Improving MV Network Efficiency with Feeder Automation

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Executive summary

This paper shows how increasing the level of network automation and control improves the operating efficiency of medium-voltage distribution networks. It evaluates the investment necessary for various technological solutions to minimize power unavailability. Solutions discussed range from fault passage indicators (FPIs) and remote control, to automatic circuit reclosers (ACRs) and sectionalizers used in a feeder automation scheme.

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Summary

Abstract

This paper shows how improving the network management by increasing the level of network automation and control improves the operating efficiency of medium voltage distribution networks. The presentation shows the steps to equip the network according to progressive investment capability, from fault passage indicators (FPIs) and remote control, to automatic circuit reclosers (ACRs) and sectionalizers used in a feeder automation scheme to minimize the number of disturbances and the outage times experienced during them.

Introduction

An increasing demand for energy

A direct consequence of population growth and related economic development at the industrial, commercial, and tertiary levels is an increasing demand for energy. To meet that, utilities need to produce more power but also to improve their transmission and distribution networks for customers who demand more energy reliability.
In countries with fast growing economies, MV distribution networks spread at such a speed that utilities and their employees need very efficient global solutions to decrease outage occurrences and duration, hence improving the quality of service.

Depending on the technical solutions chosen, it is possible to help chase the revenue losses (non-distributed energy or non-technical losses).
The present paper describes the benefits of fault tracking and network reconfiguration to help achieve these goals.

Measuring the quality of supply

To reach the required level of quality of service, it is first necessary to accurately quantify it. To do so, utilities commonly use measurement indexes (source: CEER EU-25 3rd benchmarking report on quality of electricity supply):

- the "SAIDI" (System Average Interruption Duration Index) measures the average cumulated power outage time during one year and per customer
- the "SAIFI" (System Average Interruption Frequency Index) measures the average number of outages.

When comparing the SAIDI measured in the 1990s on the LV standpoint, we can see that this index varied from 16 min to 11 h 30. In France, the quality of service in the 10 largest cities continually improved from 1990 to 1997 thanks to EDF's investment efforts: in seven years the SAIDI went from 2 h 00 to 19 min.

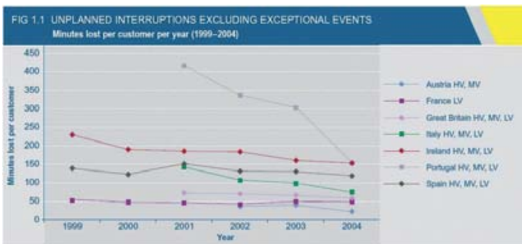


Fig. 1 - Source: CEER 2005 report

But the picture is not as nice when "exceptional situations" are taken into account:

Fig. 2 - Source: CEER 2005 report

Last but not least, if we look at the cause of faults, 25 per cent come from the HV network, 25 per cent from the LV network, and 50 per cent from the MV network. The MV network is therefore the part of the overall network to which the greatest care should be taken to improve the quality of service.

Another variable to be taken into account in the quality of service is the cost estimation for non-distributed 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. That is why this cost can vary from 5 to 30 dollars per kWh.

A global approach

Each of the significant problems listed here (safety, voltage losses and drops, long outages, and numerous short outages) can be solved by taking appropriate actions on the MV network, such as protection, reactive compensation, an adapted neutral system with ASC, multiple sectionalizing, and the use of appropriate fault detection tools.

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

- standalone FPIs
- remote monitored FPIs
- remote controlled switchgears
- recloser and sectionalizer automation.

These solutions of feeder automation can be used separately or together. Historically, the remote control with SCADA comes from European networks, while the recloser and sectionalizer automation without remote control is inspired by American networks.

The choice between these kinds of solutions is indeed a technical-economical choice, FPIs being a very economical solution to significantly improve the quality of service, while remote controlled systems require a bigger investment but allow an even bigger impact. Pole mounted reclosers used in distribution lines are a very efficient solution to clear transient faults and isolate faulty sections, however no utility is rich enough to install on every branch.

The global approach concept aims to increase the efficiency of network management, in terms of investment optimization, reduction of minutes lost, reduction of customers concerned by loss of voltage, and reduction of time to localize and reconfigure.

It involves the segmentation of the network into three levels. Three types of substations will split the distribution network into three types of section.

Three types of substations

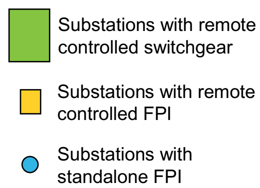
The fault location and network reconfiguration scheme is defined by the use of three main types of substation:

- Type 1: S/S or pole mounted switch with standalone FPI
- Type 2: S/S or pole mounted switch fitted with remote controlled FPI
- Type 3: S/S or pole mounted switch fitted with a remote control cabinet including FPI function.

A trade-off is to mix the three types according to various criteria such as number of customers, accessibility of the S/S, importance of customers in each section (hospital, ministry, plant, etc.).

