SIMULATOR FOR TRAINING OF OUTAGE CREWS

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ABSTRACT

Reduction of outage time is one of the major goals of network operators. One way to reduce the outage time is to train outage crews in fast and efficient outage restoration. This paper describes a training program for outage crews set up by Enexis, one of the major distribution network operators in The Netherlands. The most important part of this training is given with two simulators, both a hardware version and a software version. This paper describes the whole training that has been set up, with special attention to the application of the software simulator.

INTRODUCTION

Society is becoming more and more dependent on a reliable supply of electricity. Reduction of outage time is therefore one of the major goals of network operators. The reduction can be achieved for example by automation in the network, but also by training the crews that have to perform the restoration of the network after occurrence of an outage.
For fast restoration of a fault, especially indications given by protection relays (which relays picked-up, which gave a trip, is it an earth-fault or not, etc.), and short-circuit indicators are important. Many people involved in the outage restoration process find it difficult however to correctly interpret these signals and to use this information during the process of outage restoration. As a large part of the older employees, with a lot of experience, will retire the coming years, it is increasingly important to train employees, to guarantee a fast and efficient restoration of outages.

This paper will describe a training that is setup by Enexis, one of the major distribution network operators in the Netherlands, to train its outage crews. After a short discussion of different methods to reduce the outage time, the paper first a description is given of the main goals that have to be reached with the training for outage crews. It will continue by describing the content of the training and the planning of it.
The main focus point of the training is to use the information given by protection relays and short-circuit indicators for fast restoration of the outage. Therefore two outage simulators have been developed. Both simulators will be discussed in in two separate chapters.

The first one is a hardware simulator. It contains a network model in which a fault can be made. Protection relays will give the same response to the fault as they would do in reality. In this way people can get more familiar with the protection relays and their response.

The second one is a software outage simulation tool, based on the network analysis program Vision of Phase to Phase. It contains network models in which a fault can be created, and next the crew has to take all the steps that are required to find the faulted cable section and restore the power. Realistic representations of the response of protection relays and short-circuit indicators are given. The paper describes the different steps that have to be made with the outage simulator, to find the fault and to restore the power.

REDUCTION OF OUTAGE TIME

As mentioned in the introduction, reduction of outage time is one of the major goals of network operators. The reduction in outage time can be achieved by either reduction of the number of outages or by reduction of the duration of outages.

Reduction of number of outages

Measures that network operators apply to reduce the number of outages are, amongst others, replacement programs for old components, diagnostic equipment that can predict the occurrence of a fault and measures to prevent that cables are hit during digging. Especially replacement of components requires high investments however. Therefore also measures for reduction of the duration of outages.

Distribution Automation

One of the sometimes applied measures to reduce the outage time is the introduction of Distribution Automation (DA) in the network, to enable remote switching of (parts of) the network. In 2011 Enexis started a large-scale roll-out of DA [1]. With this DA, parts of the network can be restored remotely within a few minutes, instead of more than an hour as is the case with manual restoration.
The key concept is shown in figure 1 [2]. 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.

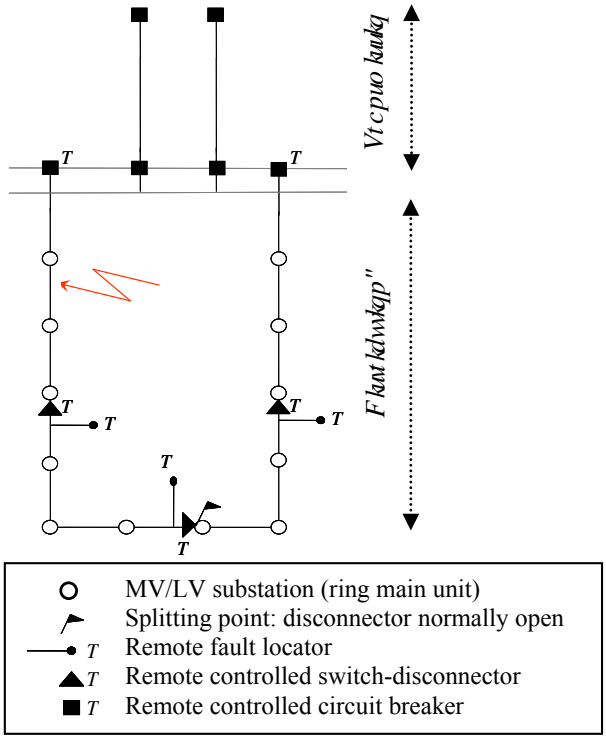

Figure 1: Enexis' Distribution Automation concept

Since the start in 2011, more than 500 substations have been automated. The first results show the effectiveness of the strategy, and are even better than expected. Instead of the 40% reduction in outage time that was expected, in practice it is often even more than 50%.

