Introducing smart grids : practical experience of a DSO

INTRODUCING SMART GRIDS – PRACTICAL EXPERIENCE OF A DSO

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ABSTRACT

One of the main issues for Distribution System Operators is the introduction of so-called smart grids. Enexis B.V., one of the major Distribution System Operators in The Netherlands started two years ago with the preparation of a large-scale roll-out of distribution automation, which can be considered as a part, or form of a smart grid. In the preparation and the pilot phase of the project it became clear however that a lot of practical issues had to be solved before smart grids can be rolled out. This contribution describes the experiences of Enexis and compares theory and practice of the introduction of smart grids.

INTRODUCTION

Electricity networks are currently challenged by a number of issues. In the past networks were passive and the power was flowing top-down. More and more small-scale distributed generation is connected to the network however, making power flows bidirectional and operation of the network more difficult.
Most of the electricity networks have been build in the 50's and 60's, meaning that they are approaching the end of their lifetime. Meanwhile, society is becoming more and more dependent on a secure supply of electricity. Power outages are no longer accepted as inevitable or inherent to the supply of electricity. Public information supply during power interruptions is getting more important.
The density of traffic is increasing. In the classical way of solving an interruption, a lot of switching is done manually, meaning that technicians have to travel between different locations. Especially in large cities (during rush-hour) this takes a long time, leading to long restoration times.
The average age of the employees is high, meaning that in the near future the companies need a lot of new personnel. With the shortage of students with technical education on all levels, this will become a problem in the future.
The trends described above imply that in the future, in a society that's becoming more and more dependent on electricity, the network is becoming older and more complicated, while there are less employees. Solutions have to be found to face these challenges. One of the possible solutions, which are discussed extensively in literature nowadays, is to introduce more automation and intelligence in the networks. A general term for this is 'smart grids' [1]. At Enexis, one of the major Distribution System Operators (DSOs) in the Netherlands, a project was started in 2008, to introduce so-called 'Distribution Automation' (DA) in the network, which is one of the elements of a smart grid. In this contribution the lessons learnt during the preparation of the large-scale roll-out of Enexis' DA concept are discussed.
The paper starts with a brief description of the basic concept of the DA program at Enexis. This is followed by a description of the functional design that has been defined. In the next chapter it is described how the pilot projects that have been done showed a large difference between theory and practice. Then a description is given of all the problems that had to be faced during the preparation of the large-scale roll-out of the distribution automation concept. The paper concludes with the most important lessons Enexis has learned so far.

DISTRIBUTION AUTOMATION: CONCEPT

Enexis used its Risk Based Asset Management (RBAM), [2], approach to find the optimal solution for the challenges described in the introduction, as described in [3]. The result was the introduction of the DA concept. The concept requires changes in the MV-grid, but also in the operational processes and IT-systems. This paper will focus on the implementation of the DA-concept in the MV-grid. The DA-concept itself will be described in this chapter.
The MV-networks of Enexis typically consist of a transmission part, that is designed redundantly (n-1 secure), and a distribution part, that has a ring-configuration, but is operated as a radial grid. In case of a failure, the fault is cleared automatically. The isolation of the faulty section however, and the subsequent restoration of power is done manually. This implies a great potential for improvement of reliability and a reduction of labour-intensity by applying DA. Moreover, DA will also facilitate information supply. Therefore, a concept of remote switching and fault location in the MV-distribution grid was developed. Many variants of remote control are possible: in theory all circuit breakers and switch-disconnectors could be equipped with remote control, but at a certain point the additional reliability improvement is no longer worthwhile, i.e. the additional investment does not pay off. In [3] it has been described how the most optimal solution has been found by applying the Risk Based Asset Management (RBAM) approach.
The key concept is shown in the figure below. As soon as a fault occurs the circuit breaker will disconnect the feeder. In the conventional situation the fault had first to be located and isolated, and then power supply to the feeder could be restored. With DA, the load-break switches (RMU's) and

circuit breakers marked with R can be controlled remotely. Depending on whether the fault is in the first or the second part of the feeder, at least one half of the feeder can be reconnected remotely within a few minutes, resulting in a significant reduction of the CML.

