I-NET, THE REALITY OF AN INTELLIGENT DISTRIBUTION NETWORK

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ABSTRACT

The Smart Grid has become reality in a district of Amsterdam. The Dutch energy network company Liander (part of Alliander) has made a serious commitment to the smart grid. Among the ambitious initiatives to bring intelligence to the network one is a project called i-Net that set out the objective to reinforce and automate their medium voltage grid.

Liander started implementing i-Net in early 2011. Today, its smart grid concept has already successfully been implemented in one district of Amsterdam with approximately 10,000 households being served. The power of Liander's concept lies in the fact that 90% of existing parts of the original grid are being reused making it financially feasible. The network allows for bidirectional operation and provides self-healing functionality as well as automatic fault localization. In the future, Liander plans to roll out the i-Net concept in other areas in The Netherlands aiming to deploy it in about 20% of its service area.

INTRODUCTION

Smart energy and the smart grid are hot topics on today's business agenda. Grid companies have to take a serious look at how to best adjust and upgrade their infrastructure to ensure reliability and cost efficiency of the network both now and in the future. A main driver for change is the increase in distributed generation of energy from sources such as wind, solar, combined heat and power, biomass, local battery storage or eventually even the back-feed of electric vehicles, etc.

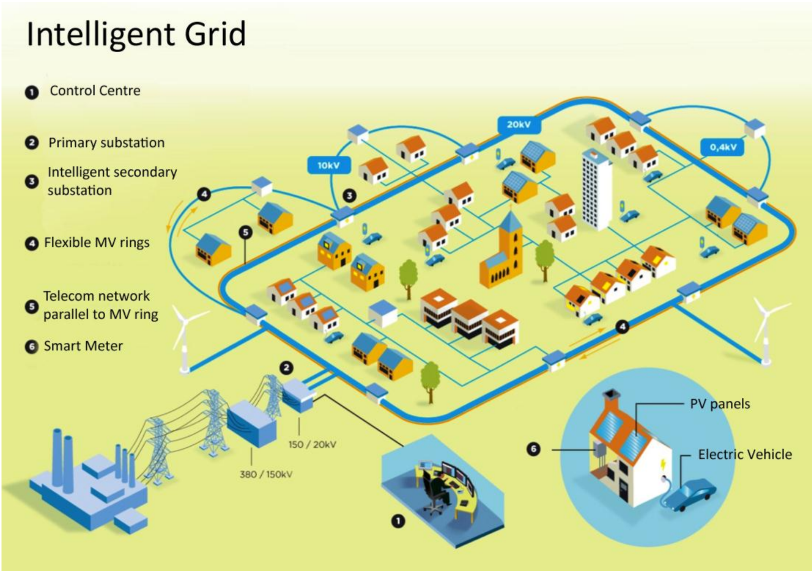

Figure 1: Key components of Liander's smart grid solution include continuous monitoring (1), intelligent substations (2), intelligent secondary substations (3), a bidirectional grid (4), fibre optic telecom (5) and smart metering (6)

The network requirements are changing significantly as energy is being fed into the network at various and variable points as well as times. On top of this, the network capacity has to increase as consumption is expected to continue to rise with a growing number of electric vehicles and electric heating pumps connected to the grid.
With this in mind, energy network company Liander, the largest distribution system operator in The Netherlands, made the decision to go ahead with a smart grid project at the end of 2010. Liander has over 6,000 employees and about 3 million customers and operates a network with 320 primary substations and 40,000 secondary substations. For the first phase of this smart grid project, the utility company picked a central district in the Western part of Amsterdam with more than 10,000 households over 18 km^2 requiring a power supply of 9 MVA. The penetration of smart meters in this area is high and the percentage of homes equipped with solar panels is amongst the highest in Amsterdam.

FULLY BI-DIRECTIONAL GRID - I-NET

Liander developed a rather unique concept to facilitate the upcoming energy transition by introducing a performance improving backbone network on top of the existing distribution infrastructure, named i-Net.
The goal right from the start was to use as much existing infrastructure as possible to enable a compelling business case for the changes. Besides preparing the network for new technologies like electric vehicles and heat pumps, as well as decentralized renewable energy sources, Liander also looks to improve the performance, in terms of a reduction in the number and duration of power outages.
To meet these goals Liander developed a concept whereby the existing 10 kV cables are maintained and connected to a new 20 kV backbone cable. This 20 kV backbone is formed as a ring and connected to the primary substation. The 10 kV cables are transformed into secondary loops: closed circuits that connect back to the backbone via intelligent secondary substations (iDR). This configuration subsequently enables bi-directional energy flow in both 10kV as well as 20kV rings.