Training of outage crews

Although the roll-out of DA has been started, still in the largest part of the network DA is not available. And although DA enables remote switching, still a part of the restoration process has to be done manually.
In order to improve the efficiency of the manual part of the restoration process, Enexis started a large-scale training program for its outage crews to help them to restore outages faster and more efficient. This training program will be described in the following chapters.

TRAINING PROGRAM

In this section an overview of the training program for the outage crews is described. First the training goals are given, followed by a description of the courses that are given and finally the planning of the courses.

Training goals

With the training of the outage crews the following goals have to be achieved:

- Learn outage crew to follow the procedures that have been made for outage restoration;
- Improve cooperation between outage crews and network operators in the control room;
- Learn outage crews to interpret indications given by protection relays and use this information during the outage restoration;
- Show the impact of distributed generation in the network on indications of protection relays and fault indicators, to avoid wrong interpretation;
- Introduce the increasing application of DA and learn how this influences the restoration process.

Content of training

The content of the training is based on the goals presented in the previous chapter. The two-day training is build up with the following courses:

- Characteristics of distribution networks
- Distribution network protection
- Training with hardware simulator
- Outage restoration
- Discussion of outages
- Training with software simulator

Characteristics of distribution networks

First of all the outage crews have to be familiar with the distribution networks. After a short overview of structure and components of the network, special attention is paid to characteristics that are important in case of outages. An example of this is the earthing principle of the network. This will determine how large earth-fault currents are. It is important that outage crews are familiar with this, in order to be able to understand the response of protection relays and fault indicators, in case of a single-phase fault. Also important is the impact of distributed generation in the network. This might result in incorrect operation of fault indicators. A final important issue are the fault currents. It is important to know, at least approximately, how large they are and how they behave during a fault.

Distribution network protection

Faults in the distribution network will be switched off by protection relays. It is therefore important that outage crews know the (basic) principles of protection relays and how they will switch off fault currents. Also the protection philosophy, describing the combination of all protection relays for protection of the whole network, is important to understand.

Training with hardware simulator

After the first two courses, the participants start with practical exercises to apply what they have learned in the first courses. This is done with the hardware simulator,

which will be described in more detail in the next chapter.

Outage restoration
Network operators always have certain agreements and procedures for the process of outage restoration. Important issues are for example the responsibilities of respectively the operators in the control centre and the outage crews outside, information exchange between them, but also which of the substations will be visited first. Although those procedures are known, the course can be used to refresh this information.

Discussion of outages
An important part of the whole training is to discuss a number of outages that have occurred in the previous years. They can be used as practical cases to discuss how an outage can be cleared in the fastest and most efficient way, and also to learn from possible failures that have been made in the past. Both relatively 'simple' outages and very complex outages are discussed.

Training with software simulator
The last step is the training with the software simulator. In this simulator all items that have been discussed will come back and participants can exercise with the simulator. The simulator is described in more detail in a next chapter.

Planning

As mentioned before outage restoration is one of the key activities of network operators. Therefore it is important to train the outage crews continuously. Therefore a schedule is made such that the outage crews have to redo the training every four years. The training as described in this chapter is the basic training with which outage crews start. After they have finished this course they have to follow a repeating course every four years. This course is modified every four years, such that it can be adapted to issues that are important at that moment.

HARDWARE SIMULATOR

During the first day of the course, the participants work with the hardware simulator for half a day. The hardware simulator contains a number of the most common protection relays that are used at Enexis, and a network model of a medium voltage network. In this network faults can be made, and the protection relays will respond in the same way as in reality. Based on the indications given by the protection relays, the participants have to find the component (either a cable or a substation) that contains the fault. The simulator is build up in such a way that they only can 'visit' one substation at a time.
The original simulator, originally developed in 2001 and modified in 2011, is shown in figure 2 (partly).


