CASE STUDIES

TRAINING SIMULATORS OF UNDERGROUND NETWORKS

1. Case metadata

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2. Organisations involved

Public Power Corporation S.A.

3. Description of the case

3.1. Introduction

Public Power Corporation S.A. (PPC) is the main producer of electricity in Greece. Apart from production, PPC also has exclusive control over power transport and distribution networks countrywide. A large and ever-increasing portion of the Distribution networks in Greek urban centers, particularly in Athens and Thessaloniki are underground. Their main components are: the Medium Voltage (M.V.) networks, predominantly at 20 kV, but also 6.6 kV in parts of Athens, the city substations where M.V. is stepped down to L.V. (Low Voltage) 400/230 V and the L.V. networks.

Unscheduled power interruptions to L.V. consumers, which are usually made known either by customer-complaint or by signals received at the Load Dispatching Centers, may be classified to several groups according to their material cause and, in order for them to be remedied, it is imperative in each individual case to ascertain the cause of interruption, the location of the problem-point and to perform the necessary operations.

The Repair Crew intervention takes place under conditions of great stress due to time constraints, often severe customer complaints and lack of precise information. This combination of conditions is conducive to work-related accidents and, indeed, in the past several such have been recorded, happily none of them fatal or resulting in serious bodily injury.

3.2. Aims

The aim of the intervention was to make training of personnel on safe operation significantly more systematic and detailed. It was also aimed to achieve a working-level where personnel could tackle network problems without reluctance, avoiding accident-proneness and, consequently, with an increase of outage-time. Moreover, on the basis of its accumulated experience the Department of Training identified as the primary objective to offer trainees an opportunity to perform in the classroom all operations on network nodes under realistic conditions without the risk of incurring unacceptable damage.

3.3. What was done, and how?

The main classes of causes for power-supply interruption were:

1. Blown fuse(s) at L.V. fuse cabinet from overload due to increased load demand
2. Short-circuit between phases
3. Short-circuit between phase and earth
4. Any combination of 2 and 3.
5. Damaged cable

(Without reference to the factor(s) that led to above situations 2 to 5)

The problems faced by the repair crew and the risky intervention that needed to be done, briefly, were:

- The replacement of blown fuses from cause 1 could be made safely, whereas in cases 2 to 4 the replacement of blown fuses without prior examination and taking safety precautions might lead to explosions with unpredictable, at best, consequences.
- Identification of the problem location often involved sectionalizing the network by removing links and reconfiguring it by inserting such links.
- Repair work on the faulty item (cable section, T-joint, straight joint) could only start after the item has been electrically isolated from all possible connections. The isolation is confirmed by electrical measurements taken at the L.V. switch cabinets and/or at the link-boxes.
- A potentially risky operation that was often performed in order to expedite the restoration of service was the deliberate insertion of fuses upstream of network sections known or reasonably suspected to contain at least one short-circuit, the purpose being either clear the fault, if it was transitory, or to precisely locate it. This sort of operation might be safely carried out only on the basis of good knowledge of network conditions, which in turn was based on electric measurements.
- At several locations along the course of underground cables, two or more of them run side-by-side making it imperative, before repair work on any of them, to positively identify it in reference to the L.V. fuse-cabinet outgoing feeders.
- A special problem encountered ever more often in recent years is the unauthorized and, indeed, illegal use of private generators by certain customers during power outages. As a result, sections of the network that, after isolation, should be expected to be voltage-free, turn out to actually be live. In this case, too, the performance of measurements and earthing were necessary safety measures.

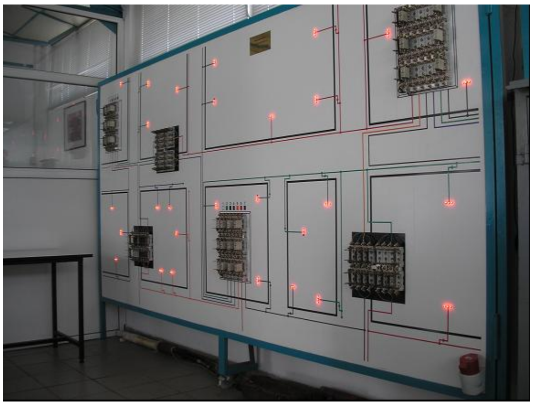
In response to workers' suggestions in various workplaces through their representatives or directly to management, requests from several Area Distribution Units for the upgrading and enhancing of training on L.V. distribution networks were forwarded to the Department of Training. These requests received the full support of the Division of Distribution. The idea of a training *simulator* was adopted.

A simulator on electronic computer seemed inadequate since it could not provide the actual physical experience and, besides, it would make familiarity with electronic computers a prerequisite to obtain full benefit of the training, an assumption far from being true for many of the technicians involved. Therefore, a realistic and handy simulator was designed.

The first simulator was designed and built completely by company personnel in 1999. It consisted of a panel 3X2 m suitable for stationary wall mounting. Its wiring was on the back side, hidden, as in real life, from the trainees, whereas on the front side the course and interconnection of cables and network nodes was marked in mimic-diagram fashion (with separate line for each phase), approximating the typical aspect of a cabling diagram a technician would be consulting in field work.

