WIRELESS REMOTE CONTROL IN RING MAIN UNITS: EXPERIENCES IN INTELLIGENT GRIDS

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ABSTRACT

The grid of DELTA Netwerkbedrijf B.V. (DNWB), a grid owner in Zeeland, the Netherlands, is moving towards more intelligence in the grid. On the other hand, the Dutch Government is setting goals related to the availability of the grid by using IEEE reliability indices SAIDI and SAIFI. The conventional grid has already remote monitoring and control capabilities at the level of distribution substations. In the Ring Main Units, the secondary switchgear, no remote monitoring and control capabilities are available. General available automation components are quite expensive and big, so it is not the optimal solution for the compact Ring Main Units.
Together with Eaton, as manufacturer of medium voltage switchgear, a solution was designed by adding intelligent components specifically designed for medium voltage areas in order to have an efficient, integrated and compact solution in the ring substations. This design is set up as a pilot project rolled out in a couple of distribution rings to gain knowledge about the practical impact of the implementation in the existing grid. After evaluation of the results this concept will be rolled out broader in the grid.

INTRODUCTION

End 2011 DNWB started a project to get more experiences with remote controllable Medium Voltage (MV) switchgear in their distribution grid. The aim of the project is to decrease the average outage time for the low voltage end-user and to have more inside information of the grid status of the grid and its components. The grid of the peninsula Tholen in Zeeland was appointed for this pilot project. Due to the geographic situation, the travel times to the locations of the Ring Main Units are relatively long. Therefore the best result is expected at this peninsula to decrease the outage time.

GOAL OF THE PROJECT

The goal of this pilot project is to get experiences with remote controllable and monitored MV switchgear at the distribution substations. These experiences concern the necessary mobile communication as well as the use of remote controllable switchgear.

LAYOUT OF THE EXISTING MEDIUM VOLTAGE NETWORK AT THOLEN

The distribution network is principally ring-shaped, and operated radially (in open rings). This creates an n-1 redundancy in the structure, but not in the operation mode. At the beginning of the open ring, a circuit-breaker is placed in the feeding substation.
In Figure 1, the basic topography of the situation in the MV network at Tholen is shown. This topography is like in the rest of the Netherlands and most other countries.

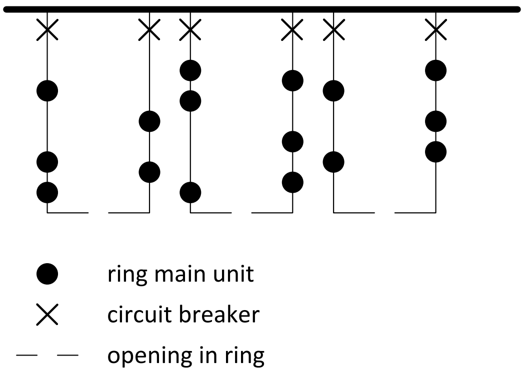

Figure 1: Basic topography MV network at Tholen

In the Ring Main Units and the secondary switchgear, no remote monitoring and control capabilities are available.
In the Netherlands 95% of the MV networks are 10 kV and cables are underground. A cable breakdown in such a system leads to an interruption of the supply which can only be restored after a number of (manual) switching operations. In the period from 2002 – 2011 the average outage time for an LV customer in the Netherlands was 28 minutes per year. 64% of this was due to breakdowns in the MV network [1].

PROJECT DESCRIPTION

The project is rolled out for the grid of the peninsula Tholen in Zeeland, in the South West part of the Netherlands.
The grid for this pilot project includes about 65 km medium voltage cable distributed over four 10 kV rings, 65 distribution stations, 300 medium voltage coupling sleeves and 3000 end-users.
The pilot project contains the plan to replace the

conventional hand-operated MV switchgear by remote controllable switchgear at strategic nodes in the ring.
Applying this remote controllable switchgear, the grid ring can be split up in four separate parts remotely. Additional electronic short circuit detectors are added in the various parts of the ring. These detectors can be remote monitored. The Control Centre of DNWB receives all the information.