Figure 2. Part of the original hardware simulator

In 2015 a new training centre for so-called PAC-equipment (Protection, Automation and Control) is put in operation at Enexis, and therefore the old hardware simulator has been replaced for a new one. A part of it is shown in figure 3.


Figure 3. Part of the new hardware simulator

SOFTWARE SIMULATOR

Besides the hardware simulator also a software simulator has been developed. It will be described in this chapter.
The simulator is based on the network analysis program Vision of the company Phase to Phase, which is widely used in the Netherlands [3]. It has the advantage that models of all medium voltage networks of Enexis are available already in Vision. In the network model a fault is simulated and afterwards the crew has to take all the steps that are required to find the faulted cable section and restore the power. Realistic representations of the response of protection relays and short-circuit indicators are given. During the simulation a clock is counting the time that the employees need to restore the power.

Different stages of fault restoration

As a starting point, an overview of the network is given. An example is given in figure 4. In this network file it is not possible to see where the fault has been made. After starting the training, the participants receive messages that are related to the fault. For example from protection relays that have tripped or from customers who phone that they are without power. See figure 5.

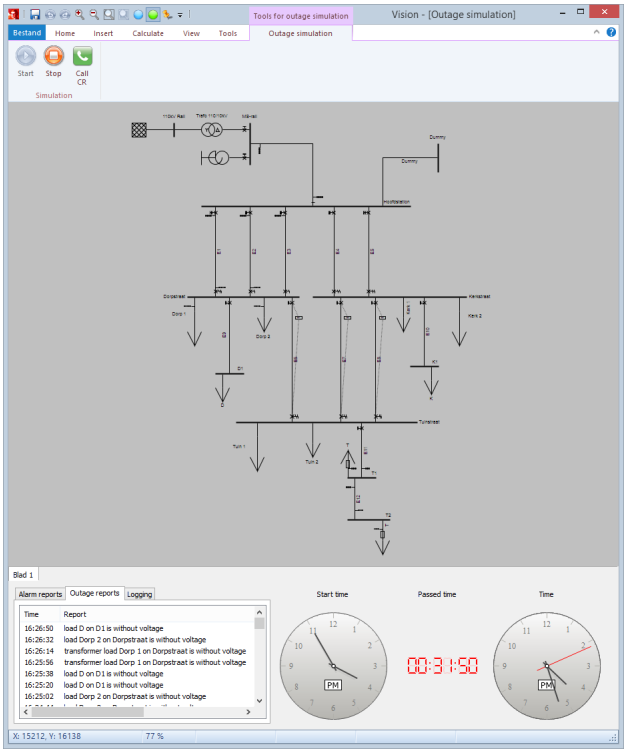

Figure 4. Network overview

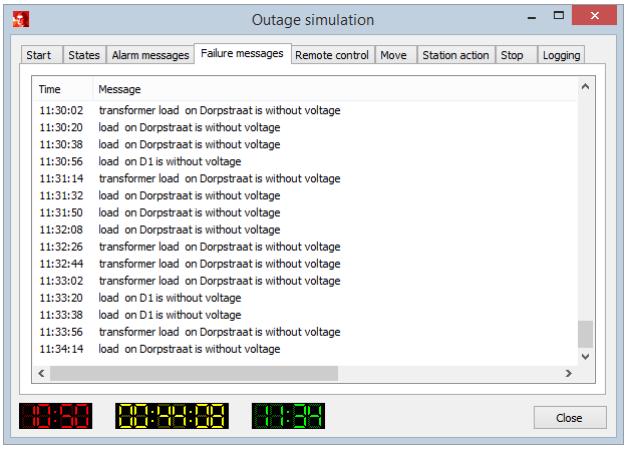

Figure 5. Messages

Some substation can be controlled remotely. They can be accessed in the simulator to switch them remotely. An example of the window in which this can be done is shown in figure 6.

