Managing MV Networks for Quality of Service

The efficiency of this approach is analyzed in terms of quality of service, optimization of investment, optimization of installation, maintenance, and simplification of operation

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The process of restructuring, privatization, and deregulation has created a competitive global marketplace for energy. Early preparation to meet market competition and make the best use of technology will determine success in this new and challenging environment. The utilities of the future will be focused on their expertise in order to do what they do best. Moreover, twenty-first century utilities will try to further improve system reliability and efficiency by upgrading and modernizing the network's infrastructure while simultaneously being cost effective.

In today's deregulated marketplace, simply delivering power to customers is no longer sufficient; utilities must provide a certain level of quality of service and must deliver the commodity safely, reliably, and cost-effectively. Moreover, information traditionally used only within a given utility is now desired by many players, since the integration, consolidation, and dissemination of information both inter- and intra-utility has become a critical part of the deregulation picture. Exponential advances in hardware, software, and communication equipment allow the transportation, storing, and manipulation of vast quantities of data at blinding speed relative to just a few years ago. As a result, utilities have shifted their focus to information technology and automation to optimize operations and improve the bottom line.

This article proposes a global approach for the management and control of medium-voltage (MV) networks. The efficiency of this approach is analyzed in terms of quality of service, optimization of investment, optimization of installation, maintenance, and simplification of operation.

Fault Detection, Management, and Control Needs

From the analysis of the causes of faults, it has been found that the majority of faults comes from MV networks, while the faults in high-voltage (HV) and low-voltage (LV) networks are fewer (Figure 1). Consequently, the MV network is the part of the whole network to which the greatest care should be taken in order to improve the quality of service.

The MV underground network is made up of numerous substations. Substations could be manually operated, have difficult access (geographical constraints,

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distance, traffic), or be subjected to bad weather conditions. These particularities could result in poor quality of service, high operating costs, and safety problems for operating staff and people.

The MV overhead network is made up of long lines (radial lines from 10 to 100 km long) and is very sensitive to harsh environments (confronted with all types of weather conditions, pollution, etc.). The result is a lack of efficiency and poor quality of service: numerous short breaks due to transient faults, long outages, considerable voltage drops, an overloaded network, and considerable losses. Operating costs are often high as well, whereas operators and the public can be subjected to safety problems.

In addition, the requirements of network managers for data to operate and maintain networks is becoming an increasingly important part of their business, especially where regulating authorities exert a high level of pressure. For example, in today's deregulated marketplace, the traditional substation control methods, either locally or remotely (fault indicators, remote control), are not adequate. Indeed, network operators must have all the information concerning the installations on the network (substation equipment, installation status, load curves, etc.) in a simple and economical manner.

Parameters Affecting Selection of Equipment

From the above analysis of the needs of the MV network managers and operators, it is concluded that it is important to manage and control the MV distribution network in order to improve customer service and satisfaction as well as to optimize the network operation.

However, the selection of equipment for network fault detection, management, and control is not an easy task. This selection must fulfill certain criteria, such as mastering of investment, optimization of maintenance, mastering of distribution quality index, globalization, and compatibility of the solution.

To be able to provide a certain level of quality of service, it is necessary to accurately quantify it in a factual manner. Electric power utilities commonly use measurement indicators for their quality of service, such as system average interruption duration index, system average interruption duration index for permanent outages only, system average interruption frequency index, system average interruption frequency index for permanent outages only, system average interruption frequency index for short outages only.

Another variable to be taken into account is the cost estimation for nondistributed energy per year. It increases with the number of faults per year, the peak power demand, the length of distribution lines or cables that are connected to each feeder, the length of the outage, the billed price per kWh, and, above all, the cost of consequences.

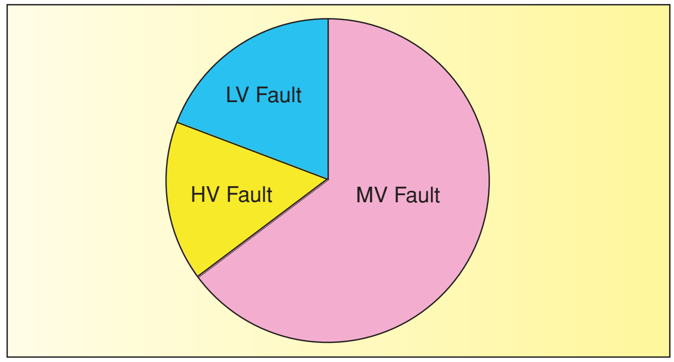

Figure 1. Analysis of network faults

In brief, the quality of service depends on the type and density of the population (rural or urban), the type of distribution (overhead or underground), and the stakes and total costs that were accepted as the consequence of a break in service.