To turn this configuration into a true smart grid, it needed introduction of sensors, computers, communication and remote controllable switchgear into the network. Both the primary substations and the secondary stations connecting the 20kV and the 10kV rings had to be made intelligent so that Liander can protect, monitor and remotely control them.

AUTOMATION OF MV SWITCHGEAR

Liander started implementing i-Net in early 2011 as a pilot in four areas for learning the do-and-don't before a full roll-out can be decided upon. For the automation part of the pilot project the SASensor® technology from Locamation is used which is currently also rolled out in all of Liander's HV/MV primary substations. By integrating SASensor products into intelligent distribution substations (iDR - 20/10kV) Liander is creating transparency in the grid.
The goal is to obtain accurate data from the grid, like current and voltage, monitor the power quality and register any faults and create an advanced protection scheme for the newly introduced 20kV backbone.

As part of i-Net, three types of SASensor I/O modules and a control unit have been incorporated into the MV switchgear technology, which was provided by Eaton (SVS and Xiria). The three phase currents of inductive CT's are measured by the Current Interface Module in both measuring and protection range. The Voltage Interface Module measures the three phase voltages supplied by conventional VT's. The Breaker Interface Module enables monitoring and fail-safe switching of the primary equipment. The output of the modules connects to a Central Control Unit (CCU) - a computer that collects the data, processes it and displays it on a LCD touch screen, which can be used for local operation of the complete system.

Thus, switchgear with SASensor technology allows for a wide range of functionality, such as alarm and event handling, protection, all power measurements, revenue metering (kWh measurement), voltage phasor measurements, remote and local control, power quality monitoring and digital fault recording.

ENABLING A SELF-HEALING NETWORK

The successful implementation of SASensor technology into the medium voltage switchgear enabled the creation of a self-healing network. In case of a failure on the backbone in one of the substations, this substation is automatically switched off within seconds. The two adjacent substations take over with customers experiencing almost no disruption at all. This is a vast improvement on the traditional method whereby the utility company is notified through an alarm system in the central control room and customers are without power until an engineer has been sent to the field and identified and fixed the fault.
If there is a disruption in the secondary loop of the i-Net grid (10kV-ring) the protection function in one or both of the feeding iDR's will trip the secondary ring. In de secondary ring about 10-15% of the 10/0.4kV substations are made intelligent and remote controllable with compact switchgear (iMSR). In the pilot Liander used SASensor and Xiria switchgear to prototype the iMSR substation concept. Directly after a fault SASensor will send a digital fault record to the control center where fault localization software will determine the fault location in the secondary ring. The faulty section between two iMSR substations is remotely

