SECONDARY SUBSTATION MONITORING AND COMMUNICATION - A PILOT PROJECT IN STOCKHOLM

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ABSTRACT

Today equipment in Fortum Distribution’s secondary substations in Stockholm is locally handled, and communication is reduced to a sum alarm via control cables in the ground. A pilot project has been carried out to test a system for improved monitoring and communication with a secondary substation. This paper will describe Fortum Distribution’s experiences from installing such a system. The technical solution is based on Netcontrol’s Netcon 100 concept. An automatic switch-over functionality has also been implemented together with HM Power’s medium voltage switchgear Smart Ring. Radio planning of mobile communication, development of system architecture and a requirement specification are all important parts, but the major challenge of this project proved to be the installation. New technology, a larger number of companies involved and new requirements on the staff’s competence level were some of the challenges. The monitoring and communication system is now up and running.

BACKGROUND

In central Stockholm, the distribution system operator Fortum Distribution has approximately 1,700 secondary substations. Standard equipment for monitoring and control in the secondary substations includes e.g. a standalone power quality measurement instrument, earth fault and short circuit indicators, an alarm panel, and if appropriate also an automatic switch-over device for the two redundant medium voltage systems. These are all locally handled without any remote communication.

The only communication with the secondary station is reduced to a combined sum alarm function from each of the secondary substations. A sum alarm consists of 5-15 unique alarms caused by e.g. high transformer temperature or a tripped circuit breaker. Any of these alarms triggers a sum alarm via control cables in the ground to the feeding primary substation and from there via the SCADA-system to the network operations centre.

The aging control cable network in Stockholm means steadily increasing maintenance costs and prolonged repair time due to its location in a dense urban area.

For technical reasons the control cables are not suitable for high speed data communication. A modern mobile data communication solution would bring increased bandwidth and two-way communication which is better suited for supervision, data acquisition and control.

Furthermore Fortum Distribution foresees an increased need for control at the customer end of the grid, which also implies more intelligent control equipment in secondary substations.

With this in mind, Fortum Distribution has started a series of pilot projects one of which is described in this paper. The main purpose of the described project is to gain experience and evaluate one technical solution regarding both:

- Improved monitoring of secondary substations.
- Mobile communication as a replacement of the control cable network in Stockholm.

This paper will describe the experiences from the planning, design, implementation, commissioning, and early operation phases of the project.

PLANNING AND DESIGN

The location of the installation is a new indoor served site-built secondary substation in the expanding urban area called Stockholm Royal Seaport, see Figure 1.

Medium Voltage Switchgear

In central Stockholm the medium voltage network is a double cable network. In the pilot station the medium voltage switchgear has four cable bays to connect to these two systems. Two 1,000 kVA transformers are used to transform from 11 kV to 0.4 kV.

The switch-over between the two medium voltage systems is executed by Smart Ring, a medium voltage switchgear from HM Power. Full range circuit breakers are chosen in every bay in order to enable remote manoeuvring of the breakers in the future.
Remote Terminal Unit

Netcontrol's Netcon 100 concept was selected as a remote terminal unit (RTU), see Figure 2. The platform is a modular and scalable solution for intelligent distribution networks and monitoring and control of secondary substations. A similar system deployment project has earlier been described in another paper [1].

Netcon 100 provides e.g. the following functionality:
- Fault management for medium-voltage networks.
- Quality measurement of current, voltage, power etc. in low and medium voltage networks.
- Transformer temperature measurement.
- Event recording and alarm logic.
- Remotely controllable I/O:s.
- A comprehensive range of data communication features:
  - Data communication protection by encryption and tunnelling.
  - Built-in 3G/GPRS.
  - Data communication gateway function.
- A wide range of remote-operation protocols to the network operations centre.
- Local human-machine interface.
- Battery charging and voltage and condition monitoring.
- Centralized management of software versions and configurations.

In addition, a new automatic switch-over functionality for the two redundant medium voltage systems was developed and implemented in the Netcon 100 specifically for Fortum Distribution.

Radio Planning

Early in the planning phase mobile coverage measurements were performed on site to verify the communication in the area and one of the public mobile 3G network operators was chosen.

Selection of the antenna was also important. We identified three main aspects to consider in an urban area:
- Radio characteristics.
- Aesthetic appearance of the antenna itself, as well as its final installation on the substation.
- Design to minimize the risk of sabotage.

We came to the conclusion that while radio characteristics should be the most important requirement, there will always have to be a trade-off between the three criteria for different kinds of stations. In this case we chose a small hockey puck shaped antenna that was mounted on the roof of the substation.

The RTU may get its system time via its built-in GPS or from the SCADA system via an internet time server, alternatively via the IEC 60870-5-104 protocol. We chose the latter to avoid using a second separate GPS antenna or a combined antenna with two cables.

System Architecture

Considerable effort was spent on creating a robust communication solution. Still, we decided to keep the old control cable sum alarm as a fall-back alternative. The solution can be divided into three parts:
- **SCADA.** The IEC 60870-5-104 protocol and a secure gateway server were already implemented and well proven within Fortum Distribution's systems.
- **Power quality data.** We set up a secure, unidirectional file transfer function of the power quality files to the analysis cloud server. Since the server was located outside Fortum Distribution's network, the most important requirement was to eliminate the risk of any intrusion or manipulation attempts.