According to all these above considerations, a typical network feeder could be organised as follows:

- 1 to 3 S/S with full remote control
- 5 to 10 S/S with remote controlled FPI
- all other S/S with 1 FPI for all other S/S.



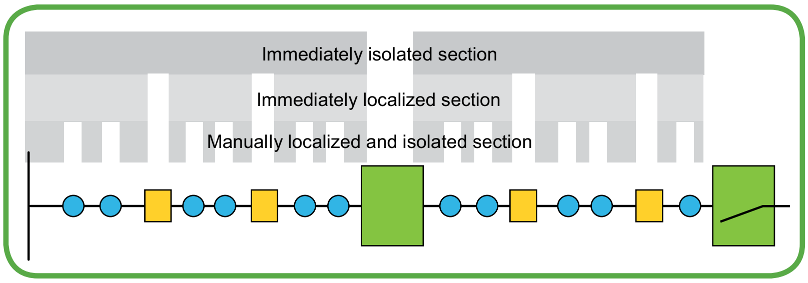


Fig.3

A graduate solution

The concept of the definition of three main types of sections helps to simplify the investment analysis regarding the reality of the network. A network could be equipped gradually according to progressive investment capability.

The first step is to place FPIs in all ground mounted S/S. The benefit is immediately visible in terms of time to locate faults, but also in terms of saving assets because FPIs are easy to install in an existing network and the localization of the faulty section is done relatively quickly by a patrol. The second step is either to install fully remote controlled S/S, which offers the benefit of quickly isolating the faulty section from the control centre, or to install an FPI connected to the control centre in order to decrease the duration of outages.

Fault passage indicators

Standalone FPIs

Fig. 4 - UG: FPI embedded in the RMU

The fault detection function must be seen as a part of the network protection plan. So, depending on local specificity of line and cable distribution, the setting should be adapted for greater accuracy of the function.

Fig.5 - OH: clip-on fault passage indicators

Remote controlled FPIs

Clip-on FPIs

The first solution was simply to add a radio chip inside an existing clip-on FPI, which was sending a short range radio signal to a radio receiver located in direct line of sight at 10 metres from it. The contact of the receiver was connected to the digital input of a small RTU that was forwarding the signal to the SCADA. Since then, users have discovered that this technical solution lacked three main features:

- First, it was impossible to remotely test the short range radio link: if a tree branch grew in the path of the direct line of sight between the FPI and its receiver, then the whole system stopped working.
- Second, when the battery was empty, the receiver could not be informed and so the SCADA operator would not get an alarm.
- Third, given the fact that there is a remote communicating indicator installed, it should be possible to get current measurements as well, in order to optimize the data communication costs (GPRS, etc.).

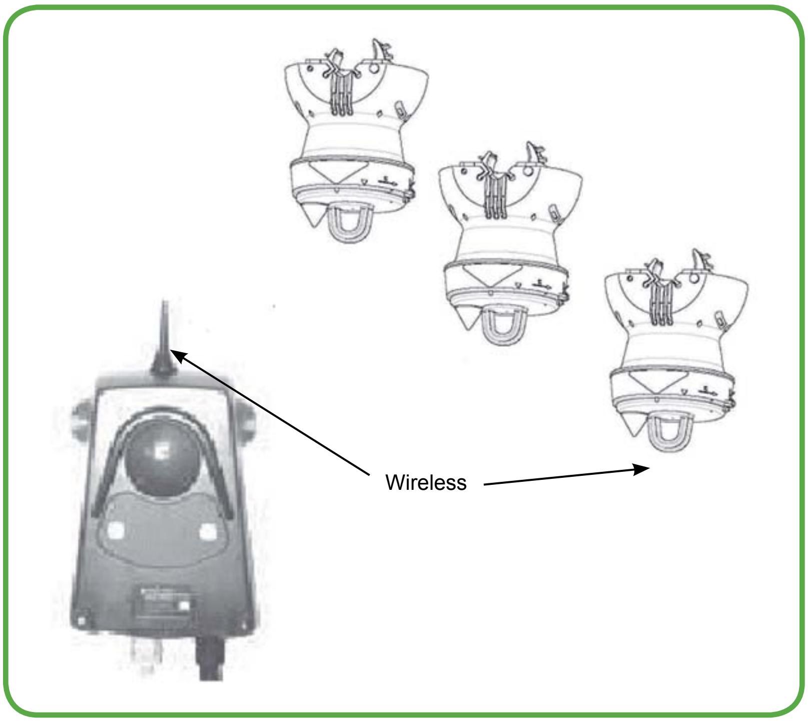


Fig.6

Some manufacturers have covered the gap, by designing a system where the FPI and the receiver use a bidirectional radio communication system, and where the receiver is based on a true RTU with advanced features like remote FPI configuration (fault thresholds, etc.), more than three FPIs connected to a receiver, and metering functions.

Pole-mounted FPIs

Obviously such FPIs do not suffer the drawbacks of a wireless link. It is very easy to connect the dry contact output relay of a standalone FPI to a small RTU and this allows it to report an alarm to the SCADA.

