Upgrading MV-grids: A compromise between technological development and cost-efficient solutions

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ABSTRACT

Due to the Energy transition and increasing reliability requirements Alliander has stablished a program to upgrade its MV-grids. The strategy is to migrate to a higher voltage level in the MV grids and implement automation in an efficient way. The program involves:

- *Raising the voltage from 10 to 20 kV*
- *Splitting automation and secondary technology from primary technology (separation of concerns)*
- *Developing and implementing automation on an economical viable way. For telecom Alliander rolls out an own telecom network with CDMA technology.*

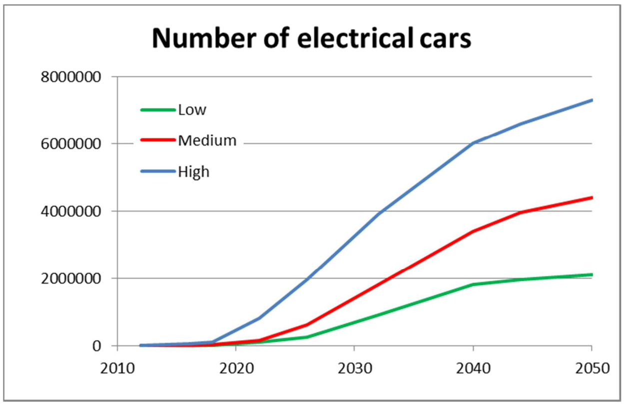

Figure 1. Scenarios for increment of electrical vehicles

INTRODUCTION

Because of the Energy transition and increasing reliability requirements, it has become a challenge to design and operate power grids. Due to their long lifetime and capital intensive assets these grids are not flexible to modify.

Alliander has stablished a program to upgrade its MV-grids. A wide range of experiences have been acquired through a diversity of pilots carried out within this program.

RAISING THE GRID VOLTAGE FROM 10 KV TO 20 KV

Increasing welfare will cause a slow but stable increase of power consumption. Also the energy transition will have significant effects on the power consumption. On the one hand local generation, like solar energy and demand side management can reduce the peak power per costumer. On the other hand electrical vehicles and electrical heat pumps can cause a significant increase in power need per costumer (Figure 1).

For the investment planning, Alliander takes various scenarios for the energy transition into account. Most realistic scenarios will indicate a significant increase of power transmission over the MV-grids. In an extreme scenario the power transport could be doubled over a few decades.

Alliander has a wide 10 kV grid. A large part of the assets has already been in operation for more than 40 years (Figure 2). At this moment still only a small part of the assets are replaced due to natural causes (natural replacement). Main reasons for replacement of the assets and expansion of the infrastructure are quality and capacity bottlenecks. Based on several future scenarios, the expectation is that the combination of aged assets and power increase will cause a high level of grid investments. These investments were reasons to reconsider the voltage level in MV grids. At 20 kV power transmission will be more economic. For that reason Alliander has chosen a policy to migrate from 10 kV to 20 kV.

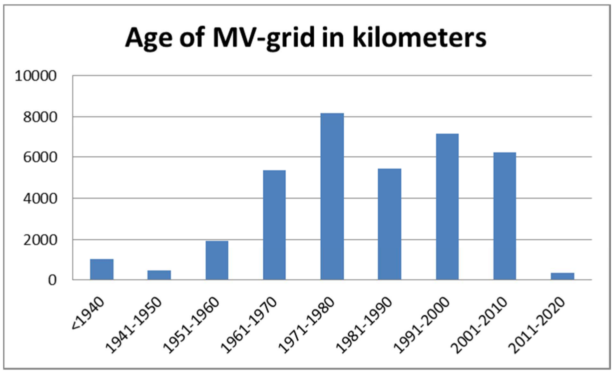

Figure 2. Age of the MV-grid. An increasing part becoming older than 40 years

It's a challenge to change the voltage level on an economical way. In the feeding 150/10 kV substations new 150/20 kV, 20/10 kV and 20 kV switchgears will be installed. Due to limited space in substations smart configurations have been developed to perform the transition to 20 kV step by step. Also in the 10 kV distribution grids smart solutions for the transition have been developed. To avoid premature depreciation the strategy is to reuse/retrofit the existing assets as much as possible. All new components will be rated for 20 kV, also in the grids that will be operated at 10 kV. This will make a smooth transition possible.