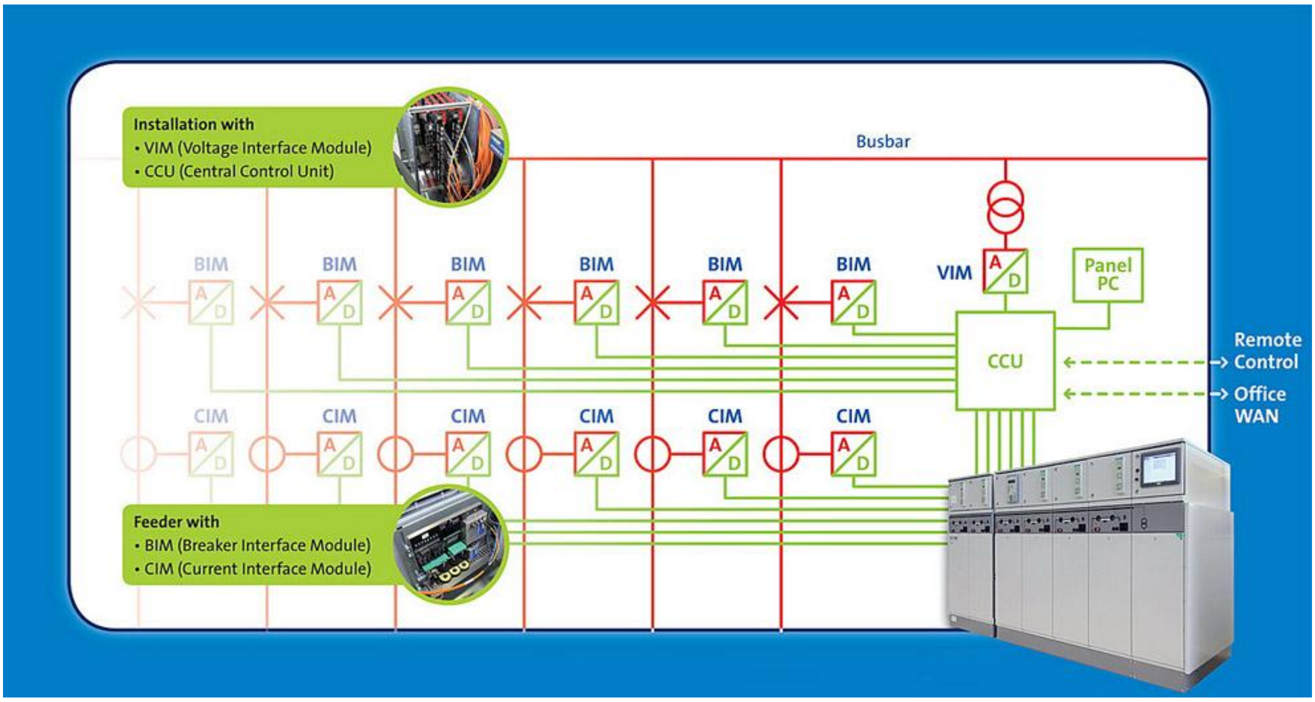

Figure 2: Intelligent Distribution Substation

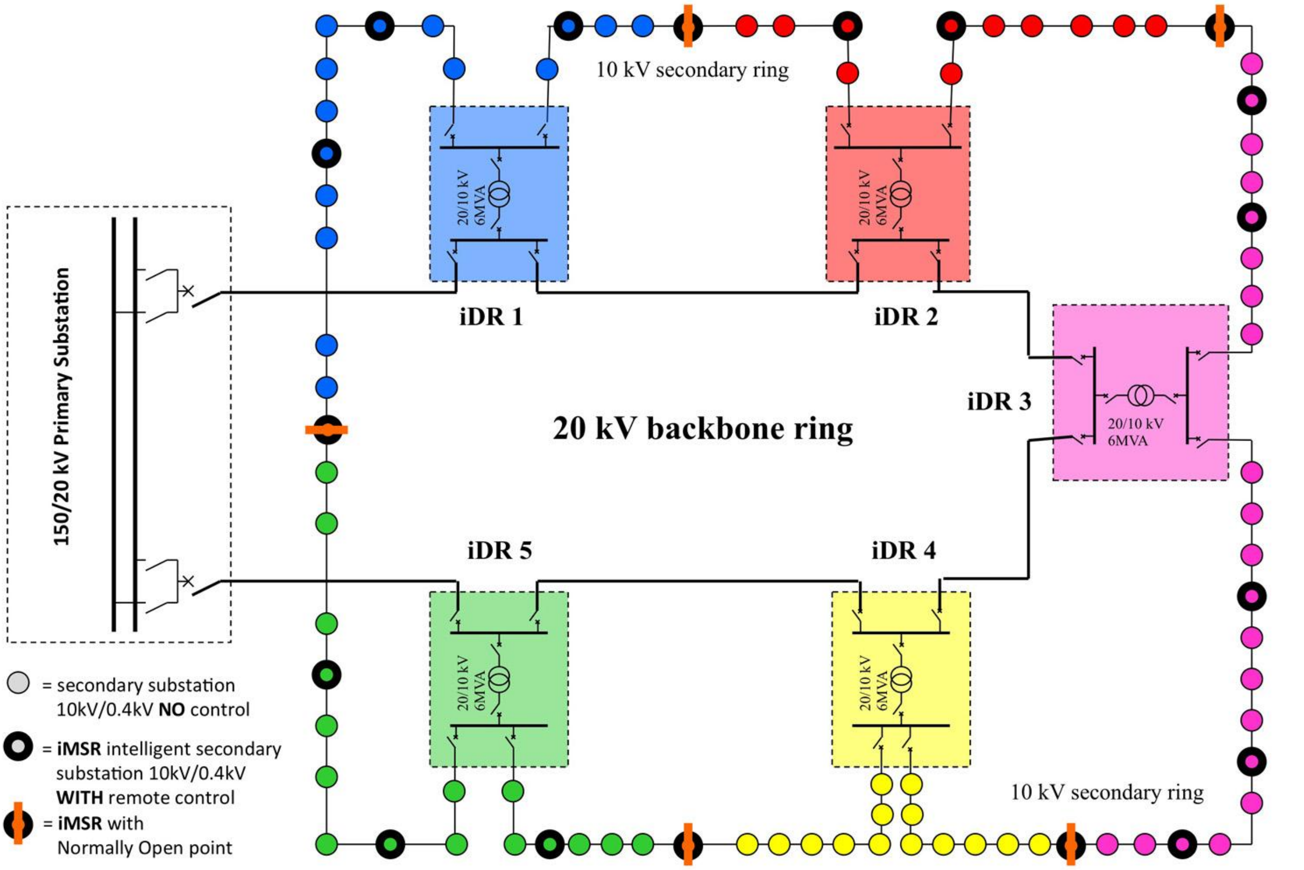

Figure 3: Schematic structure of i-Net with the new overlay of a 20kV ring

isolated and the healthy sections are switch-on directly. In the pilot project the control center operators perform the remote switching, but in future this will be done fully automatically. The isolated section between the two iMSR substation will be inspected manually but with the additional information of the fault location. Manual switching in the secondary substation within the faulty section will isolate the affected cable. The non-affected parts will be powered on remotely after approval of the local personnel.