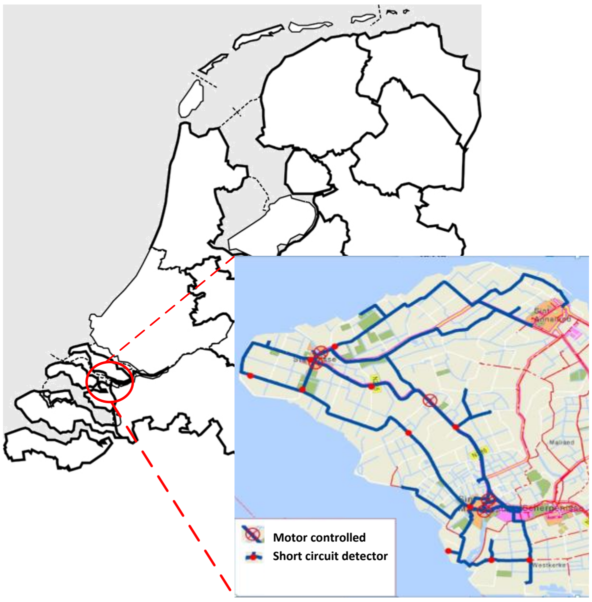

Figure 2: Location and architecture of the grid

The peninsula Tholen is chosen because this location has the relative longest response times in case of a failure and therefore the highest yield in reducing outage minutes.
Another consideration was the availability of walk-in transformer stations at the strategically nodes in the grid to have enough room to place the new switchgear.

Objectives of the project

Outage time reduction

When a breakdown occurs somewhere in the grid, the circuit breaker of the feeder will trip and one or more short circuit detectors will send an overcurrent message to the Control Centre. The moment the Control Centre receives one or more messages from the short circuit detectors the location of the failure can be determined. That gives DNWB the opportunity to send a service team directly to the correct location. Via remote control of the nearby Ring Main Units the faulty part of the grid can be isolated and the remaining healthy part can be supplied through the other side of the grid.
By this, very shortly after a failure occurs, the healthy part of the ring can be re-energized and the number of end-users without power is limited.

Maintenance time reduction

For maintenance purposes the 10 kV ring can be opened and closed remotely which will save time for the maintenance staff. They are concentrating on the maintenance actions; the Control Centre takes care of the switching procedure.

Project Architecture

At five strategic nodes in the grid, remote controllable MV switchgears will be placed. All incoming and outgoing cable fields of the switchgear are motor controlled and the status of cable and transformer fields can be monitored. Current, voltage and power are measured as well as directional earth leakage current and directional short circuit current. Remote control and monitoring is realized by use of a Remote Terminal Unit (RTU). The RTU has an integrated GPRS modem for remote access. The Control Centre of DNWB communicates with the RTU through a secured connection over the public network.

COMPONENT SELECTION

To realize this project several components have been defined:

- MV switchgear with motor control
- RTU with GPRS communication
- Public mobile communication network
- Security facilities to prevent unauthorized access to the system
- SCADA System to collect the information

MV switchgear with motor control

The Eaton Automated Xiria is chosen as the Ring Main Unit switchgear. The Xiria is metal enclosed and air insulated, equipped with 3-pole load-break switches, circuit breakers and integrated earthing. The vacuum interrupters, the main busbars and the change-over/earthing switches are mounted inside a fully sealed metal enclosure for protection against the ingress of moist and dust and are maintenance free. The Xiria is an environmental friendly, SF6 free system and is designed for substation automation with remote control.
DNWB already has good experiences with the hand-operated version of this type of switchgear in its substations.

RTU with GPRS communication

Mounted inside the Xiria switchgear Eaton delivers an RTU with integrated GPRS modem. Also part of the system is a power supply with battery backup. The Eaton RTU is especially developed for use in MV environment and complies with IEC 62271-1 and -304, IEC standards for high voltage switchgear and controlgear. Remote access can be set up through both wired and wireless communication using TCP/IP. Communication protocols like IEC 61850, IEC 60870-5-104 and Modbus RTU are integrated. Control and status monitoring up to 5 panels is possible without extension modules. The RTU can be programmed using the several programming techniques as defined in IEC 61131-3. Alarming, event recording and data logging are standard features. A web server is integrated in the RTU for monitoring and easy configuration.

