Abstract — The use of simulators for training operators of electrical distribution systems is becoming more and more important. Modern industrial electrical distribution systems are very reliable and switching operations are not often performed. Mistakes can be very dangerous for personnel and equipment as well as being costly due to the production losses incurred. The authors describe the integration of a simulator into an Electrical Network Monitoring and Control System (ENMCS) in a chemical production facility in the south of France and how it is used to provide operator training as well as the preparation of switching operations. The addition of an ENMCS in an existing plant in commercial operation is also illustrated in this paper.

Index Terms — electrical substations, electrical network monitoring and control systems, electrical distribution, simulator.

I. INTRODUCTION

As new production units are added in existing plants, the electrical distribution system must be expanded in order to supply the additional loads. Often due to investment restrictions, the electrical distribution system is adapted based only on the new process unit power requirements and not on far-term goals. The operations and maintenance staff are then confronted with an electrical distribution system that has many possible configurations, some of which are viable, many of which will soon lead to overload conditions and a partial or total plant shutdown.

Prior to switching any devices, the operator must be sure that he will not accidentally isolate part of the plant or overload any circuits resulting in operation of protection relays leading to shutdowns. Since modern industrial electrical distribution systems are quite reliable, switching operations are much more infrequent than before and operators are no longer used to performing switching sequences. In plants where there are many possible configurations, several of which are not suitable, it is easy to make mistakes which can lead to production losses, or worse, can be hazardous to operating personnel and destroy equipment.

Knowing how the system will react to a sequence of switching operations is essential if the operator is to avoid any mistakes. Detailed knowledge of the limits of the electrical distribution system in the many possible configurations is a requirement for the maintenance staff in order to be able to correctly prepare the system for isolation of equipment. The incorporation of a simulator in the Electrical Network Monitoring and Control System (ENMCS) provides a means of training the operations and maintenance staff based on real conditions without actually operating any devices. Operations and maintenance staff can validate proposed switching sequences prior to executing them to be sure that all loads will be correctly supplied at all times. The paper describes the principles of a simulator that has been integrated into an ENMCS and highlights the benefits that it has brought to a production facility in the south of France.

The plant was initially designed and constructed without consideration given to the need for an ENMCS. Once it had been decided that an ENMCS was required, it was necessary to determine how such a system could be installed and commissioned without disrupting production. This is a step-by-step process and requires close coordination between the plant process operators and electrical staff. The ENMCS at this site shows that this is possible.

Both circuit-breakers and switches are used at this site. To facilitate reading the paper, the term breaker will be used for both.

II. BACKGROUND

A. Description of the plant

The plant produces several products including 270,000 tons per year of chlorine and 405,000 tons per year of monomeric vinyl chloride which is used to manufacture PVC. The site is linked to neighboring plants via pipelines in order to get the raw materials it requires and to export its finished products. The plant was created in 1976 and initially had one chlorine production facility. Another chlorine production unit was added in 1980 together with the monomeric vinyl chloride (MVC) unit. In 1991 the production of MVC was doubled and in 1992 another chlorine unit was added.

Fig. 1 is an aerial view of the plant. The 225kV substation is shown in the bottom left corner. This substation supplies all of the production units at the site with power at 20kV. The production unit substations are located throughout the whole facility and are several hundred meters from each other and from the engineer's office which is located near the 225kV substation. The large number of substations and their location were important factors in the decision to invest in an ENMCS in the first place. Prior to the installation of the ENMCS, when an incident occurred much time was wasted.
sending engineers to each substation to try to locate the fault and to determine what switching operations were necessary to get the production units back in operation. With the ENMCS this information is now immediately available at a central point thereby eliminating the time wasted gathering data.

B. The expansion of the electrical distribution system

Each time a new production unit was added, the electrical distribution system was modified in order to supply the additional load. A second 100MVA 225kV/20kV transformer was soon added and the new production units were supplied using 20kV loops operated in an open configuration. In order to increase the reliability and availability of the system additional connections between production unit substations were added explaining the fairly complicated distribution system in operation today shown in the simplified single-line diagram in Fig. 2.