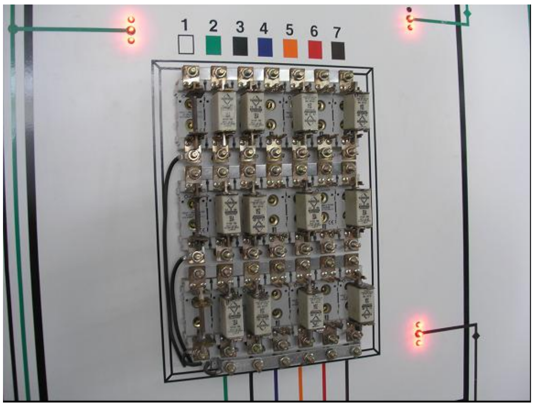
At the node locations special knockouts were made to host fully functional scaled-down replicas of the real items, complete with commercial knifeblade fuses (of a smaller dimensional series) and links. The operating voltage of the simulator was three-phase 40/23 V supply and the presence of tension at various points was indicated by red LEDs (see figure 1 till 4).

Figure 1. View of simulator



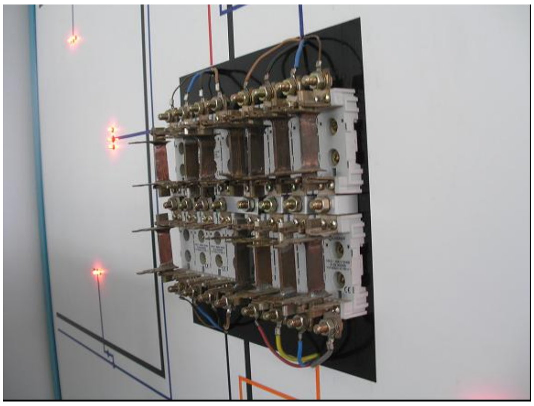
Source: Public Power Corporation S.A.

Figure 2. Fuses of simulator



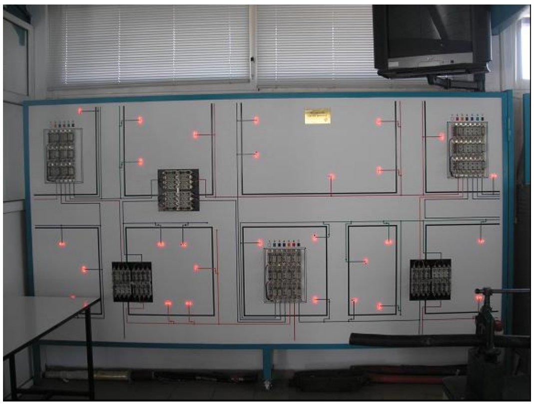
Source: Public Power Corporation S.A.

Figure 3. Other view of fuse cabinets



Source: Public Power Corporation S.A.

Figure 4. Other view of simulator



Source: Public Power Corporation S.A.

The effectiveness of training with the simulator created high demand by the Distribution Units, which, however, was hard to meet, especially outside Athens, due to high workload of technicians and the consequent inability to leave their place of work. For this reason, beginning in 2004, the Department of Training embarked in the construction of portable simulators that could be transported to the requesting workplaces by the instructors in a mobile unit (see figure 5).

Figure 5. Mobile Unit with simulator

Source: Public Power Corporation S.A.

The construction and performance specifications were the same as those of the stationary simulator, with the exception of size (1.2X1.2 m) and weight and the use, in place of LED indicators, of voltage test points for use with multimeters for better investigation of circuit conditions (see figure 6). Up to now three (3) mobile simulators were built.

Figure 6. Inside view of the mobile simulator

Source: Public Power Corporation S.A.

3.4. What was achieved?

- With the use of this simulator the technicians could:
    - familiarise themselves with all possible conditions arising in their daily occupation, even the rarest cases
    - perform all operations while exposing themselves to the consequences of mistakes in a safe way, thanks to the Very Low Voltage (V.L.V) used (40/23V).
- Accidents in underground distribution networks were not common because the work teams were highly specialized and had accumulated experience. For example in the period 1992-1998 there were 4 accidents recorded (none lethal), whereas since 1999 there is no record of accident affecting safety of personnel.
- Training with L.V. underground network simulators is typically carried out for groups of 8 technicians and lasts for 16 hours, i.e. 2/3 of the total training package. To date (2008) they had been offered approximately to 50 Area Units (in some cases with repeats) while some 30 Area Units were in the waiting list.
- The cost of construction of one stationary and three portable simulators has been approximately EUR 12,500 in materials. All labor was performed by Company personnel. This cost was comparable to that of repairing a material damage on L.V. distribution panels due to false operation. Of course, possible consequences to personnel were beyond comparison. Moreover, technical staff had reached a higher level of job satisfaction and self-confidence.

3.5. Success factors

The key factors which contributed to the success of the changes introduced were the following:

- People involved were experts on their specific fields and that assured that every aspect of the project was taken into account. The departments of Training, Repair Crew, Division of Distribution Health and Safety Division participated in the design of the project and the construction of the simulator.
- Employees themselves were also involved throughout the whole process. Such training packages are very popular and their demand exceeds by far the capability for delivery. Employees reported thoughts and aspects, they tested the system and they were trained on it.
- The most important aspect of this project was the construction quality of the simulator, which was based on Corporation's knowledge and know-how and has a thoroughly designed format to be

easy to use. Moreover, it was Corporation's technicians, who designed and constructed the simulator. The work team was highly specialised and have accumulated experience.

3.6. Further information

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3.7. Transferability

The philosophy of the technical solution for simulator construction may be also applied in many other sectors of electricity production that have respective or similar characteristics. However, the monopoly of Public Power Corporation S.A. in Greece constrains the possibility of an other electricity production corporation establishing it. Nevertheless, it is important to mention that the general philosophy to simulate a dangerous process in order to train employees to better tackle with problems in a safe way could be applied in many cases, especially in safety critical operations where the role of human is central and in large organisations where the cost per employee trained is in reasonable levels.

4. References, resources:

Information provided by Public Power Corporation S.A. in the framework of the Good Practice Award Competition 2008/2009.