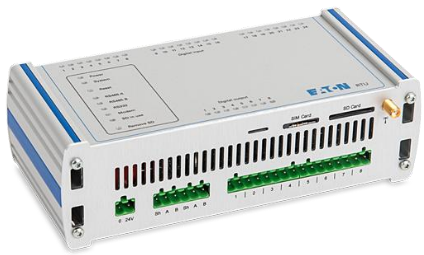

Figure 3: Eaton RTU with integrated GPRS modem

Public mobile communication network

The already existing remote control and monitoring at the distribution substations is realized via hardwired interfaces. To interface the Ring Main Units, DNWB has chosen to communicate via the public GPRS data network. It is not feasible to connect the Control Centre hardwired to all Ring Main Units due to the number and locations of the Ring Main Units.

DNWB selected a provider according to following conditions:

- high level of security
- maximum availability
- network operational before December 31st 2012

Vodafone appeared to be the best provider to realize this mobile communication network.

High level of security

Vodafone creates a Corporate Access environment (Customer specific Cloud) which is only accessible for authorized users. The authentication is done by a RADIUS server. Normally, this RADIUS server will be configured and managed by the telecom operator. For DNWB, this is not desirable. For future changes, DNWB wants to be independent of third parties. DNWB wants to be able to add users (RTUs) to the network by themselves and they also don't want to share network credentials. Vodafone can support a RADIUS server located and managed by the end-user. This RADIUS server will authenticate the user by username and password.

Maximum availability

Every transmission location of the public network of Vodafone has its own Uninterruptable Power Supply (UPS). Usually during an outage the GSM communication on the public network will increase. Unfortunately on the network GSM traffic has a higher priority than GPRS traffic. This pilot project will give us more information on the behaviour and availability of the network during real live.

Network operational December 31st 2012

Vodafone has already experience with mobile communication networks for RTUs of other grid owners. Therefore a base design for the network was already available. As a result of this it was possible to have the network in operation before end December 2012.
Vodafone also understood the specific needs for a network serving RTUs.

Mobile communication network architecture

The global design of the communication network is given in Figure 4.

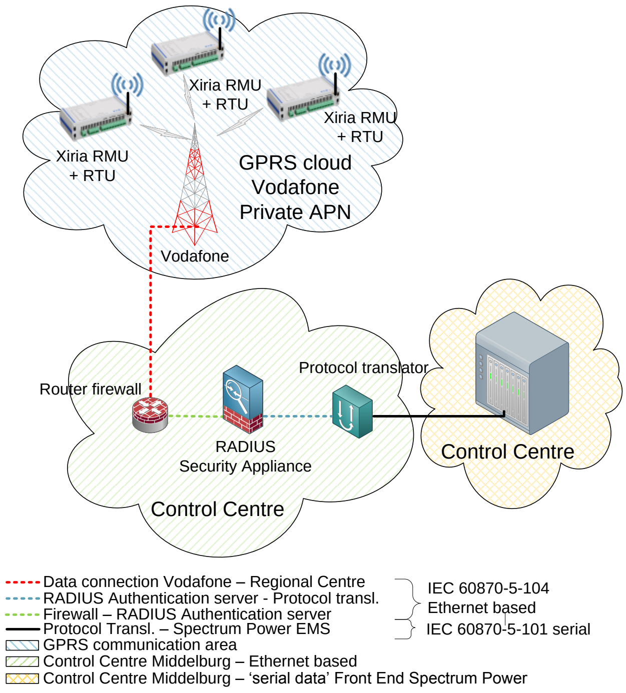

Figure 4: Global design mobile network

Security facilities to prevent unauthorized access to the system

To guarantee a high level of security in the whole network, DNWB has chosen to manage its own users in his Private Network. Each RTU has its own unique username and password combination, which it makes easy to block one specific user. The access to the RTU is locked by a firewall on the wireless network interface. A direct connection via Ethernet is password protected. Also the connection to the SCADA system is protected with a firewall.