Network management involves remote control (telecontrol) functionality. MV distribution networks often have a tree structure mainly with overhead lines. The selection and placement of equipment and control systems in these networks require careful planning to optimize performance. There are many possible ways to place remote control points and fault passage indicators (FPI) on the network:

- Install telecontrol on existing pole mounted or substation switchgear, the difficult point being the motorization of the existing MV switches
- Install FPI function on existing pole mounted or substation switchgear
- Create new telecontrolled points (pole mounted or substation) corresponding to the available power growth in the MV network
- Create telecontrolled network points for improving network dependability without increasing the available power (installation of one to three MV switches without MV/LV transformer)
- Anticipate the expansion of telecontrolled points by systematically installing motorized MV switches.

The selection and placement of equipment must increase the efficiency of the network management in terms of investment optimization, reduction of minutes of loss, reduction of customers concerned by loss of voltage, and reduction of time to localize the fault and reconfigure the network.

Equipment

Within the considered framework, the improvement of service and customer satisfaction is achieved through the reduction of the duration of outages and the reduction of the number of outages. The disturbances could be short breaks or long breaks. Figure 2 presents a scheme for the improvement of the continuity of supply. For example, in order to avoid short breaks, network monitoring and preventive maintenance are followed; for

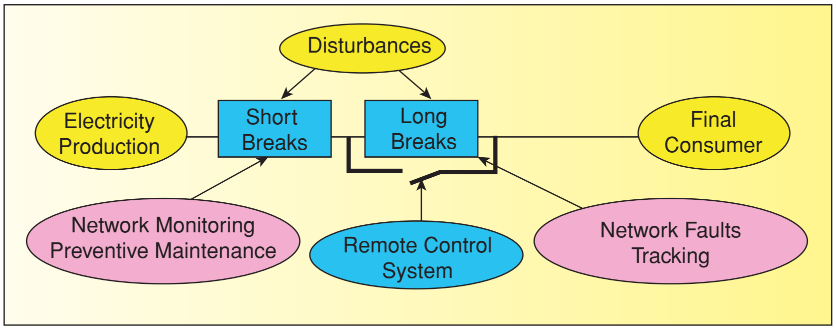

Figure 2. Scheme for the improvement of the continuity of supply

long breaks, network fault tracking and remote control are used.

The improvement of network operation is achieved through the reduction of the time for fault localization and the elimination of equipment damage.

Among these different problems, two of them, long outages and numerous short outages, can be solved using two kind of solutions:

- Fault passage indicators
- Automation and remote control systems.

Fault Passage Indicators

FPIs comprise a cost-effective solution to locate faulty network sections. A comprehensive range of FPIs is available in the market, using either a directional or current-based fault detection method and covering all types of MV networks neutral grounding.

The fault detection function must be seen as a part of the network protection plan. So, depending on local specification of line and cable distribution, the setting should be adapted for a better accuracy of the function. Consequently, the FPI function must be fully programmable on-site. Obviously, it is also a key economic factor, as it allows stock management optimization.

FPIs with contacts intended for connection of remote terminal units (RTU) permit remote fault detection. In order to simplify the communication function, it is recommended to use a solution compatible with the control unit one (same protocol and same transmission system).

Figure 3. Integrated substation control unit for four feeders

Automation and Remote Control Systems

In a substation with remote control functions, the electronic component must provide the following functionality:

- RTU communication with control center
  - Range of protocol
  - Various transmission systems
- Uninterrupted power supply for
  - Substation motorization
  - Transmission system
  - All electronic devices
- FPI function including
  - Direct acquisition from current transformer
  - Phase-to-phase over-current
  - Phase-to-earth over-current
- Interface with the switchgear
  - Ready to connect
  - Capacity from one to numerous feeders
- Local control and maintenance facilities.

Various manufacturers could supply all these functions. Obviously, economic is not an optimized solution. Thus, in term of efficiency of network control, a single unit, fully tested in the manufacturing site, is the only kind of equipment, that can guarantee safe installation, simplified commissioning, comprehensive maintenance, and EMC compatibility. Figure 3 shows an integrated substation control unit for four feeders. The reduction of cabling in such units significantly increases the quality and the availability of the control system.

Mixed Solution

Automation and remote control systems as well as FPIs can be used separately but also in combination (mixed solution). In the mixed case, part of the substations use remote control and/or automation capabilities, while the other ones use FPIs. The choice between these two kinds of solutions is indeed a technical and economic choice. FPIs are a very economical solution to improve significantly quality of service, while remote control systems, with higher investment, allow even higher impact. Figure 4 presents the MV network equipment for the improvement of the continuity of service.