The plant consumes 122.5 MW and is supplied by both 100 MVA transformers. The rectifiers connected to boards R1 and R2 account for approximately 90% of the plant load. Due to the high prospective short-circuit current the transformers cannot be operated in parallel. This means that each production unit is supplied by either one transformer or the other. In order to be able to change the transformer to which a production unit is connected, all load must be switched to 1 transformer by momentarily closing the 20kV tie-breaker 341 located between switchboards R1 and R2 and then tripping the incoming circuit of the other transformer. Trying to switch power sources in the production unit 20kV switchgear when both transformers supply power will cause large circulating currents in the 20kV plant loops resulting in the tripping of units. When all loads have been transferred to 1 transformer, switching at the 20kV level in the production units can be done. Since production must be decreased to allow the use of 1 transformer only, switching production units to the other source is done very rarely. Fig. 2 shows the normal power supply configuration. The ampere frame of each switch is shown in the single-line diagram.

The policy at this site is to keep all circuits which are not used energized. This is done by closing the breaker at the source side but keeping the load-side breaker open. Keeping equipment energized reduces the risk of failure when the circuit is actually needed. The exceptions are shown in dotted lines in Fig. 2.

C. Switching operations in the electrical distribution system

The process units are in continuous operation 24 hours a day and there are no switching operations required for production purposes. Electrical staff is present at site only

Fig. 1 Aerial view of the production facility
during the day shift, however they are on call should any incident occur outside of that 8 hour period or on weekends.

The maintenance policy at this site requires however, that all switching devices be operated at least once a year. Since production cannot be stopped for this it is first necessary to transfer the power supply to a different circuit. After the transfer has been completed it is possible to test the switching devices on the circuit which was previously used to supply the unit. After testing has been completed the unit will be transferred back to its normal supply.

As mentioned above, switching operations are rare and therefore operators are hesitant to open or close breakers. Opening the wrong circuit at the MVC unit can result in a substantial loss of production since it can take up to 5 days to get the unit back on line even after a brief power outage. Prior to switching a unit to another circuit it is also necessary to check that this circuit can support the additional load. Since there are many different possible operating configurations the current flowing in a particular circuit can vary widely even though the process loads themselves are constant. The two main reasons for implementing a simulator in the ENMCS were to train operators so that they would be familiar with switching operations, and to be able to determine the loading in each circuit during different switching sequences to prevent overloading and subsequent nuisance tripping.

D. Plant shutdown periods

There are different types of shutdown periods at the plant. A process shutdown occurs when a production unit stops due to lack of raw material it needs from one of the neighboring plants. During this period the production is stopped but the unit remains in operation, ready to start production as soon as raw material becomes available. The chemical products required for the process are present in the process equipment and must be kept at certain conditions of temperature and flow to prevent danger to process equipment. This means that the electrical distribution system must be operating correctly during such shutdown periods. The load is substantially less than during production periods so certain switching operations can be done that could not be done otherwise, but the results of incorrect switching can still be very dangerous.

Another type of plant shutdown is for the overhaul of the process equipment. During this shutdown the process equipment is emptied of all chemical products so there is no danger should the electrical distribution system not be in...
service. It is only during this type of shutdown that certain electrical maintenance operations such as busbar inspection can be performed. In order to maximize the return on investment, this type of plant shutdown is scheduled every 5 years—previously they were scheduled every 2 to 3 years.

There is also the shutdown due to a failure in one of the utilities such as the electrical power supply. During the first years of operation the utility supply was quite unreliable causing frequent shutdowns. The utility supply was upgraded an now there are few incidents related to the incoming supply. The plant automatic transfer system is designed to transfer loads to the healthy supply in less than 0.9 seconds and this enables the process equipment to ride through approximately 50% of the disturbances. Contactors are held in the closed position during 1.5 seconds by means of battery backed auxiliary supplies resulting in reacceleration of all critical motors immediately after the transfer has been executed.

