NEW FEATURES DURING REFURBISHMENT OF SUBSTATIONS

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INTRODUCTION: ‘THE PAST’

In the beginning of the seventies, Nuon a multi utility in the Netherlands started their digital automation of the high voltage substations and dispatch center. The analog devices that fulfilled the protection, control and communication function were considered to be replaced by digital ones. In the mid seventies an internal workgroup cancelled the considered digital automation of the existing analog dispatch center. The reason was that the digital devices did not meet the dominant items of the automation performance criteria. The automation performance criteria reflected the needs for the high voltage grid that had to be reliable, cost effective and flexible. The digital automation devices at that time could not fulfill the required response times, which affected the reliability of the grid. Furthermore, the analog devices preformed a more reliable and flexible control and communication function and were at that time a better solution to fulfill the grid needs.

End seventies the digital automation discussion was restarted in combination with the introduction of the Gas Insulated Switchgear (GIS) in Nuon’s grid. The life cycle costs of a modern digitally automated GIS substation were expected to be lower than an analog automated open air substation on the breakpoint that the installation exceeded more than 8 bays. And in such a compact installation it was plausible that digital substation automation would bring more flexibility than the old space consuming analog ones.

The first substations were digitally automated by the manufacturers Siemens and ABB. The heart of the Siemens system was the so-called ‘Schaltfehler Schutz’, a control device for every bay itself. The interlocking was made on field level in the schaltfehler schutz of the coupling feeder with stand alone interconnections to the other feeders. The central system embedded even then the communication function in the remote terminal unit of the system. Based on the Sinaut 8 protocol the remote terminal unit (RTU) communicated with the dispatch centre. This protocol was in favor because of its independent bay principle. ABB equipment was at that time much more flexible, and was a derivative from their normal industrial automation program. In one 19 inch box the automation of two or three feeders was implemented! This flexibility however was the reason of a lot of extra effort during installation and parameterization of all the necessary software. In principle it was the choice between flexibility and rigid simplicity.

The combination of GIS substation and digital automation has given us a lot of knowledge about the earthing principles and EMC. Special attention of the earthing was necessary to avoid problems during operation of circuit breakers and switches. Mid eighties the digital protection devices for 150 kV installations were introduced in the grid. Now, more than 15 years later, in 2003, we may conclude that these devices work more reliable than the old analog ones. To accomplish this, special attention given to the EMC earthing is vital. In case a digital device shows strange errors or is malfunctioning, it is in general caused by an imperfect earthing!

After these successes the digital automation of the analog dispatch center was started in 1987. In Arnhem, Nuon built a Siemens automation system based on the automation of a Boeing 747 of that time, composed of three super fast real-time Gould computers. One computer in operation, one hot stand by and one cold stand by. The whole project lasted 6 years and came in service in 1992.

Photo 1. The fully renewed Nuon control room
With 3 x 7 matrix video wall

In 1999 the digital automation of the dispatch center was renewed to an ‘open architecture’ system. The cost of this renewal was about 30 % less then the costs of the first automation seven years before and therefore perfectly met our criteria of cost effectiveness. Even the flexibility was hereby increased with new features and more commercial possibilities. Meanwhile, nine new substations were digitally automated.
After 18 years of experience, we may conclude that high voltage substation automation did not result in the expected credits. The digitally automated substations are outdated and less flexible. The digital hybrid automation extensions for one added bay are in general more expensive than the refurbishment of the whole automation due to digital incompatibility of the new components, boosting the cost with communication adaptors. Also the maintenance costs of the automation are too high due to the numerous breakdowns of the circuit boards. The technical lifetime of the primary components is 75 years. Considering the 15 year lifetime of the automation, this automation has to be refurbished at least 5 times. In short, high voltage substation automation was not cost effective and inflexible! Therefore Nuon started focusing bottom up, concentrating on low and medium voltage automation.

MEDIUM VOLTAGE AUTOMATION:
‘THE PRESENT’

At this moment many Nuon substations have to be upgraded with new protections, controls and innovative medium and high voltage features. When this refurbishment is performed using the common technology, it would result into a disaster, both technical and economical. The common technology is too expensive, not only because of the very high investment costs but also the necessarily investments every 15 years, for updating the secondary installation.

At the end of the nineties this was the trigger for Nuon to focus on the automation possibilities in the medium and low voltage grid and no longer at the high voltage grid. Despite the fact that the medium voltage is a totally cabled, seventy percent of the outage time of a consumer is caused by medium voltage faults. In order to reduce this outage time Nuon focused together with ABB on digital fault location. The results were published during the Cired of Nice in 1998 [1]. We proved that it would be possible to reduce the average outage time of a medium voltage failure in our grid from 90 to 60 minutes. For the total outage time per year for consumers, this would result into more than 25% reduction, from 30 back to 22 minutes per year.

To accomplish this, the fault impedance is calculated automatically from the digital measured voltage and currents of the faulted feeder. This calculation is performed in the in the central control room. Within 5 minutes after the occurrence of the fault, the control room knows the location of the failure with an accuracy of less than five hundred meters [2]. Because of the distance between MV-houses, this accuracy is more than sufficient to know where to start switching for network restoration. So in the future our skilled worker may transfer from ‘failure-solver’ to ‘fast-switcher’. When within 10 years the fault locator tool is implemented in every substation, Nuon will have less risk and may have skilled workers with less experience and education. So in the future, Nuon operate its MV grid with less effort. To realize this dream we started with a pilot project in substation Zaltbommel. Figure 1 shows our basic ideas.

