Training simulator reduces outage time

A new hardware training simulator is in use at the new training center for protection, automation and control equipment.

Training Simulator Reduces Outage Times

Enexis employs simulator to train outage crews to improve network reliability and reduce restoration times.

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As a result of increasing electrification and the vast increase in automation and information technologies, society is demanding a more reliable supply of electrical energy.

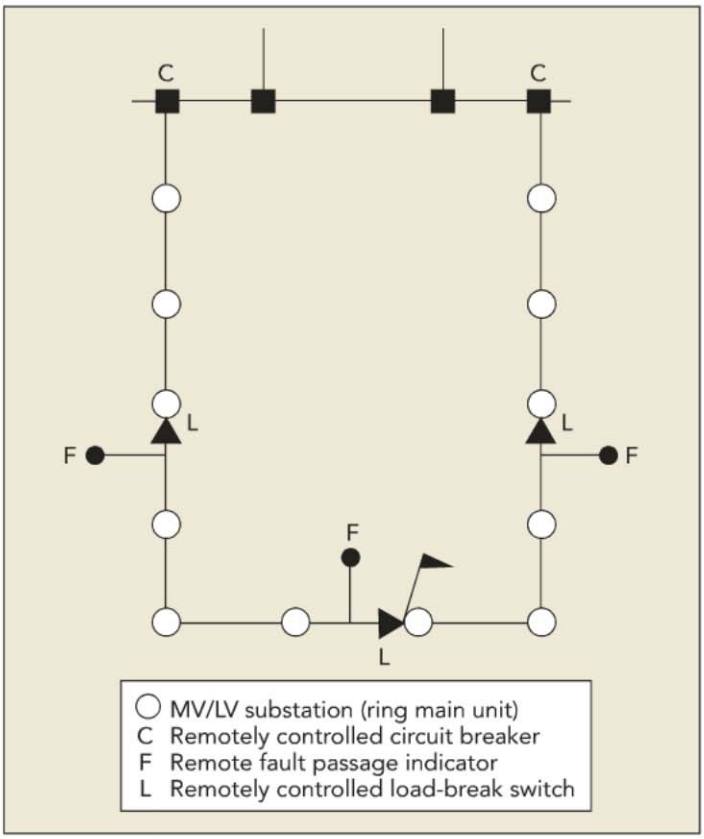
Developed in the 1950s and 1960s, the distribution networks are becoming time-expired, which may result in an increasing number of faults and the need to replace network components. The load on the distribution network is fluctuating more (because of heat pumps and electric vehicles, for example), which may result in higher stress on components. Networks are becoming smarter and, therefore, less predictable, making planning and operation of the network more complex. With the focus on renewable energy sources, an increasing volume of renewables, such as wind turbines and solar panels, are being integrated into distribution networks.

Although the reliability of distribution networks is high, faults can occur, resulting in a section of the network being disconnected. Currently, restoration of supply is often undertaken manually. On receipt of customer messages, outage crews are dispatched to the area where customers are without power. Based on information available from trip indications on protection relays and short-circuit indicators, the outage crews locate the component that failed and restore supplies to the healthy sections of the network. The failed component is repaired or replaced, and normal network configuration is restored.

The reduction of outage time has always been one of the main goals of network operators. Increasing dependency on a stable and secure supply has made this goal even more important; therefore, fast and efficient restoration in the event of a fault is critical. Network operators are applying different technologies to achieve this goal. Enexis, which operates the medium-voltage and low-voltage networks in the north and south of the Netherlands, has invested in several solutions for faster and more efficient fault restoration, such as the application of distribution automation (DA) and the continuous training of its outage crews.

Distribution Automation

DA can reduce the outage time and number of customers



The Enexis distribution automation concept, with its ring-shaped network split into four sections, is remotely controlled with circuit breakers and load-break switches. The load-break switch with the flag is open under normal operating conditions.