Global Approach

This article proposes a global approach for fault detection, management, and control of medium voltage networks. The approach aims at increasing the efficiency of the network management in term of investment optimization, reduction of minutes of loss, reduction of customers concerned by loss of voltage, and reduction of time to localize the fault and reconfigure the network.

The proposed approach involves a segmentation of the network into sections according to the type of substations used and suggests an efficient scheme for fault detection, management and control. Moreover, it presents a new multifunctional device for substation remote management and monitoring.

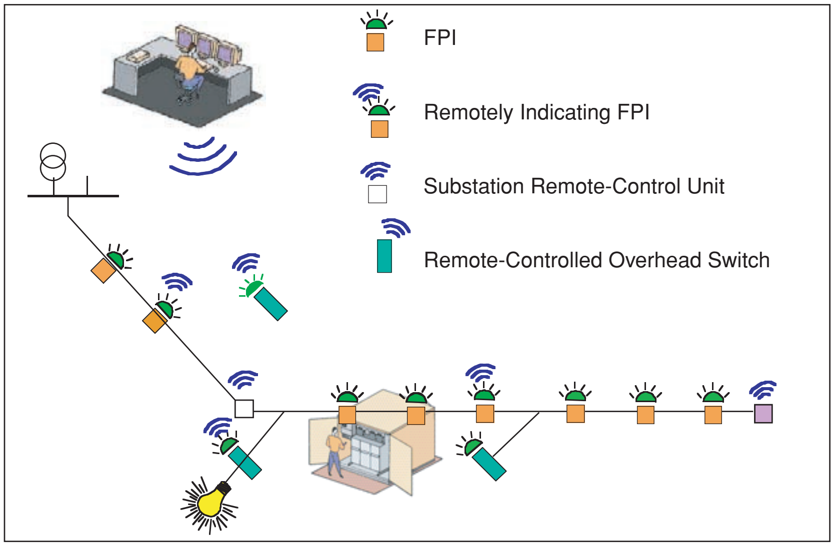

Figure 4. Medium-voltage network equipment for the improvement of the continuity of service

Network Segmentation

The fault localization and network reconfiguration scheme is defined from the use of three main types of substations:

- Substations or pole mounted switches with a telecontrol unit including FPI function
- Substations or pole mounted switches with SCADA connected FPI
- Substations or pole mounted switches with standalone FPIs.

These three types of substation split the network into three main sections, and each of these sections has different characteristics:

- Large section edged by fully telecontrolled substations or pole mounted switches
- Medium section edged by substations or pole mounted switches with SCADA connected FPI
- Small section edged by substations or pole mounted switches with standalone FPIs.

The telecontrol center can immediately isolate the large section. All customers in this section are not reenergized when the network is reconfigured. The larger the section, the bigger the number of customers with a long outage.

The medium section in fault is immediately localized at the control center. The maintenance crew can be dispatched directly to the manual switch and operate accordingly. The result is that all customers in the healthy medium sections are supplied in a relatively medium time.

The small section needs the maintenance crew to patrol on the network. The time to access and isolate the section is rather long. Generally, this section is as short as possible and needs the FPI function to be installed in each substation (underground network) or at each new branch (overhead network).

Efficiency of Fault Detection

Figure 5 illustrates the localization of a faulty section and the reconfiguration of the network from the control center. In case of fault occurrence, the FPI memorizes the passage of fault current and the upstream protection opens. The reconfiguration of the network from the control center includes polling remote control substations, isolating the faulty section, restoring supply on the upstream section, and restoring supply on the downstream section.

The most efficient scheme is to equip all substations with full telecontrol units, but this is not an optimal situation in terms of an economical approach. The best-optimized solution is to mix the three types according to various criteria such as:

- Number of substations on a feeder
- Number of customers in each section
- Importance of customer in each section (hospital, ministry, plant, ...)
- Accessibility of the substation
- Transmission facilities for remote indication
- Motorization facilities in existing substation.