III. SIMULATORS

A. General description of simulators

A simulator is a mathematical model that is designed to represent the behavior in real time of equipment or a system. The simulator must also be designed to respond to the actions of operators and other external influences such as ambient temperature. The most familiar simulator is the one used for training pilots.

Different types of simulators for electrical distribution systems are available. Utilities use simulators to model the behavior over long periods of time of complete national grids. These help determine control measures to prevent outages due to incidents which occur within the national grid and also which occur in other systems connected to them. Smaller simulators are used for industrial applications in order to determine the long-term stability of frequency and voltage control in sites where power is provided by local generation. Such simulators which model the dynamic behavior of the electrical network require detailed information regarding the mechanical characteristics of rotating machines in addition to the electrical characteristics of the whole distribution system.

A solution that is sometimes adopted is to implant electrical network calculation software in the same system as the ENMCS. Real-time data can be fed to the software which can then be used to perform some calculations such as load flows and short-circuit current calculations. Since certain electrical values such as the phase angle of supply voltages are generally not available from the ENMCS, there are limitations in the type of calculations that can be performed. This combination of ENMCS and network calculation software does not replace a simulator but can be thought of as a first step in that direction.

The simulator needed for the production site described in this paper was not required to reproduce the dynamic response of the system but only its static performance. For this it is necessary to calculate the magnitude and direction of currents flowing in each circuit before and after switching operations are performed. This does not require the large amount of mathematical operations of a dynamic simulation. It does require however, the real-time topology of the network. This information is readily available from the microprocessor-based multifunction relays which are an integral part of the ENMCS at this site.

B. Specifying simulators

A simulator is not something that is routinely ordered and they are always made to measure. Specifying a simulator is therefore not an easy task. In addition most of the cost associated with a simulator is for development and therefore particular care in specifying requirements is essential. Some points that are to be considered are:

- response time (must be short enough to be able to simulate the phenomena to be observed under all defined conditions)
- operator interface (how the operator is to control and visualize the equipment or system that is simulated)
- simulator output (how best to convey the response of the equipment or system being simulated to the operator)
- initial conditions (how to set up the simulator to match different initial conditions)
- modifications (how to adapt the simulator to system upgrades)
- testing (how to validate the simulator)

IV. DETAILED SIMULATOR DESCRIPTION

The simulator required for this plant had to be able to determine the source of power for each switchboard, i.e. from transformer TR1 or TR2, and how much current was flowing in each circuit. In addition the direction of the power flow needed to be determined and displayed to the operator in order to be able to clearly identify what equipment would be disconnected should a breaker be tripped.

A. Description of the ENMCS

The ENMCS consists of 2 fixed and 1 portable workstation interfaced to the 20kV switchgear microprocessor-based multifunction relays. This is done via PLCs connected to a high speed Ethernet fiber optic network. The architecture of the ENMCS is shown in Fig. 3. One of the main functions of the PLCs is to facilitate the transfer of data from the relays. The automatic transfer of load between the 100MVA transformers is performed by a PLC located in the 225kV substation. This PLC existed prior to the installation of the ENMCS and was integrated into the new system without modifying any of the transfer scheme logic. Some other PLCs at site performed load shedding and automatic restarting in conjunction with substation emergency power supplies.

The main function of the ENMCS at this site is the monitoring of the electrical distribution system. Prior to the installation of the ENMCS the electrical engineer had to go to each of the 10 substations which are located throughout the whole site in order to know the status of the equipment after an incident. This resulted in an increase in the time required to get the production unit back on line and was actually one of the main reasons the plant management decided that an ENMCS was indispensable.