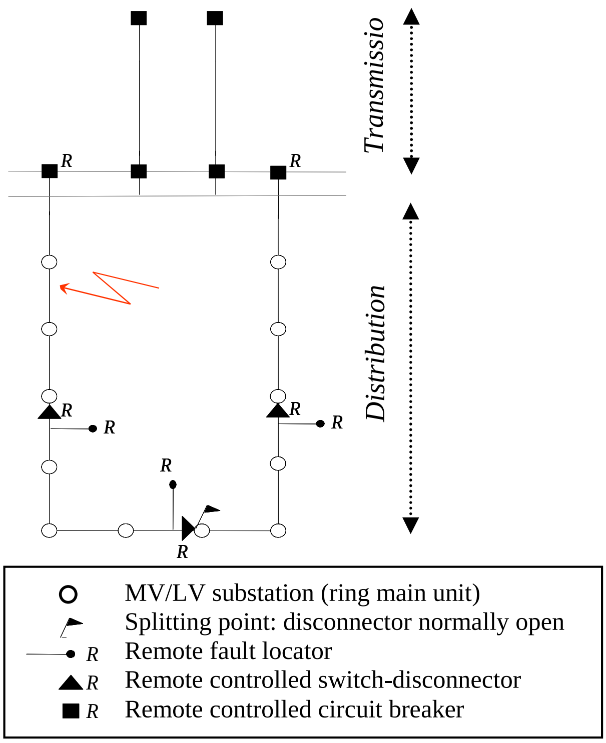


Figure 1: Enexis' Distribution Automation concept

IMPLEMENTATION : FUNCTIONAL DESIGN

In 2008 Enexis started with the implementation of the DA program. The first step was to translate the strategy described in the previous chapter into practical solutions. The result is a functional design, describing how to retrofit load-break switches and circuit breakers for remote control, how to detect faults (and which faults), which data should be acquired and how to communicate and process the data. The functional design for the two most important locations in the network will be described shortly.

Strategic RMU's

The core of the strategy is to reconfigure quarters of a distribution ring. This requires that on the half of each feeder and at the normally open point a RMU should be located which can be controlled remotely. This requires that the RMU should have a motor-drive for automatic opening and closing the load-break switches. Because it has to operate at the moment when there is no power, there should be a battery with enough capacity to switch the load-break switches several times.

In order to know whether the fault was in the first or in the second half of the feeder there should be a short-circuit/earth-fault indicator on at least one of the two feeders connected to the RMU. In the case that there is local generation in the feeders it might even be required that the indicator is direction-sensitive.

For network management and planning, load conditions are needed, requiring some additional measurements.

For exchange of data and control signals a communication-medium is required. It became clear that, because of the large number of RMU's, often in rural area's, GPRS was the most cost-effective solution for communication.

In order to make quick installation (and replacement, if necessary) possible it was required that all functionally should be put together in one so-called 'black box'.

MV/MV substations

In order to be able to switch quarters of the distribution ring 'on' and 'off' it should also be possible that the circuit breakers at the beginning of each feeder are remotely-controllable. In case of distribution feeders directly connected to the primary switchgear in the HV/MV substations this is in most cases no problem, as the circuit breakers are already suited for remote control. Enexis has a grid-structure however in which most distribution feeders are connected to MV/MV substations and in these substations the circuit breakers are not remotely controllable. In some of the newest substations motor-control of the circuit breakers is already available, but in older substations even this is not possible, and the switchgear has to be retrofitted or replaced.

Fault information and data is acquired by digital protection relays, which also control the circuit-breakers. The relays are interconnected by a LAN-based network.

For communication with the SCADA-system GPRS is the preferred medium for the short term (for the same reasons as mentioned above for the MV/LV substations).

PILOTS: THEORY AND PRACTICE

Before starting the large-scale roll-out a number of pilots have been done. These pilots gave a lot of valuable lessons. They showed that for a lot of issues there is a large difference between the theory and the practice of DA (and most probably also for 'smart grids' in a more general sense). Some of these issues, mainly applicable for the MV/LV substations, are described in this chapter.