Enexis Distribution Network Statistics	
Length of the low-voltage network (400 V)	90,800 km (56,421 miles)
Length of the medium-voltage network (10 kV and 20 kV)	44,300 km (27,527 miles)
Number of customers	2,667,000
Energy consumption	17,470 GWh
Geographical area	About 40% of the Netherlands (in the north and south)

affected by a fault outage. Therefore, in 2011, Enexis started a large-scale rollout of DA in its medium-voltage networks, which include only underground cables. With DA, sections of the network can be restored remotely within a few minutes, instead of more than an hour, as is the case with manual restoration.

As soon as a fault occurs, the circuit breaker will disconnect the feeder. In a conventional situation, the fault first had to be located and isolated manually. When this was done, power supply to the feeder could be restored. With DA, the load-break switches (ring main units) and circuit breakers 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 customer minutes lost.

Since the rollout of DA in 2011, some 1,000 distribution substations have been automated. Initial results show the ef-

The original hardware simulator used for training outage crews was a 110-VAC network that included the most common protection relays used by Enexis so that single-, two- or three-phase faults could be simulated.

fectiveness of this strategy is even better than the utility expected. In the coming years, Enexis will continue its rollout of DA. It is expected more than 50% of the utility's distribution network will be controlled with the DA concept by 2020.

Outage Crew Training Program

While the rollout has started, DA is not yet available for the largest section of Enexis' distribution network. Although DA enables remote switching, the restoration process still requires some manual input. Therefore, to improve the efficiency of manual operations required in the restoration process, Enexis started a large-scale training program in 2011 to enable outage crews to restore outages faster and more efficiently. Currently, the scope of the training is limited to the medium-voltage network, as most of the customer minutes lost are caused by outages on this section of the network.

The outage crews received specified training goals:

- During the restoration of a fault, close cooperation between the outage crews and the network operators in the control room is required.
- Network operators all have their own procedures for outage restoration, and it is important outages crews know these procedures in detail and apply them.
- In the process of finding the location of a fault, interpretation of the indications on protection relays and fault indicators is important.
- Distributed generation has an impact on the flow of fault currents in the network and, therefore, also has influence on the indications given by protection relays and fault indicators.
- The number of substations with DA is steadily increasing, and outage crews have to understand the principles of DA and how it interacts with the manual fault restoration.

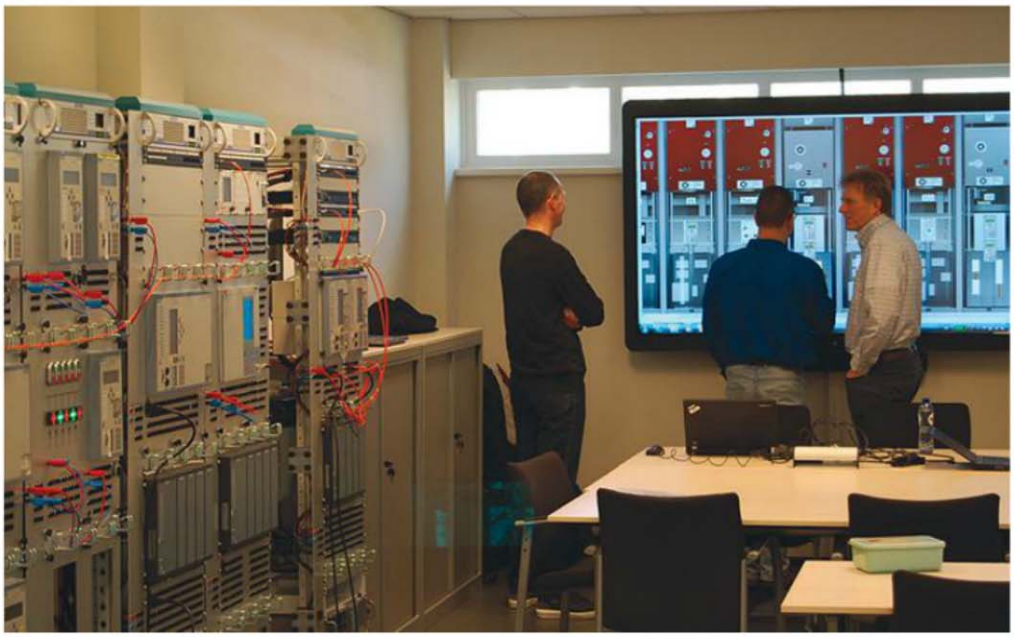
To meet the training goals, the two-day training program consists of five courses:

1. *Characteristics of distribution networks.* The outage crews must be familiar with the medium-voltage distribution network and, in particular, the earthing principles of the network. This helps the crews to determine the magnitude of single-phase earth-fault currents. Equally important is the impact of distributed generation on the network, as this might result in incorrect operation of fault indicators.
2. *Distribution network protection.* Faults in the distribution network will be isolated by protection relays. Therefore, it is important for outage crews to know the basic principles of protection relays, the protection philosophy and the combination of protection relays that provide the protection of the complete distribution network.
3. *Training with hardware simulator.* Following the first two courses, participants receive practical exercises to apply the knowledge gained.
4. *Outage restoration.* Network operators always have certain agreements and procedures for the process of outage restoration. For example, important issues are the responsibilities of the operators in the control center and the outage crews outside, the information exchange between them and the order in which the substations are visited, respectively.
5. *Training.* The final step is training with the software simulator.

Outage restoration is one of the key activities of network operators. Therefore, it is important to train outage crews continuously. Enexis has decided its outage crews must repeat the training program every four years, and courses are continually updated and adapted to include the changing important issues.

The training program started in 2011 with a basic training period of two days and was given to some 250 staff members of the outage crews. Now, every year, 60 to 80 staff members of the outage crews receive a two-day repetition course in groups

of eight to 12. The training is delivered by a team of two to three trainers. All new outage crew staff members must take the basic course first, followed by repetition training courses every four years afterward.



The most recent crew training session is discussed among the operators who conducted the training. The software simulator, which is key to the fifth step of the crew training, is located on the back wall and the hardware simulator is on the left wall.

Hardware Simulator

The hardware simulator is designed to include several of the most common protection relays used by Enexis and a network model of a medium-voltage network. The 110-VAC network comprises several discrete components that make it possible to simulate single-, two- or three-phase faults on several locations in the network. Protection relays connected directly to this network (without current and voltage transformers) will respond to the fault current and operate accordingly. Based on the indications given by the protection relays, the participants have to identify the component (either a cable or a substation) that contains the fault.

The simulator is built in such a way participants are only able to visit one substation at a time, just as in reality. This trains them to register what they have seen in a substation before they go to another one. The usage of the hardware simulator has proven to be quite effective, as even the well-trained outage crew members report this form of training with the simulator is both useful and instructive. In the spring of 2015, two new training centers for so-called protection, automation and control equipment were put in operation at Enexis. These new centers have a new version of the hardware simulator installed that offers greater flexibility. Faults are no longer simulated in a 110-V network with discrete components but rather with test equipment from OMICRON or similar devices.