After 1.5 year of cooperation with GE from Calgary Canada and ‘Phase To Phase’ from the Netherlands we succeeded the implementation of an innovated digital automation system in the substation of Zaltbommel in February 2003. This automation system provides the medium voltage power grid protection, control and diagnostics as well as the remote communication. It was based on the philosophy of lower costs and as little as possible linked independent devices. The system was composed of the devices as given in figure 2.

Figure 1. Nuon’s medium voltage automation at the start

Figure 2. The GE solution: One D25 as control & protection device for 3 feeders

The GE HARRIS Power link D20/D200 RTU provides the communication function for the remote control of the whole substation. It is used for the
local controls, remote diagnostics, remote communication and local diagnostics. A major step has been made by the use of the D25. This device integrates the functions of the local protection and control for three feeders in one box. The main feeder protection is a Siemens 7SJ600 maximum current/time device. Inside the D25 three protections for three bays is used as backup. This is the first time, that in a control unit three maximum current devices for several feeders where implemented. Both protection and control are no longer unique boxes, but only a software piece inside a device. This solution was gained after intensive debating sessions with the GE protection department.

Another function of the D25 is the continuous registration of the currents and voltages with 64 samples per period. This information is used for fault location and protection functions. The D25 boxes are linked with a standard Ethernet bus to a local area network.

THE FUTURE SUBSTATION AUTOMATION

In our ideas, the substation of tomorrow has only one computer device in which all the functions are concentrated.

![Substation central computing system](image)

**Figure 3. Tomorrow’s substation computer**

In Zaltbommel maximum current protection functions for three feeders were embedded into one device. In the future all protection, all of the controls and diagnostics of the whole substation will be implemented in just one computer. This computer will be able to work with a standard operating system. This computer communicates with the standard software tools of the manufactures, by means of a kind of an abstraction layer. Replacing the substation computer by a newer one with a total other operating system can simply be put together in one device which provides no longer energy of 10 VA or 100 VA but only a continuous bit stream to the bus. There is no longer a difference between a measuring coil and a protection coil. There is no longer a need to have several types of coils.

A simple calculation learns, that more than 200 life 50 Hz signals with a sampling frequency of about 5 kHz will not occupy more than 10% of the bus capacity, of a normal cheap substation bus of 100 MBits / sec. When we want to have the current from for instance a HV feeder we simply ask the computer for the specific IP address, and we have it.

A lot of innovations are required to make these dreams come true. The future substation system can only work with intelligent primary equipment. All apparatus, power transformers, voltage and current transformers, switches and circuit breakers have to become intelligent. All of them will get there own typical IP address. Besides the 110 volt supply, a glass fiber will be the only connection to the substation communication bus. A circuit breaker will become intelligent by implementing for instance a D25 in its connection cabinet. The protection people have to become familiar with the fact, that the “out” signal is no longer sent over a copper wire but directly via the bus. When two separated ‘outs’ are required, we only need to give such a breaker two IP addresses. The moment that this is accepted, there is no restriction for the distance between central computer and the circuit breaker, nowadays 250 meter in an open air field. The current and voltage transformers can simply be put together in one device which provides no longer energy of 10 VA or 100 VA but only a continuous bit stream to the bus. There is no longer a difference between a measuring coil and a protection coil. There is no longer a need to have several types of coils.

The future substation is shown in figure 4.

![Figure 4. The future substation](image)
Nowadays, the power transformer in America is already intelligent. They put for instance a D25 in the connection cabinet for all the transformer diagnostics. The same D25 which gives an idea about the amount of dissolved gasses in the oil is also used to regulate the tap changer.

In this way the costs of the secondary installation will be reduced to only a few hundred thousand euros. The substation is also very flexible. When after 10 years such a substation has to be extended with for example another power transformer, the only requirements are two new central computers in the substation, a few new connections to the substation local area network and you are done! Life will become easy for future engineers.

THE FINAL PUZZLE

The automation of the substation is only one piece of the communication puzzle. Within Nuon there is a project to connect all substations in a communication grid. The connections have a rate of more than 2 Mbit/sec and are made from either copper or glass fibers. In every substation we will install an ABB Fox 515 to be ready for the future. Photo 2 gives an idea of such a communication cabinet from ABB.

Photo 2. The Fox 515 in a ‘19 inch’ cabinet

Furthermore the last two years Nuon has performed a lot of tests with “internet” via the “hot” low voltage wires to the sockets in the home. Our conclusion after this two years experiment is, that internet via power line carrier (PLC) is possible, but requires substantial investments. The competition with ADSL, Cable and ISDN is very tough, and also the price will never be much lower than the others. Nuon is not sure to continue this experiment, due to financial risks.

Nuon is now performing tests on how to communicate with PLC on one phase of our medium voltage grid. It operates in the CENELEC EN 50065 A-band PLC of about 100 kHz. We have seen that we can bridge a distance of more than 12 km with about 10 medium voltage houses in between without the use of amplifiers or repeaters. This opens the possibility to communicate with every house as shown in figure 5.

![Figure 5. The future communication to the customer](image)

With this system everything we want is possible. We can perform automatic meter reading with PLC technology, distribution management information of the grid, outage time registration of every client, an exact registration of the power quality at every customer, switching streetlights and switching all our electrical boilers in the houses etc. When every medium voltage house is equipped with this kind of low and medium voltage PLC technology all types of signals registration are within reach. Also the gas-pressure measurement in our gas-grid is possible.

One thing has become clear; the next 10 years will be exiting for everybody who works in our business. In the past it was possible to focus on one specific problem at a time. Nowadays everything has to do with everything and so decision making has become rather complicated.