A typical network could be equipped with:

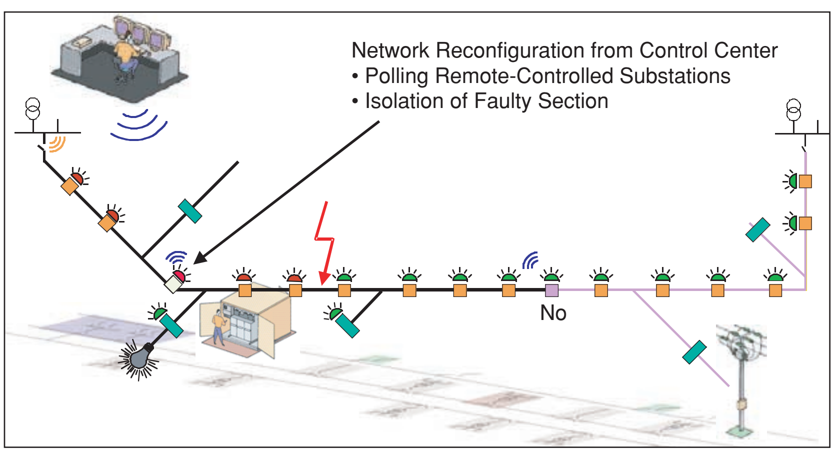

Figure 5. Localization of the faulty section

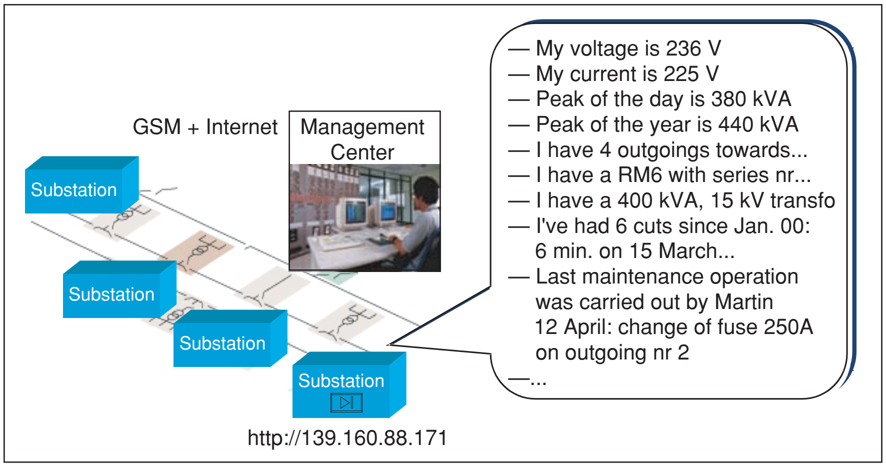

Figure 6. Communication system

- One to three fully telecontrolled substations per primary feeder
- All substations equipped with FPIs
- Some substations equipped with remote FPIs.

A very good solution is the following: 10 to 15% of the network is remote controlled, 20 to 30% of the network is equipped with remote FPIs, and the rest of the network is equipped with FPIs.

Progressive Investments

The automation of an existing network through progressive, long-term investment is suggested, since the replacement of all existing substations by new ones requires a long time and is very expensive. Moreover, motorization of old equipment is difficult, and its reliability is not guaranteed.

Placement of FPIs in all underground substations is strongly advised. The benefit is immediately visible in terms of time to localize a fault, but also in terms of saving the asset, since it is easy to install FPIs on an existing network, and the localization of the faulty section is done by a patrol relatively fast.

Remote controlled substations can be used in order to meet new supply needs. Another solution is to add remote control network points between existing substations, to use remote control interfaces for the remote command of substations, and to gradually automate the network.

Remote Management and Monitoring of Substations

In the following, a new multifunctional device dedicated to substation remote management and monitoring is proposed.

Hardware Architecture

The system comprises a device called a remote management unit in each distribution substation and a Web server situated on the user's intranet, which concentrates information access. The Web server and the remote management units are linked via the global system for mobile communication (GSM) network. The server has a telephone modem. This architecture (first phase) allows access to data in the client Intranet. Moreover, a second phase involves placing the server on the Internet. The aim is to provide data access for different correspondents and to enhance the service provision. The architecture for the second phase will be similar to that of the first phase, however the server will be hosted by a service provider and must integrate data access security.

The remote management unit is situated in the LV switchgear of the distribution substation.

The Web server is a personal computer (PC) or an equivalent tool of the market, which is exclusively used as a data concentrator. The server is connected to the Intranet network via a standard Ethernet link. The maximum number of remote management units used with a single server is 8,000.

The system, thanks to new Web and GSM technologies, which are becoming less and less expensive, makes it possible to:

- Access pertinent information from anywhere via communications standards (GSM, Web browser)
- Propose a delocalized maintenance service to utilities (asset management)
- Provide utilities with information about load curves, quality of service, alarms on events, and substation equipment characteristics.

From his/her PC, the user can access information using a simple navigator. If an alarm occurs, the user receives an e-mail or a short message service (SMS) message. Figure 6 presents the whole communication system.

