during outsourced secondary substation maintenance has been introduced. For this purpose the contractors use load level monitoring to find appropriate time for the work.

Provision of access to the measurement management system to customers who own their MV/LV substation is also discussed. This could be easily accomplished by creating additional users to the PQNet system.

First results of the measurement data management system indicate that network load calculations and measurements seem to provide different results in some cases. Studying these results more closely investment optimization may be achieved in the future. Also the influences of future energy saving technologies can be seen in results when analyzing the power quality data.

A few alarms have been received from internal monitoring of substations. This indicates that the system improves preventive maintenance, as expected.

Some problems have been encountered in the communication. There have been communications outages and a few communication overload situations with GPRS communication. These problems have been solved by altered communication settings, and the reliability of the communication is considered adequate. 3G communication, applied so far in a few substations, seems to provide improvement both in communication speed and reliability.

CONCLUSIONS

A unique system for secondary substation monitoring and control system, utilizing wireless communication and including MV fault management functions has been successfully implemented. According to present experience, the major benefits of the system are the following:

- Reduction of customer outage time through better fault management
- Power quality management
- Improved asset life cycle management

None of the functions alone justifies the investment in the system, but the overall combination provides a good benefit/cost ratio.

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