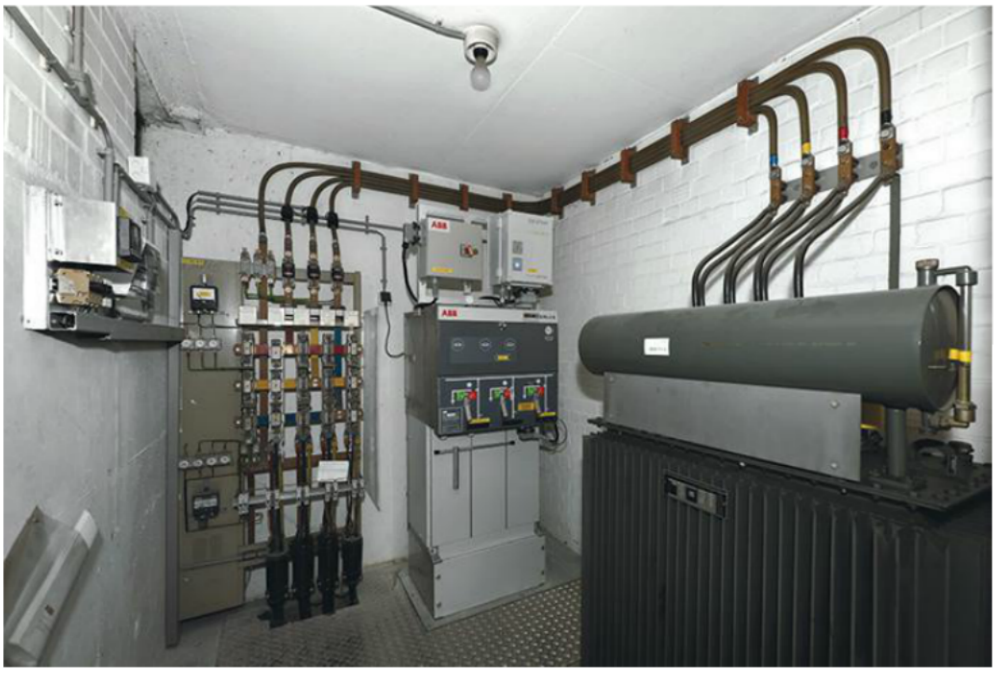
Software Simulator

The software simulator is based on the Vision Network Analysis program developed by Phase to Phase, which is widely used in the Netherlands. The advantage of basing the simulator on Vision is all Enexis' MV network models are available already in Vision. The program has a special training environment in which a fault can be introduced in the network model, resulting in a fault for which the protection relays and fault indicators show the same indications as they do in reality.

Based on the messages received in the control room, outage crews have to start the restoration of the fault by visiting substations, interpreting the indications on the protection relays and taking all actions needed to restore power. During the simulation, a clock is recording the time the outage crew takes to restore power.

As a starting point, an overview of the network is given that has no information on the position of the fault. Following the training, participants receive messages related to the fault from protection relays that have tripped or from customers who are without power. Using this information, they have to decide how they will start restoration of the network in a section where the substations can be controlled remotely. This is common for most high-voltage/medium-voltage substations and also for substations equipped with DA. The simulator offers the possibility to switch them remotely, just as it is done in reality from the control center.

However, the majority of substations are not subject to remote control and, therefore, require a substation visit. During the simulation, all time taken to visit subsequent substations is recorded, so it is important participants select the correct sequence to reduce their time and, depending on the infor-



This is a typical Enexis medium-voltage/low-voltage indoor substation that includes a MV/LV distribution transformer, MV switchgear and a LV distribution board that has been upgraded to include distribution automation.

mation received, visit some substations equipped without DA. Normally, the information from the substations with remote control is analyzed before a decision is made on which substation to visit. In most cases, this will be a substation with protection relays, as they often provide useful information on the type and location of the fault.

A medium-voltage switchgear installation equipped with distribution automation and protection relays, showing different relay and switchgear indications.

The simulator provides the outage crew with a photograph of the substation they visit and, on entering, an overview of the switchgear installation, with all position indications and also the indications on the protection relays. By touching a protection relay, it is possible to receive more information.

In the substation, several actions can be performed, such as operating circuit breakers, voltage detection and integrity testing of cables. In this way, outage crews demonstrate they understand how the different types of switchgear have to be operated. As safety is always of utmost importance, crews also can show they understand the safety procedures and act accordingly.

When participants indicate they have performed all the necessary actions and all customers have been reconnected, the simulation is complete. Participants then receive an overview of all the actions executed, mistakes that were made, the time required to complete the simulation and whether all customers were re-energized. This report is then discussed with the instructor to highlight where improvements could have been possible in the restoration procedures.

Enexis has developed this outage restoration training program to enable its crews to restore fault outages in the fastest, most efficient and cost-effective manner. The key and most important element of the training program is the software outage simulator, which can continuously replicate all types of fault outages and record all steps taken and the time to complete the process of outage restoration. TDW

Acknowledgement

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