Software Architecture

The substation carries a remote management unit that includes four analog inputs for current measurement (three phase and one neutral), one analog input for voltage measurement, one analog input for transformer temperature measurement, six digital inputs (for alarms and events), two relay outputs, and a connector for local interface.

The archived information is adapted to substation supervision, and it includes:

- Power records covering 1 year
- Service cut-off (outage) alarms
- Alarms for temperature thresholds of distribution transformer
- Alarms for power thresholds
- Miscellaneous substation information (equipment, interventions, etc.)

- Records of input/output status changes
- Records outages and voltage dips.

In remote mode, the information is displayed via a Web browser. A Web server is, therefore, placed in the user's network (intranet or possibly Internet). For each substation, it is possible to display the following pages:

- Substation information page, which shows physical location of substation, type of equipment, maintenance operations, etc.
- Substation status page, which shows the status of the substation on the date of the last connection with the substation
- Event history page, which shows any change of status of one of the digital inputs and any exceeding of thresholds
- File loading page, used to download files contained in the remote management unit to the PC, using file transfer protocol (FTP)
- Configuration page, used to configure the remote management unit.

In local mode, a connector providing a link to a laptop PC is sufficient, and the local display is the same as the remote one.

Architecture Evaluation

The proposed architecture, dedicated to substation remote management and monitoring, has the following advantages:

- Optimizes transformer change: load of transformer is known so premature replacement for upgrading can be avoided, or, on the other hand, premature ageing due to overload can also be avoided
- Facilitates substation maintenance operations and manages the equipment inventory without site visits
- Optimizes intervention time: the cause of the problem and its location are known; the relay dates and records outages so as to quantify their number and duration
- Offers the possibility to connect input/output for remote alarms adapted to client needs: fault indicator, door sensor, etc.
- Besides traditional distribution substation control methods, it provides the operator (in a simple and economical manner) with all the information concerning the installations on his network (substation equipment, installation status, load curves, etc.) and in this way it notably contributes in the improvement of the quality of service. It is a relevant tool to make network planning.

The proposed architecture has the following advantages compared with an architecture where a server is integrated into the remote management unit of each substation:

- Rapid connection: Data access is faster with an intermediate server, because the pages have been saved. In addition, the server takes care of the telephone connection.
- No security problems: Access is secured by the client's Intranet.
- Simpler configuration: The configuration of parameters common to all remote management units is undertaken by the server in a transparent manner, i.e., the e-mail configured to receive alarms does not have to be updated in each remote management unit.

For Further Reading

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Biographies

Pavlos S. Georgilakis received the diploma in electrical and computer engineering and the Ph.D. degree from the National Technical University of Athens, Greece. In 1994, he joined Schneider Electric AE, Greece. He has worked in the Development and also the Quality Control departments of the Industrial Division of the company. He is currently the R&D manager. He is a Member of the IEEE and a member of Cigré and the Technical Chamber of Greece.

Christophe Prévé received the diploma in electrotechnic from the Ecole Supérieure d'Electricité, France. He worked 4 years as an electrical study manager in a French utility. He joined Schneider Electric in 1994 as an expert in protection and remote control of Electrical Network department. He is currently a project manager in the MV Division.

Yves Chollot received the diploma in electrotechnic from the Ecole Nationale Suprieure d'Electricité de Grenoble, France. He worked 5 years as a software engineer in a French aircraft manufacturer. He joined Schneider Electric in 1989 to manage projects in SCADA and remote control systems of MV equipment. He is currently project manager in protection and remote control of Electrical Network department.

Marc Bidaut graduated as an engineer from the Ecole Nationale Supérieure d'Arts et Métiers. He joined Merlin Gerin in 1982 as sales promoter of MV/LV substations. He became technical manager of MV switches and fuses ranges, then project leader of a technical data management system and technical manager of MV and MV/LV "applications." He is currently MV/LV application manager for the Medium Voltage Equipment and Systems department of Schneider Electric.

Philippe Deschamps received the diploma in industrial engineering from the Centre d'Etudes Supérieures Industrielles of Lyon, France. He joined Telemecanique in 1983 as automation engineer, and then as project and product manager of the power supplies line for industrial control. After changing for the MV world in Merlin Gerin, he is presently project marketing manager in the MV Division.

Nikos Londos received the diploma in electrical and computer engineering from the National Technical University of Athens, Greece, in 1992. He joined Schneider Electric AE in 1994 and has been engaged in different positions, such as application engineer and being responsible for the MV and LV Panels Design office. At present, he is MV operational marketing manager. He is member of Cigré and the Technical Chamber of Greece.