Backbones

Robust and completely digitalized 20 kV backbones are being installed all over the existing 10 kV grids to raise the grid's transport capacity and reliability. Along the backbones small digitalized 6 MVA stations will be installed with 20 kV to 10 kV transformation. The existing 10 kV distribution grids can then be connected to these stations (*Figure 3*). Nevertheless, installing these backbones in a significant part of the grid is expensive and takes relatively much time. The stations in the backbones can be seen as a distributed alternative for a 10 kV busbar in a substation.

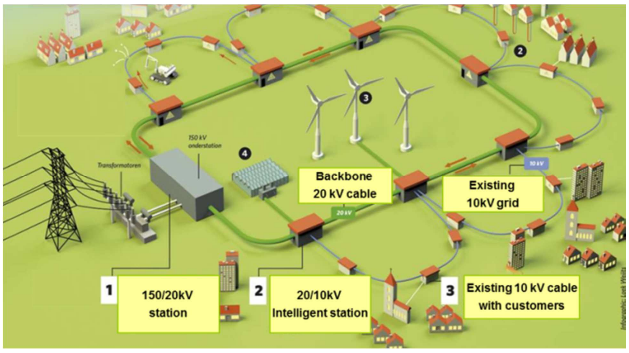

Figure 3. Transition from 10 to 20kV using a back-bone

To make use of the existing assets as much as possible, an extensive research is being carried out to upgrade existing 10 kV XLPE cables to 20 kV. This R&D trajectory has shown that already installed single core XLPE 10 kV cables can be operated at 20 kV. The critical accessories will be replaced by new ones, suitable for higher voltages. Alliander wants to start soon a first project to upgrade XLPE 10 kV feeders to 20 kV in this way. For other assets new research plans are scheduled.

STATION AUTOMATION

In substations and intelligent digitalized MV/MV and MV/LV transformer stations protection, automation and control of primary equipment is essential to manage the grid in a safe and efficient way. With more bandwidth in the telecommunication connections and faster CPU's, more data can be interchanged with the grid control center. The equipment also can be serviced at distance and data can be made available for engineers at the office or at home. The protection, automation and control system in the station has to serve a lot of people with different interests. To manage this at a reliable way, cyber security is a must. With the new techniques, the opportunities have almost no limits anymore.

Separation of concerns

The protection, automation and control equipment can be built in the primary switchgear and therefore already been installed at the factory of the switchgear's manufacturer. This saves cubicles and space. Additionally, with stronger CPU's available one CPU can handle more bays or a complete station. Extreme integration is possible, but the higher the integration, the more complex it becomes. It can result in such a complex Gordian knot that complete projects crash. Therefore Alliander had to reconsider how to make it simple. The solution is to separate the different concerns: instead of integrating systems separation has to be introduced.

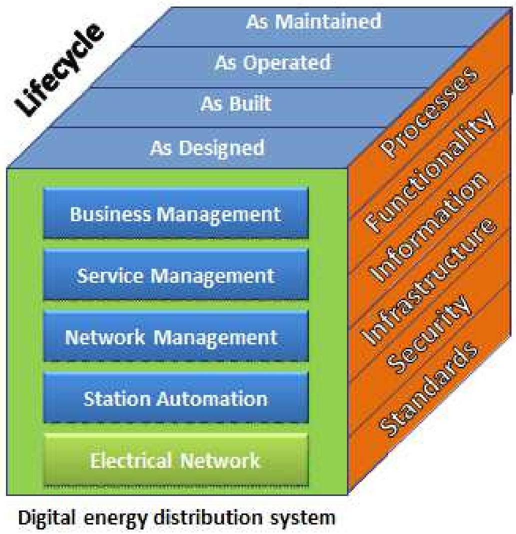

Figure 4. Different concerns

Protection, automation and control equipment will not be integrated in the primary switchgear anymore but will get a place in a separate cubicle. The protection, automation and control terminals in the primary equipment and the terminals or connectors in the protection, automation and control cubicles have been standardized. This also introduces flexibility to the system, by making it possible to renew the protection, automation and control equipment in an easy way when it reaches its end-of- life. To keep it simple, also in the bits and bytes the different concerns have to be separated. Not only in the stations but also in the central servers and systems.