However, it is not able to manage more than one MV line, except when located near a branch. In addition, it cannot accurately measure the load on the phase conductors.

Underground cables

With underground cables, the solution is even easier because there is no wireless link requested. The FPI is connected to three phase CTs. From a functional point of view, this is a downsized version of a true remote control cabinet, with the difference that it does not have the power supply to run a switch motor (it offers current and power measurement, time-stamped event recording, remote parameter settings, etc.).

Remote control

In a remote controlled S/S, electronic components have to perform a number of functions. The first one is an RTU function to control the switchgear from the SCADA when a fault occurs. The RTU supports a range of protocols (IEC, DNP3, etc.) and MODEMs (GPRS, GSM, PSTN, radio, etc.). It concentrates existing intelligent electronic devices (FPIs, protection relays, power measurement devices, etc.).

The remote controlled S/S also serves as a backup power supply for switchgear motorization, because most remote controls are operated during outages.

The FPI functions include direct acquisition from current transformer, phase over current and earth fault thresholds, load, and/or power measurement facility.

The devices also have interface functions: a dedicated interface with the switchgear, ready to connect, with a graduated capacity from one to numerous feeders and operating local interface and maintenance facilities.
Such a control cabinet may be built from standard components: however, a specially designed control cabinet (IRTU or integrated remote terminal unit), is cost effective. Fully tested units from complete control cabinet manufacturers are more attractive, for they guarantee a safe installation, a simplified commissioning, full EMC compatibility, and the minimum wiring and cabling, which dramatically increases the reliability and the availability of the control system.

Fig.7- IRTU : integrated remote terminal unit for four feeders

MV overhead feeder automation

In an effort to improve the reliability of supply, providers are rethinking the levels of sophistication deployed in their medium voltage (MV) overhead feeders. An auto-reclose cycle should clear a transient fault without interrupting supply to the customer. In most cases no further operator assistance would be required to clear the fault.

Fig.8 - Solid dielectric recloser

Some faults are however more permanent. Examples include distribution equipment, such as transformer failures and fallen power lines due to motor accidents or storms. Protection equipment is designed to minimise damage by interrupting the supply to a segment containing a fault. The supply will remain off until the fault is removed and the protection equipment is turned back on.

Today's reclosers are capable of sophisticated protection, communication, automation and analytical functionality. It is possible to operate in either a 'manual' mode where the operator has to perform the reconfiguration of the network, or in a 'loop automation' mode where the reclosers perform the task automatically.

Loop automation

Loop automation uses time, voltage, power flow, and these simple rules to isolate the fault and reconfigure the network, without any communications or operator assistance. In a loop automation network, the following actions will take place when a fault occurs:

- The recloser immediately upstream of the fault automatically trips, recloses to lockout, and remains open.
- Reclosers downstream of the fault automatically change the protection settings in anticipation of power flowing in the opposite direction.
- The normally open tie-recloser closes automatically.

Due to the fault still being present, the recloser immediately downstream of the fault trips, and locks out without reclosing. This will automatically restore power to the healthy parts of the network. An operator can now despatch line crews to the faulted segment.

Recloser and sectionalizer automation

A feeder automation network combines reclosers and sectionalizers in a feeder to provide grading on both current/time and number of operations. This is accomplished by introducing up to two sectionalizers in each zone protected by a recloser. In a feeder automation network the reclosers protect the downstream portion of the feeder up to the next recloser.

Similarly to the recloser network described earlier, the recloser will trip and reclose in the presence of a fault and the sectionalizers count the through-faults similarly to the sectionalizing switchgear network described earlier. The difference is that if the fault occurs downstream of a sectionalizer, the sectionalizer closest to the fault will open before the recloser reaches lockout. Therefore, for this system to work correctly, it is essential that the recloser is configured with four trips to lockout and the sectionalizers are configured with supply interrupt counters of three and two respectively.

Conclusions

It is now clear that in most countries, delivering electricity with a high level of quality and availability is becoming a priority challenge. For years and years the utilities have experimented with various solutions. It is now time to take advantage of all this experience.

It appears clear that remote control and fault detection are two of the key solutions. The customers are mainly affected by faults on the distribution MV network, to which, consequently, we have to pay particular attention.

The introduction of fault detection, network monitoring and control and automation needs to be driven by pragmatic and optimized actions.

The icing on the cake when using remote controlled FPIs and IRTU fitted with load measurement and feeder automation, is that utilities can easily optimize their power generation and chase non-technical losses.

The global concept described here synthesizes the experience cumulated from various utilities world wide (France, Spain, UK, Australia, Canada, etc.). The components which must be associated to such a concept, such as IRTU, remote controlled FPIs, reclosers, and sectionalizers are available on the market.

Cost effective solutions are also being proposed by the main manufacturers with embedded concepts. This allows the proposal of FPIs, IRTUs, and other electronic devices built into the RMU or into the MV cubicle.

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