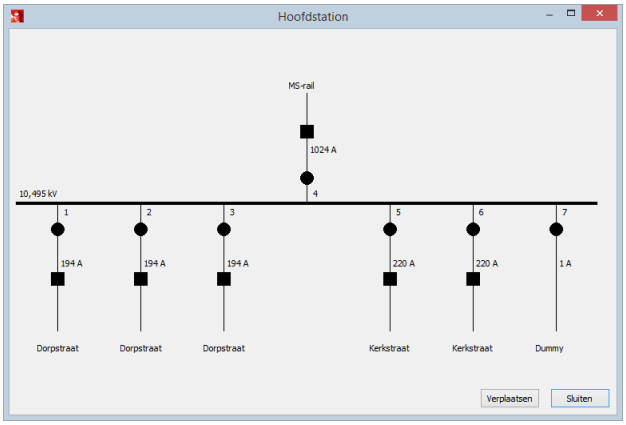

Figure 6. Remote switching of substations

Most substations cannot be controlled remotely however and people have to go there, see figure 7. When, in the simulation, the participants go to another substation, the travel time is taken into account. During the simulation, they can always see how much time passed by already. See the clocks in figure 4.
When they arrive at a certain substation, they can see what kind of substation it is, see figure 8.

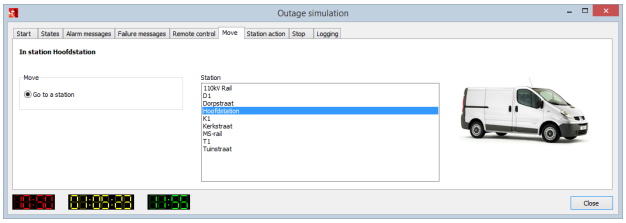

Figure 7. Travelling to another substation

Figure 8. Picture of substation

After entering the substation, an overview of the switchgear installation, with all position indications, and also the indications on the protection relays are given. See figure 9. It is also possible to zoom in on a protection relay, as shown in figure 10.

Figure 9. Switchgear installation with position indication and protection relay indications

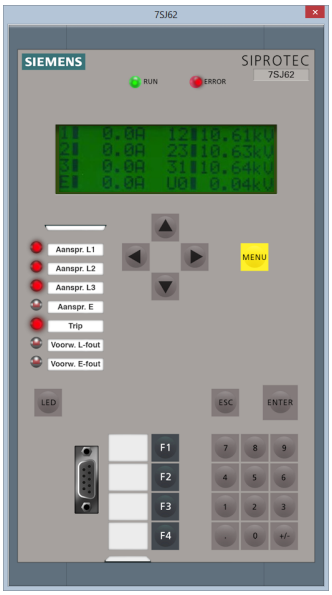

Figure 10. Protection relay with indications

In the substation several actions can be performed, such as for example switching of circuit breakers, voltage detection and measuring of cables. An overview of possible actions is shown in figure 11. The participant has to take several of those actions to investigate in which cable the fault is, to isolate the faulted section, and to restore power afterwards.

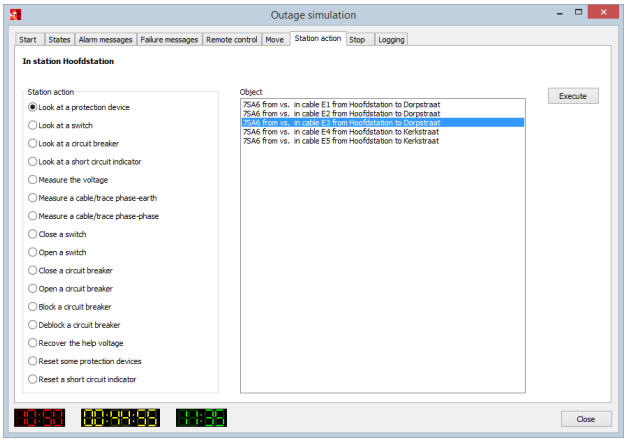

Figure 11. Actions in a substation

End of simulation

At the moment that the participant thinks that he has taken all actions that are needed, and that all customers are re-energized he can finish the simulation. When this is done, the participant will receive an overview of all actions that have been done, possible mistakes that are made, the time that was needed for the simulation, and whether really all customers are re-energized. This report can also be used by the teacher, to discuss afterwards with the participants how they have solved the outage and which improvements are maybe possible.

SUMMARY

This paper described a training that has been developed to learn outage crews how they can restore outages in a fast and efficient way. An important part of this training is an software outage simulator that can be used to exercise with all steps in the process of outage restoration.

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