- **System administration.** Fortum Distribution uses two factor authentication plus login to a security gateway for the remote access to the configuration of the RTU.

The overall communication solution can be seen in Figure 3.

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**COMMISSIONING**

**Pre-test**

It was considered essential to perform factory acceptance tests before the equipment was sent to site, since the solution was new. The RTU and the medium voltage switchgear were connected in the factory and a full scale test of the automatic switch-over functionality was performed. Other functionality of the RTU was also tested, including communication tests with the network operations centre.

**Installation**

The major challenge of the pilot project proved to be the installation phase. The chosen secondary substation is built on site with several different suppliers of equipment, which in itself is a challenge. Overall, the challenges were related to the following:

- Some equipment interfaces had not been thoroughly clarified during the planning phase.
- Incorrect documentation, caused by insufficient change management of documentation.
- Staff unfamiliar with this type of equipment.
- Missing one clearly responsible person for the complete installation.

More issues encountered during installation were, for example: current sensors on the medium voltage cables were fitted incorrectly, clamps were not removed after installation of low voltage current transformers, and the current transformer ratio was not configured correctly. The conclusion is that the more people involved, the higher are requirements on installation inspections.

**OPERATIONAL EXPERIENCES**

**Network Operations Centre**

The network operations centre of Fortum Distribution normally focuses the daily monitoring of the power grid on the primary substations. Monitor displays, alarms, events, measured values etc. are mainly visualized on that level. For the secondary substation we chose to create a corresponding surveillance view in the SCADA system, but while it is possible for an operator to actively monitor a limited number of primary substations on screens the number of secondary substations is higher in magnitude by a factor of 100. Any future monitoring of a large population of secondary substations will require a different solution for the operators.

One example scenario would be a major power loss in a primary substation, making a large number of secondary substations simultaneously lose their power. In a large scale implementation of supervision of secondary substations it will be essential to use intelligent filtering of alarm bursts sent to the network operations centre.
Communication
The experiences gained from the chosen 3G operator indicate that communication performance varies by the day. For days, the communication could run flawlessly, then suddenly performance dropped on certain days and we lost contact a number of times for longer or shorter periods. Early indications point to the effects of poor mobile network performance as well as bad weather conditions.

The effect was that we occasionally lost contact with the secondary substation from the network operations centre. A traditional RTU keeps no history records for the SCADA system, so the real-time values were lost during the "drop out" periods. However, the power quality files were still recorded locally by the Netcon 100 and have proved to be transferred to the analysis server as soon as the communication is up and running again.

When it comes to remote service management of the RTU, the shorter communication interruptions have not been critical for this single pilot project. Service management seldom requires immediate access. In a large scale implementation this could however be a problem.

Power Quality Data
As part of the concept we found the RTU functionality for built-in power quality measurements especially interesting. The power quality measurement is remotely configurable with a large variety of settings. The analysis software Netcon PQA may be licensed on standalone machines, but the project chose to use the analysis software as a cloud service.

Power quality data is accessible through a web interface. In Figure 4 apparent power and transformer temperatures are plotted for one week. As can be seen the maximum measured power is about 450 kVA, less than 25% of rated power for this secondary substation. This is because far from all customers have yet been connected. Also note that there is a 5°C difference between the two transformers. This difference is due to the fan being continuously turned on for one of the transformers. The fan should not be turned on at this low load, so this is a configuration fault or installation mistake that needed to be adjusted. Actually, this problem was first discovered through temperature measurement data.

The amount of power quality data increases rapidly, which makes it important to consider both the number of measuring points and also time resolution. The data is collected through file transfer and the files are packed into zip-format, which greatly reduces the file sizes. Ultimately, that will affect the allowed data volume of the mobile subscription.

CONCLUSIONS
Important learnings from the planning, installation, commissioning, and early operational experiences of the system are:

- A project like this is time and resource intensive, at least the first time.
- When there are more companies and people involved than for a traditional secondary substation, correct project information and documentation is even more important than earlier.
- Appointing one installation coordinator will minimize the risk of failure during installation and configuration.
- If problems do occur, we recommend immediately taking one step back in order to review relevant parts of the installation.
- New technology puts new requirements on the staff's competence level, e.g. configuration management of hardware and software.
- A well thought through system architecture is essential.
- Prioritize which data are most important to receive in order to optimize the solution for both monitoring and power quality analysis.
- An advantage of Netcon 100 is that the hardware is scalable, so that technical solutions can be adapted as needed.
- The Netcon 100 is flexible in terms of configuring which values to measure and how to aggregate them before posting the values to Netcon PQA or the SCADA system. Settings can also be changed remotely.
- Sending real values from the secondary substation to the SCADA system provides the network operations centre with new knowledge.
- The possibility of analysing statistics from both the medium and low voltage sides will help in following up disturbances.
Using wireless communication with a standardized interface means, that if one communication operator fails you can always choose another.

At the end of the day this pilot project has been a rewarding and instructive challenge for all people involved. The system is now up and running, and Fortum Distribution's evaluation of the system continues.

REFERENCES