Switchgear to be automated

The concept that has been chosen by Enexis requires automation and remote control of switchgear. In theory this can be done very easy, as all modern switchgear has the possibility for motor control. And in new substations, it can be taken into account on beforehand, that there should be enough space to locate all additional equipment (RTU's, etc.) that is necessary for DA. This ideal situation is shown in the figure below, showing a secondary switchgear installation that can be easily automated and a concrete 'compact station' that has enough possibilities to locate the additional equipment that is required for DA and that can be easily accessed.

(a) (b)

Figure 2. Examples of new types of switchgear and modern housing of switchgear

During the pilots a lot of other substations and types of switchgear were found however, showing the practice. Two examples are shown below. The picture at the left shows a very old type of switchgear that only can be operated manually. The only way to automate this is to place a robot in front of it! The picture at the right shows a very small housing for an RMU. The climatic conditions in it are extreme, there is no space for whatever kind of additional DA-equipment, and it's very difficult to access.

(a) (b)

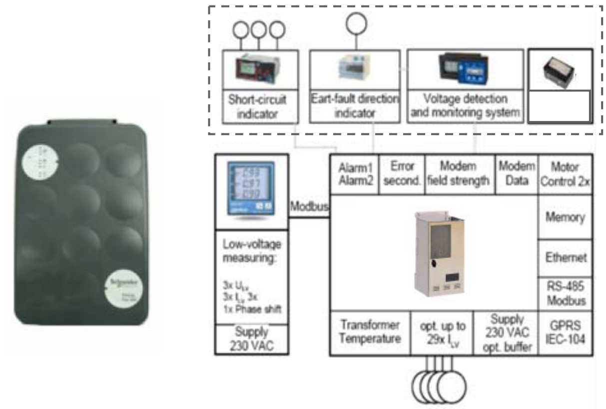
Figure 3. Examples of old types of switchgear and old housing of switchgear

So, in order to make DA possible in the first case the complete switchgear of that substation had to be replaced and in the second case the complete RMU, including housing, had to be replaced by a new one. Because the space in concrete "compact stations" is limited in dimensions however, Enexis is forced to use switchgear with minimal dimensions. This category of switchgear was not automated yet. Therefore additional functionality and improvements had to be developed before it was able to fulfil the requirements of Enexis.

Required equipment for DA

One of the key drivers for the DA program at Enexis is the fact that in the future the same amount of work has to be done by less people. This requires that the equipment has a long lifetime and is (almost) maintenance free. It also requires that in the case something has to be replaced, this can be done very easily.

Based on these requirements Enexis specified a plug-and-play 'black-box' solution, containing all DA-functionality required for an RMU, something like the one shown in figure 4a. During the preparation of the pilots it became clear however that most manufacturers active in the area of DA and 'smart grids' do not have that kind of solutions yet, for application in MV/LV substations. Proposed solutions looked more like the one shown in figure 4b, consisting of a lot of different components, which all have to be connected together in order to obtain the desired functionality.



(a) (b)

Figure 4. Black box solutions for distribution automation

Data-acquisition and fault-indication

Bi-directional fault indicators were (based on proven technology) not yet available in 2009. A second problem was that the low-end switchgear (i.e. small version) used by Enexis did not have enough space to facilitate conventional current and voltage transformers. Alternatives for these measurements had to be found.

Communication

Most descriptions of 'smart grids' assume that fast and reliable communication with a high bandwidth (such as for example glass fibre) is available everywhere. The reality is quite different however. From a research project that has been done for Enexis it became clear that at this moment GPRS-communication is the only realistic option for the Enexis-case. The used protocols and data to be transferred are not optimised for a mobile medium with its own characteristics and a data-based tariff-structure. In addition no international security-standards are available describing how to implement adequate security-measures over mobile communication networks.

PREPARATION OF LARGE-SCALE ROLL-OUT

The next step, after running the pilots for half a year and evaluating them, was the preparation of the large scale roll-out of the DA program in the MV-networks of Enexis.