VOLTAGE AND CURRENT SENSORS IN POWER CABLES

Protection, automation, control and metering solutions are connected to voltage and current transformers, to get the information they need from the primary switchgear. These instrument transformers require a lot of material to be manufactured and also a lot of space in the primary switchgear. Furthermore, voltage transformers are a weak point in MV and HV installations. The problems with this transformers are due to over-voltages caused by switching phenomena and ferroresonance. The consequences of exploded voltage and current transformers are well known. In a GIS switchgear an exploded voltage transformer results in a lot of damage and is a really costly event.

With sensor technique a combined current and voltage sensor can be built in one piece into the MV cable termination in the last half meter of the cable, in combination with the elbow connector (Figure 5). This piece is easy to calibrate in the factory and can be installed on site. This easy calibration was the reason for Alliander to start a pilot project together with different manufactures in order to develop and proof a non-conventional-metering chain based on this new sensors.

The sensors are connected to a merging unit. This unit converts the non-standard analog signals from the sensor into standardized output signals, according to IEC61850-9-2LE. This data can be used by a metering system. These standardized signals can not only be used for billing metering, but also for protection, operational measurements, power quality and diagnostics.

In a field trial is shown that non-conventional metering is possible with a relatively simple calibrating process. The difference of a conventional and a non-conventional metering chain is less than 0.2 %.

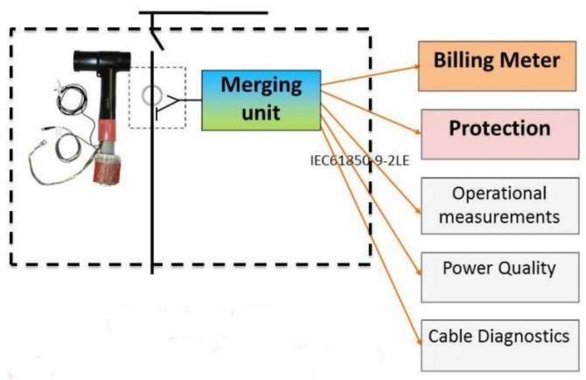

Figure 5. Current and voltage sensors integrated in cable termination

In future this solution must also be applied in HV systems. But prior to this, two topics need to be handled:

1. Improve the calibrating process and perform the type tests in the metrology laboratory.
2. Getting this new billing chain accepted.

A WIRELESS TELECOM SYSTEM BASED ON CDMA-TECHNOLOGY

A significant part of Alliander's program is the implementation of a smart grid. In the MV-grids monitoring and distance control will be installed on strategic nodes in the grids (intelligent MV-stations). Communication between the intelligent MV-stations and the grid control center requires a large data transfer. Besides the applications in MV-grids there are several applications in LV-grids and the smart meters that requires also a large data transfer. For instance, switching the public lighting is now central organized. But customers for public lighting, like municipalities, require more flexible switching so they can adopt the lighting to local circumstances. For this market Alliander is developing a system for flexible switching. This system also will communicate via wireless data transfer.

For power applications data transfer at very high availability and low costs is necessity. To meet these requirements Alliander has decided to implement a separate wireless network communication system based on CDMA-technology (Figure 6). The system operates at a frequency of 450 MHz. At most locations the 450 MHz signal has enough power inside buildings. So in most cases a small antenna is enough, only in extreme cases external antennas are necessary for reliable communication.