To allow for sophisticated remote control functionality Liander is also rolling out a new fiber optic network as part of the i-Net project.
The complete functionality for the district in Amsterdam has now been successfully live since June 2012. Liander is pleased with the outcome and in the process of making plans for rolling out the i-Net concept to other areas in The Netherlands, aiming to eventually deploy it in about 20% of its service area.

VOLTAGE PHASOR MEASUREMENTS

At the present moment distribution networks are operated in a radial manner. HV/MV substations are the exchange points with the transmission system. The open points in the distribution rings can be closed to feed the ring from two substations. In big cities the distribution networks are overlaid with either a distribution network of a higher voltage or the transmission grid. Closing of the "normally" open-points might introduce an energy flow in the distribution network which might overload the distribution ring of even violate protection setting directly. So a planned switching operation might result in an outage and customer minutes lost.

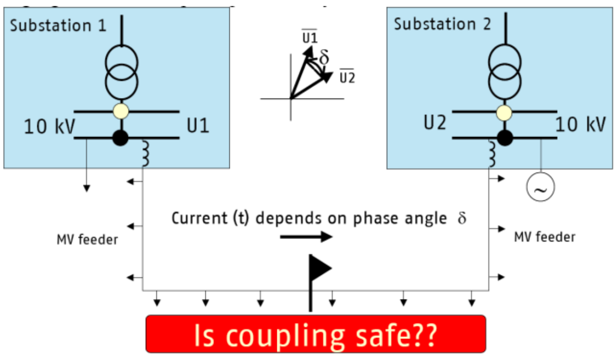

Figure 4: Normal open point closing after checking the voltage phasors

Reliable grid coupling in MV networks

Voltage Phasor Measurement technology in primary and secondary substations in combination with real time load flow calculations to maintain network stability in operation and during switching actions is a solution to overcome the mentioned problem.

All voltage phasors are measured time synchronous. The voltage phasor measurements of MV substations are sent to the control center to enable an application to estimate the equalizing currents in the involved feeders after a coupling is made.

WAN PROTECTIONS

Large penetration of distributed energy resources in the distribution networks will introduce bidirectional energy flows. Distribution protection schemes are often based on different kinds of over-current protection where selectivity is arranged by timing settings. There is common agreement that time selective protection arrangements need to be more advanced. Our society which is more and more depending on electrical energy will demand control of the customer minutes lost due to failures in the network. The capability of automated switching in the distribution network is becoming a requirement to reach this objective. Secondary substations will selectively be equipped with controllable circuit breakers. New protection arrangements are required and some of them might even have to be developed.

In order to solve the future challenges we have to migrate from a centralized way of thinking to a decentralized way and implement distributed control, protection and management solutions that continue to function even when parts of the grid become electrically islanded. The ultimate goal is to prevent outages or islanding of parts of the grid by extreme fast short circuit detection and switching, but 100% reliability doesn’t exist. Smooth degradation in case of any failure with proven backup functions, as last level of defence, is the starting point of the visionary breakthrough we envision to develop.

Fault clearing without outage

It would be nice to clear a fault in such a fast manner that effectively no customer interruption occurs and all decentralized generation remains online. In the Netherlands this means that due to regulations a fault should be cleared ≤ 150ms otherwise the decentralized generation will be disconnected from the grid, i.e. the so-called fault ride through capability. The realization of such an automation and protection scheme will require a serious investment. Besides the protection scheme it requires circuit breakers in all 20kV substations and reliable communication throughout a distribution ring. In the previously described 20kV rings of i-Net a new concept of protection is evaluated. Ring segments are protected by differential protections to clear cable fault in a short as possible time, but before the protections in the primary substations will trip. Only a short voltage dip will occur but no customer minutes lost and the distributed generation will remain online.

CONCLUSION

For the large part, the success of i-Net is based on the fact that Liander was able to reuse existing infrastructure. Here, a relevant benefit was that compact switchgear, like Eaton’s Xiria, was ready for use in fully remote controlled networks and that even though the units are extremely compact, Liander could integrate the automation and protection equipment of SASensor right into the switchgear and did not require a lot of additional space, which is generally very limited in most of the existing secondary substations.

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