Setting up the connection

To connect the RTUs with the front-end of the SCADA system, there are a few steps to take.
The RTU holds the name of the Access Point (APN) to connect with and a unique set of login details. To start the connection, the RTU sends a login request to the RADIUS server to its own login credentials. If the authorization is successful, the RADIUS server will send an acknowledgement and it assigns a fixed IP address to the client RTU. IP address pools are disabled, even further reducing the risk for unauthorized access. Now the RTU has

received an IP address and it is able to access the APN network. The Protocol Convertor will recognize the newly connected RTU and it will set up IEC 60870-5-104 connection. The Protocol Convertor is an extra security level on the first layer of the OSI model. The protocol will be converted from the IP based IEC 60870-5-104 to the serial version, IEC 60870-5-101. When the secured version of IEC 104 will be available, then DNWB can make the decision to directly connect IP based traffic to the SCADA Front-End. The moment the connection is set up, time synchronization for the internal real time clock in the RTUs will be performed from this moment onwards.

SCADA system to collect the information

DNWB already has an Energy Management System (EMS) running at their Control Centre which is also be used for this project. Actually a Data Management System (DMS) is more used for this kind of systems, but until now it is a pilot for DNWB. The moment this concept of Distribution Automation will be rolled out broader in the grid, perhaps a DMS is more useful.

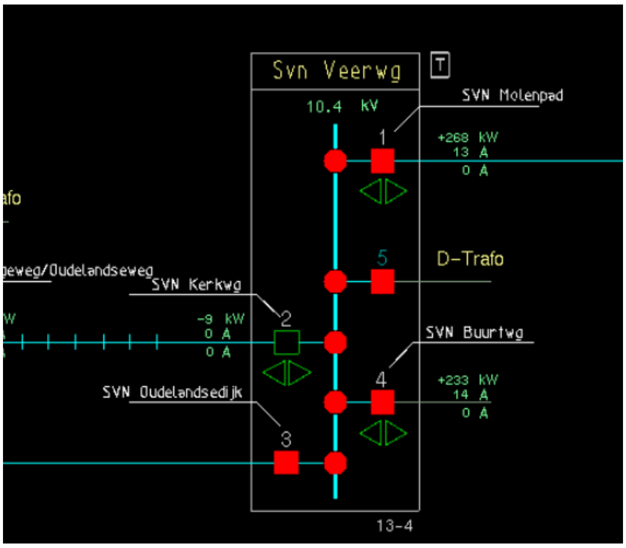

Figure 5: Screenshot detail SCADA system Tholen

APPLICATION SOFTWARE

The RTU can be programmed to meet the requirements for each individual customer. DNWB uses a program which is equal for all Xirias in their grid where Ring Main Unit specific settings can be configured via the web server in the RTU. Therefore, the IEC 60870-5-104 addressing and communication is independent from the number of panels, sensors and protection relays.

FUTURE PROOF

After evaluation of the results of this pilot project the project will be rolled out broader in the grid. The mobile communication network set up for this pilot project can easy be extended for more RTUs. The network is already designed for up to 4096 clients. Also the RTU can be extended. Other devices can be interfaced through the RTU and data from these devices can be monitored and controlled by the Control Centre.

LESSONS LEARNT

Seamless integration of all used technologies is a must to be successful in this kind of project. It is very important to have short lines between the technicians who are responsible for the separate parts of the whole system. Think of application engineers responsible for the application programs in the RTU, the engineers responsible for the configuration of the communication network and the engineers at the Control Centre of the grid owner.
To set up a system like this, different solutions are possible. To get the most appropriate design, a lot of design choices had to be made and right configurations had to be selected. It is important to speak each other's language and to understand the needs of the end-user.
Furthermore the interpretation of the IEC 60870-5-104 protocol differs from vendor to vendor. So, when possible, give the vendor enough information, check the interoperability by yourself and take time to make a good test procedure.
It can be very useful to place listening ports at well-chosen positions in the system to locate faults easily. Realize that testing with simulators brings risks to forget something, working with the real system gives always new situations.
To be flexible during such a pilot project, keep the project team small. Be aware of the possible vulnerabilities of the whole system, while starting the basic engineering.
Delivery times of IT-related specific hardware can be varying widely.

REFERENCES

[1] Haan de, E.J., 2012, "Betrouwbaarheid van elektriciteitsnetten in Nederland in 2011" KEMA Arnhem, 74101378-ETD/SGO 12-00616