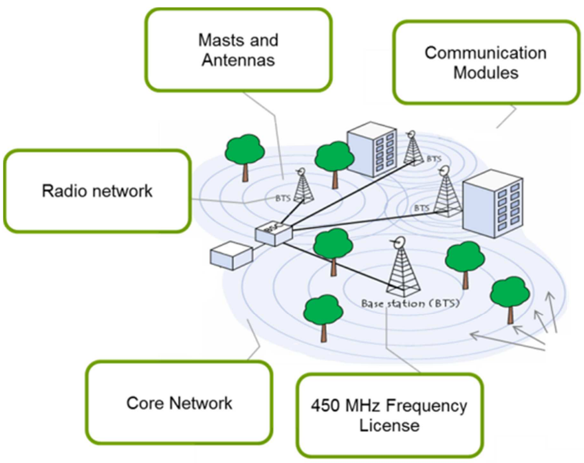

Figure 6. CDMA network

Since a few years Alliander is working on the roll out of the CDMA-network to make wireless data-transport possible. To cover the Alliander area several masts and antennas will be build and commissioned. Local devices, like smart meters and intelligent MV-stations will get CDMA routers.

The CDMA-network is already operational, with limited accessibility. Alliander is working hard to expand the coverage. All intelligent MV-stations will communicate with the grid control center of Alliander through a CDMA-modem. Also smart meters and flexible public lighting will make use of this network.

DIGITALIZED MV/MV AND MV/LV TRANSFORMER STATIONS

Using a 20 kV backbone as already described, more capacity can be introduced in the MV-grid. This creates flexibility because a big amount of power is available not far away from the customer. New customer connections can thus be realized in a shorter time.

Figure 7. Prefab MV/MV substation being placed

Completely digitalized transformer stations are being placed on strategic nodes in the MV distribution grid (*Figure 7*). At this moment the main driver to do so is the target to reduce the yearly average customer minutes lost. With automatic fault location and the ability to control the circuit breakers from the grid control centre, the greatest part of the customers can be re-energized within 5 minutes after an MV (cable) disturbance. Therefore not only new stations are digitalized but also existing transformer stations at strategic nodes are refurbished to get controlled from the grid control centre. By providing transformer stations on strategic nodes with station automation, it is possible to get wider insights on the power flows. This is specially very useful because due to the Energy Transition the energy flow can become bidirectional.

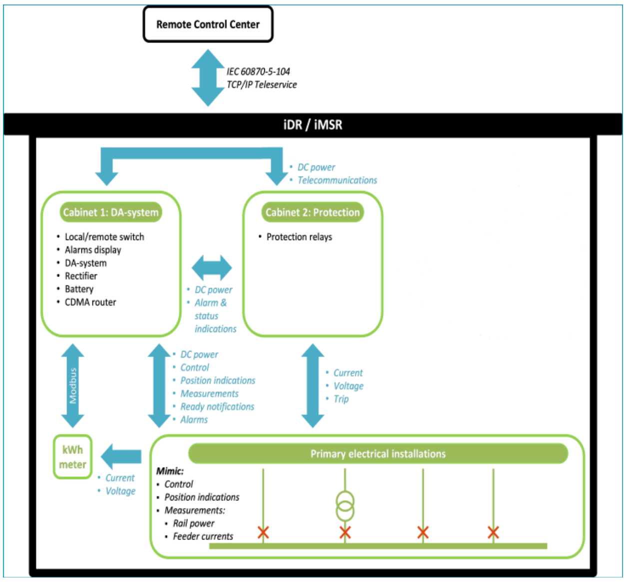

Figure 8. Measuring and control of a modern digitalized MV/MV or MV/LV station. Modular design

Network planning engineers are expected to make efficient use of the existing infrastructure bringing it more and more to the limits before proposing extensions or replacements, such that investments can be postponed. Smart monitoring of the grid together with smart calculation gives support to the network planning engineers to make the right decisions. A step further into making this concept smarter is not measuring in conventional stations anymore, but calculating the currently measured values from profiles which can be fed from measurements in the digitalized transformer stations. Together with data from the intelligent meter and for instance weather stations the calculations can become so accurate that real measurements become more and more superfluous.

CONCLUSION

To upgrade the MV-grid Alliander continues to develop solutions according to a strategy focused on low social costs, simplicity and careful risk assessment. Migration from 10 kV to 20 kV, an improved station automation concept, current and voltage measurements integrated in the cable terminations, data transfer by means of a CDMA network and digitalized transformer stations on strategic nodes are some of the main examples of the steps Alliander is taking in order to meet the challenges of the energy transition and the increasing reliability requirements from the customers.

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