At the present time remote control of the switchgear from the ENMCS is not implemented due to the fact that only the most recent switchgear was designed for remote control. An all-or-nothing approach was selected by the operators and
therefore all devices are operated locally in the substations. Remote control is one of the long-term objectives at this site. Since electrical staff is only at site during 1 shift, it is important that they be able to quickly determine if there had been any changes in the configuration of the system between shifts. To do this a snap-shot (memorizing of the status of each breaker in the ENMCS) of the system is taken at the end of the shift and this is compared to the configuration found at the start of the next shift. The ENMCS compiles a list of all discrepancies between the snap-shot and the actual configuration allowing immediate identification of any changes. This is also used after an incident in order to positively identify all status changes that occurred due to the incident.

The ENMCS also has such standard features as alarm management, event logging, trending and fine time stamping. Fine time stamping allows the listing of all events in chronological order no matter where they occurred at the site. This is very important for determining the cause of the incident. The color coding used in the ENMCS mimic diagrams allows the operators to positively identify the source of power of each busbar and which circuits are deenergized.

B. Incorporation of the simulator in the ENMCS

All of the data necessary for the simulations is available from the microprocessor-based relays installed in the 20kV equipment. The logic and calculations required for the different simulator functions were judged to be able to be performed by the ENMCS without the addition of extra equipment. It was therefore decided to implement the simulator function directly into the ENMCS. This has the advantage of not requiring additional equipment that had to be interfaced to the same relays. Also the responsibility of the whole system was with one supplier which eliminated potential interface problems. The simulator function was installed in both of the ENMCS workstations and either workstation can be used in the normal monitoring mode, or in the simulator mode. Generally only one workstation would be in the simulator mode at any particular time.

The standard ENMCS symbols were modified in order to show the direction of power flow and the circuit threshold current. Remote control from the ENMCS workstations is not implemented at the site at the present time but it can be simulated. This required the use of different control windows for the normal ENMCS operation and simulator operation.

Fig. 4 shows a circuit-breaker together with its upstream disconnecting switch, both in the closed position. The device label is shown together with the magnitude of the current flowing and its direction. Should during simulations a 20kV loop be closed causing the 100MVA transformers to be in parallel, the direction arrow will be changed to a bi-directional arrow as shown beside the symbol in Fig. 4. The value of the current will no longer be shown since it cannot be calculated by this type of simulator.
C. Starting the simulator

To begin a simulation, one of the ENMCS work stations is switched to the simulation mode. Real-time monitoring of the system can continue from the other fixed station or from the portable station anywhere within the plant.

The simulation always begins with an existing configuration. The operator has the choice to use the current configuration as a starting point or to load a configuration (snap shot) memorized previously depending on what he desires to simulate. In addition to the status of all breakers, the current and direction of power flow shown for each circuit corresponds to the situation just before switching to the simulation mode, or to the situation just prior to the selected snap shot.

The operator can now execute the switching sequences that he desires without actually operating any of the devices. With each operation the status of the switched device will change and the currents in the circuits recalculated. The direction of power flow will be updated.

D. Using the simulator to check possible sequences

The most common use of the simulator at this site is the preparation of maintenance operations. As mentioned previously, each breaker must be operated at least once per year. Prior to opening the breaker the operator must ensure that all loads are correctly supplied by circuits that will not be affected by the maintenance operations. This means checking that loads always remain energized and that no circuits are overloaded at any time.

The operator is allowed to open any breaker and to close all breakers except those that would result in paralleling the main transformers. The simulator places a danger signal with each breaker that would parallel the 100MVA transformers and will also warn the operator should he try to simulate closing the breaker. This warning signal is shown in Fig. 5 beside the circuit-breaker. Since remote opening and closing of breakers is allowed in the simulator mode but not in the monitoring mode, different breaker control windows are used in each mode. The monitoring mode control window shown in Fig. 6 has status as well as current, voltage and power measurement values. The simulator mode control window for the same device is shown in Fig. 7. It has the status and current magnitude threshold but only the current measurements are shown. No information concerning power is displayed but the on-off breaker control buttons appear since switching operations are simulated. Three sets of on/off buttons are shown since there are actually 3 devices to control – the circuit-breaker, the disconnecting switch, and the earthing switch.