Here again a large difference between theory and practice became visible. In theory the preparation can be done relatively easily. The next steps should be enough:

- Define a few standard concepts (for switchgear, substations, protection relays, etc.)
- Buy and install standard secondary equipment
- Use available equipment (a.o. protection relays)
- Form a number of project groups and start the roll-out

During the preparation of the large-scale roll-out it became clear however that the reality is a bit more complicated:

- Different types of switchgear; there is a large diversity of switchgear (> 100), both in manufacturer and type, where even the same types can have different versions
- Different types of substation; substations are different in dimensions, layout and climatic conditions, meaning that different solutions have to be found
- 60 – 80% of protection relays cannot be used (because it are mechanical relays, they have no possibility for communication with (standardised) protocols, etc.)
- Primary equipment is often not suited for automation by a motor drive, implying that a part of the primary switchgear has to be replaced in order to make distribution automation possible
- Specific knowledge, experience and skills required; installing and maintaining DA-equipment is quite different from the work that is done nowadays, implying that training of people is necessary.
- Before the last equipment has been automated, the first should have been replaced already; the life-time of the (secondary) DA-equipment is much shorter than that of the primary switchgear; everything possible should be done to guarantee that the lifetime of the equipment is as long as possible.

SOLUTIONS

In the previous chapters a number of problems experienced by Enexis have been described. Some solutions to overcome these problems have also been developed in the last 2 years:

- During the pilot-phase several manufacturers have developed a black-box solution for the MV/LV substations, in which the lessons-learned from the pilots and Enexis' requirements are incorporated.
- The required (directional) fault indicators that where not available yet, have been developed by several manufacturers, during the pilot-phase, in close discussion with Enexis. The result is a very small fault indicator which obtains the voltage from the voltage indicators and with very small current transformers.
- A nice solution has been found, and further improved for retrofitting old circuit-breakers such that they can be remotely controlled.
- Protocol-settings and data-volumes have been optimised for mobile communication networks based on GPRS and security-threats have been sold.
- For each location in the network a standardised design has been made. As an example the solution for the MV/LV substation is shown in figure 5.

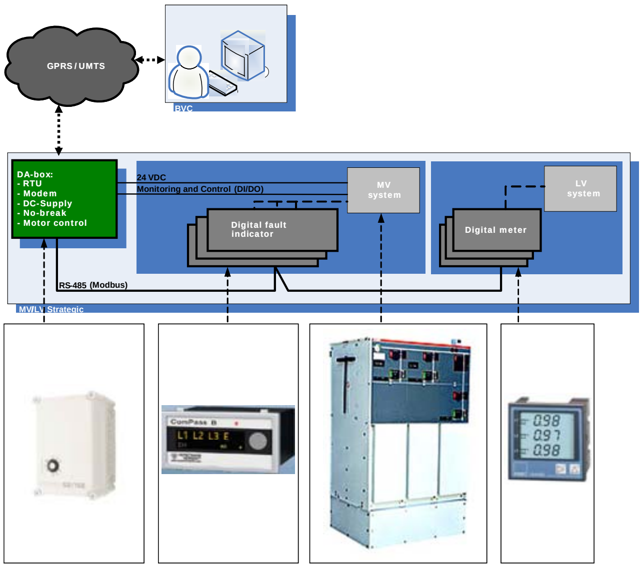


Figure 5. Technical design for MV/LV substation

CONCLUSION

This paper gave a description of the Enexis' DA program focussing on the lessons Enexis learned so far. The most important lessons that have been learned are as follows:

- At this moment almost no specific products for DA are; the existing products have mostly too much functionality and are far too expensive, it are often down-scaled substation automation products
- Life-time is a huge problem; the DA concept at Enexis B.V. has been introduced to reduce the amount of work; care should be taken however that the work-load does not increase because of the limited lifetime of the DA equipment
- Bandwidth is limited; at by far the most locations no high-bandwidth communication such as fibre-optics is available and communication should be done by GPRS or other wireless technique, resulting in a rather limited bandwidth and no optimal connection-characteristic
- Huge diversity in installed based; network operators have a history of 100 years, resulting in a huge diversity in installed base of switchgear, protection etc., giving huge problems for standardisation.

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