The maximum current that should not be exceeded in the circuit is shown beneath the current measurements, “Seuil” being the French word for threshold. There are other buttons on both the control windows in addition to the on-off control buttons shown beside the circuit-breaker in the simulator control window.

![Fig. 6 Information for normal operation](image)

![Fig. 7 Simulator control window](image)
substations. It also avoids the problem that multiple copies of the same document are often not identical.

The button with the 3 dots opens the window in which it is possible to change the value of the circuit threshold current.

The last button opens a window in which trend curves can be viewed. These curves show the change over time of certain measured values such as current, voltage and temperature. This information is especially important for preventative maintenance.

V. USE OF SIMULATOR AT PLANT

With the help of the simulator the operator can determine the switching sequence to be executed. After he is satisfied that the switching sequence can be performed without the risk of an incident, it is necessary to execute the sequence. How this is done at site is explained based on an example. The example chosen is the isolation of switchboard R1. This effectively isolates transformer TR1 and requires power to flow via the bus-tie in substation P3.

A. Example of switching simulation

In order to illustrate the importance of simulating operations prior to actually switching devices, the flow of power during normal operation shown in Fig. 8 is compared to the flow of power shown in Fig. 9 when only 1 transformer is in service.

The normal flow of power in Fig. 8 is similar to a radial distribution. It is easy to determine the consequences of switching devices in this configuration. The loads are well within the capacity of the circuits and there is a clear separation between loads supplied by each transformer.

When only 1 transformer is in service, the flow of power to most of the plant substations is completely different. Substation P8 is now used to transmit all the power required by the loads previously supplied by the board R1. The magnitude of the current to P8 changes from 15A to 403A. Its direction in the circuit connecting P5 to P8 changes as well. Board P5 which is normally operated with the bus-tie closed is now operated with the bus-tie opened in order to prevent overloading the feeder from R2 and tripping switches 112 or 701. The bus-tie of P3 is closed in order to allow

Fig. 8 Loads during normal operation
power to flow from substations supplied from R2 to substations D1, P1 and P2.

Several switching operations are required to go from the configuration in Fig. 8 to that in Fig. 9. It is not evident when starting from Fig. 8 what the order of the switching sequence should be to avoid power outages from incorrect switching or due to overload conditions. The operators also only have 1 chance to get it right. This is a good example to illustrate the importance of the simulator to test the various possible switching sequences in order to determine which one is the most suitable. After each step the simulator displays the currents in each circuit and enables the operator to determine if that particular order is acceptable or not. Since the switching done at this site is manual, temporary overload conditions must be avoided since the time required between switching 2 devices can be several tens of minutes.

It often occurs that switching will be correct up to a point but cannot continue without tripping a load or overloading a circuit. In order to avoid the operator having to start all over again, an undo function is provided. This, together with the use of the simulator snap shot function makes the trial and error process very easy. All of the operations are memorized by the simulator so that once the successful sequence has been found, there is no risk of the operator having forgotten how he got there. This sequence can also be replayed just prior to actually switching the devices to ensure that nothing has changed that could create a problem.

B. Actual switching operations

As mentioned above, at this site remote control of the equipment has not yet been implemented for historical reasons. This means that all switching must be done at the equipment in the substations. There is much more involved in switching the breakers than simply opening and closing them. The earthing switches must be closed if maintenance on the circuit is to be performed. In addition there are key interlocks on some equipment meaning that the key must be available in order to execute the sequence. These additional details are listed in a separate switching procedure that is associated with each device. Information as to which key is required and where it is located is given in these documents. The operator clicks the W button on the breaker control window and can visualize and/or print the instructions. This can also be done using the portable ENMCS workstation meaning that this information is available at any time and anywhere in the plant. With these procedures and the sequence determined previously by simulation, the operator can now perform the switching.

Even though the switching is done manually, the ENMCS is used to follow the switching operations. The ENMCS is placed in the monitoring mode when switching operations are to be carried out. The first operation that is done is the comparison of the status of the electrical distribution system with that used for making the simulation. It is essential that
the same configuration be present in order to be sure that the switching operations that were simulated can be executed correctly. After the comparison has been made, the memorized sequence is initiated. The device to be switched is highlighted on the ENMCS single-line diagram. After the device has been switched by the operator in the substation, the ENMCS will update the status on its single-line diagram and highlight the next device to be switched. This is done until all devices in the sequence have been switched. It is possible to abort a sequence at any time. Each operation is monitored by a timer and an alarm is generated should the time between operations exceed 1 hour.

In order to facilitate the switching in the substation, the next step that is planned at this site is the addition of signaling lights on the existing equipment to mimic the device highlighting that is done on the ENMCS single-line diagrams. Each cubicle where switching must be performed will have a light that will be lit by the ENMCS indicating that the switching operation to be performed next will be at this location. The operator then executes the switching at this cubicle in accordance with the standard procedures mentioned above. After the switching operation at this location is finished the ENMCS will be informed of the status via the breaker auxiliary contacts and will go to the next step. The next step will be indicated by extinguishing the light on the cubicle where the switching was just performed and the lighting of a light on the next cubicle where switching is to be done. Often this cubicle will be in a different substation which is one reason why operation at this plant is difficult and subject to errors. The addition of signaling lights illustrates part of the step-by-step integration of an ENMCS at an existing site where equipment was installed in the past without being equipped for interfacing to a control system.

In a plant where all the electrical equipment is designed for remote control, the ENMCS would actually execute the memorized switching sequence automatically. Implementing remote control provides a substantial gain in time. It is also very reliable since the sequence has been tested prior to its execution. The integration of remote control is one of the difficulties faced when adding an ENMCS into an existing facility. It is much easier to install an ENMCS in a new plant right from the start than to integrate one in a plant in commercial operation.

VI. DESIGN OF THE SIMULATOR

The design of the simulator did not require the integration of third party software nor additional devices since the simulator function is embedded in the ENMCS itself. The data required for the simulations was available in the microprocessor-based relays which were installed for use with the ENMCS. The only modifications required in the existing PLCs was the changing of the memory map in order for the ENMCS to have access to all the data required. In addition all engineering was done by one vendor eliminating the cost of purchasing and integrating third-party software.

Design time was short since little additional data was required for the simulator. More sophisticated simulators must model the dynamic reaction of rotating machines which requires governor and exciter transfer functions, motor and load torque curves etc. This information is notoriously difficult to get and there are often doubts as to its validity. Since the calculations of this particular simulator are based on static measurements, none of this difficult-to-obtain data was required.

The decision to invest money to purchase and install an ENMCS (with or without a simulator function) was made on the same basis as any other investment. The return on investment was justified by the decrease in down time and related reduction of production losses. This is a direct result of the maintenance team immediately having correct information allowing a much quicker resolution of problems affecting production. As one electrical engineer stated, "No process engineer would conceive of running a process blind without a DCS yet often we are required to run the whole electrical distribution system blind". It is always more difficult to justify investments that are not directly linked to the production tool. The fact that the process cannot operate without a reliable source of electrical energy seems often to be ignored or is simply taken for granted.

VII. LIMITS OF THIS SIMULATOR

The simulator functions required for this site were based on the fact that the process loads are relatively constant and that the incoming supplies are not connected in parallel. This makes the calculation algorithms reasonably simple which permits their integration into the ENMCS.

One limitation of this simulator is that estimations cannot be made of the current flowing in the closed-loop circuits should the 2 incoming supplies be connected in parallel. This would require more data and a program capable of performing load flow calculations since the voltage on both incoming supplies could be different. Since parallel operation is not possible at this site this limitation is of no importance.

Dynamic simulations such as motor starting cannot be performed. Since the loads are supplied by a very strong national grid and there are no generators at this site, there is no need to perform dynamic simulations in this plant.

VIII. SIMULATOR COMMISSIONING

The installation and commissioning of the ENMCS and simulator lasted several months. It was necessary to add the new equipment and install and connect the new Ethernet plant-wide fiber optic cable. In addition the memory map of the existing PLCs had to be reconfigured. The PLCs are located in equipment and substations supplying process equipment in commercial operation. No process interruptions were allowed and thus this work could only be done during scheduled outages. Equipment and systems were tested in the factory prior to shipment at site in order to ensure that there would be no problems with communication among the devices and that the exchange of information would be correct.

The commissioning of the ENMCS itself required the verification of all measurement and status information. Since there is no remote control executed by the ENMCS this commissioning phase was not as difficult as when the ENMCS actually controls devices. The acceptance testing of the ENMCS as a whole was able to be carried out during a planned maintenance shutdown.

After commissioning of the ENMCS portion showing that the data retrieved from the switchgear was correct, it was possible to validate the simulator functions. Since these are
all off-line this could be done without waiting for any scheduled shutdowns.

IX. OPERATOR TRAINING

Operator training was done after the commissioning of the complete ENMCS. Using the simulator makes training much easier since realistic switching sequences can be carried out without there being any danger of accidental incorrect switching and loss of production.

Operators were not familiar with carrying out switching operations and were even reluctant at the start to try different sequences on the simulator. This demonstrated the danger associated with infrequent operations and provided additional justification of the need for a simulator. The parallel with a flight simulator is interesting even if not 100% applicable.

It is very important that a training simulator should reflect what the operator will be confronted with when using the real thing. By integrating the simulator directly into the ENMCS this is achieved very easily. The operator will use the same screens and see the same symbols when using both the simulator and the ENMCS.

X. CONCLUSION

This simulator allowed the operators in the plant to be trained to be at ease when working with the electrical distribution system. The additional cost of implementing the simulator function in the ENMCS is paid by avoiding one switching mistake.

The authors think that this application is very interesting for two reasons. First it demonstrates that an ENMCS can be added to an existing site in a step-by-step manner without causing any loss in production. Its use is justified by reduced outage time and lower production losses. Secondly, for sites where there is an ENMCS already in operation, it shows that it is possible to add a simulator function described in this paper as a low-cost alternative to a dedicated training simulator.

In today's world where maintenance is often outsourced, and where there are frequent changes in personnel, operator training becomes more and more important. The simulator embedded in the ENMCS offers a good solution since the operator will be trained on the system that he will actually be using. The other advantage is that the operator can prepare the switching sequence himself and be aware of the consequences of each operation. He is better prepared to act correctly in an emergency than if he was used to simply follow switching sequences proposed by an expert system. Providing too much assistance for operators can actually have negative effects.

The algorithms used by the simulator are suitable for petrochemical facilities since the loads are fairly constant over long periods of time. Dynamic response is not required. The limitations of static calculations should be reviewed when deciding what type of simulator is required.

XI. REFERENCES


XII. VITAS

Terence Hazel received his BSc in Electrical Engineering from the University of Manitoba Canada in 1970. After graduation he worked in Perth Australia for 1 year as a power coordination engineer, and in Frankfurt Germany as a consulting engineer until he joined Merlin Gerin (now called Schneider Electric) in 1980. For 15 years he was the technical team leader for several major international projects involving process control and power distribution. Since then he has been with the tendering section of the industrial projects department and often meets with clients during the front end engineering stage to discuss and compare the various possible electrical distribution systems. He is a senior member of IEEE and has presented several papers and tutorials dealing with electrical power distribution at the PCIC and other conferences.

Isabelle Condamin is the head of the electrical department at the Atofina chemical complex located in Fos-sur-Mer France.

Fabrice Audemard is the head of electrical maintenance at the Atofina chemical complex in Fos-sur-Mer France. The idea of the embedded simulator function came as a result of his 10 years of experience at the chemical plant.