TECHNICAL SOLUTION FOR

IMPROVMENT OF DISTRIBUTED ELECTRICITY RELIABILITY AND REVENUE IMPROVEMENT

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1. INTRODUCTION

An increasing demand for energy

A direct consequence from population growth and related economic development at industrial, commercial and tertiary levels is an increasing demand for energy, among which electricity.
To fit that requirement, utilities need to produce more power but also to improve their transmission & distribution networks, for customers demand more energy reliability.
In countries with fast growing economy, MV distribution networks spread at such a speed that utilities and their employees need very efficient global solutions to decrease outages occurrences and duration, hence improving the quality of service.
Depending on the technical solutions chosen, it is possible to help chasing the revenue losses (non-distributed energy or non-technical losses).
The present conference describes the benefits of fault tracking and network reconfiguration that help to achieve these goals.

De-regulation

Sooner or later, most utilities are facing de-regulation, which leads to various adaptations and new concepts of network operation.
Even in countries where the de-regulation process has not yet started, these concepts are applicable to improve the distributed electricity reliability and revenues.

Measuring the quality of service

To reach the required level of quality of service, it is first necessary to accurately quantify it in a factual manner. To do so, utilities commonly use measurement indexes (sources: CEPSI 98, SEE 98):

- the “**SAIDI**” (system Average Interruption Duration Index) measures the average cumulated power outage time during one year,
- the “**SAIDIp**” (system Average Interruption Duration Index for only permanent outages) measures the average cumulated long outages (exceeding 1 minute) during one year,
- the “**SAIFI**” (system Average Interruption Frequency Index) measures the average number of outages per year and per customer,

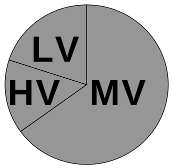
- the “**SAIFIp**” (system Average Interruption Frequency Index for only permanent outages) measures the average number of long outages per year and per customer,
- the “**SAIFIsh**” (system Average Interruption Frequency Index for only short outages) measures the average number of short outages (from 15 to 30 seconds) per year and per customer.

When comparing the SAIDIp measured in the ‘90s on the LV standpoint, we can see that this index varied from 16 min (RWE, Germany) down to 11h30 (Light, Brazil). For EDF France, it was 52 min in 1998.

In few big well-supplied cities, the SAIDIp index varied from a few minutes to several dozen of minutes (Rotterdam 1991: 9.3 min, Tokyo 1991: 11 min, Berlin 1991: 16 min, Copenhagen 1991: 25 min, London 1995: 54 min, New York 1995: 1 min) but the SAIFIp index was often less than a unit (Rotterdam 1991: 0.12, Copenhagen 1991: 0.45, London 1995: 0.34).

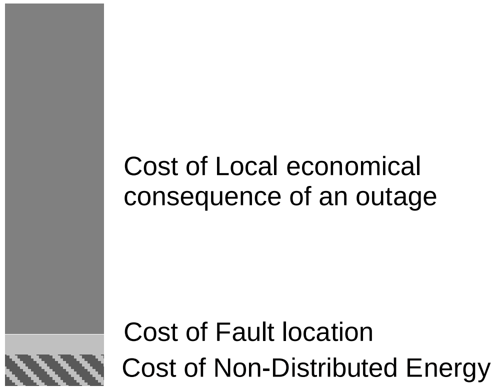
In France, the quality of service in the 10 largest cities continually improved from 1990 to 1997 thanks to EDF investment efforts: in 7 years the SAIDIp went from 2h00 down to 19 min, the SAIFIp from 2.2 down to 0.59 and the SAIFIsh from 2.3 down to 0.31.

Last but not least, if we look at the cause of faults, 25% come from the HV network, 25% from the LV network and 50% from the MV network.



The MV network is therefore the part of the whole 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 (7 to 10 dollars according to TNB Malaysia).



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 effects and costs that were accepted as the consequence of an outage.
The experience of many utilities shows that the quality of service can be improved when some technical solutions are applied on the electrical network itself: splitting the network into short sections, increasing its redundancy and implementing appropriate automation, increasing the dependability of network components and implementing remote control and fault detection devices.

Outages

The Medium Voltage (MV) network is the first part to take care of. Faults may come from both Distribution lines as from Underground cables.

Underground network are made of numerous MV/ MV and MV/ LV substations that are manually operated and difficult to access due to geographical constraints, distance or automobile traffic. They are affected by bad weather conditions (floods, etc.) and may offer a poor quality of service that translates into numerous long outages (SAIDIp varying from 2 to 10 hours), high operating costs, and safety problems for maintenance staff and consumers.

Overhead networks are often made up of long lines (radial lines from 10 to 100 km long), and are affected by harsh environment conditions (sand storms, rain, snow, quick temperature variations, industrial or natural pollution, etc.). The result may lead to poor efficiency and poor quality of service: numerous short breaks due to transient faults, long outages

(SAIDIp from 3 to 15 hours), considerable voltage drops, an overloaded network and considerable losses (from 10 to 15, even 20 % loss). Operating costs are often high as well whereas operators and the public can be subjected to safety problems.

Each of the significant problems listed here (safety, voltage losses and drops, long outages, numerous short outages) can be solved taking appropriate actions on the MV network, such as protection and control-monitoring, reactive compensation, multiple sectionalising and use of appropriate fault detection tools.

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

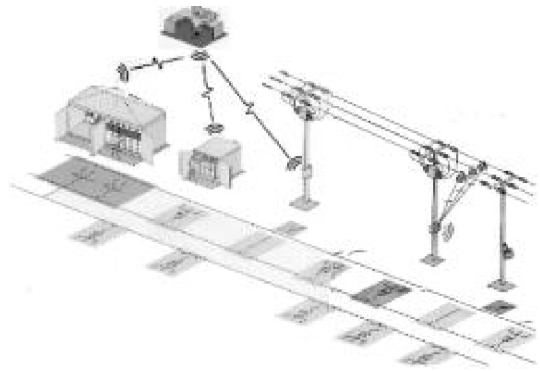
- Standalone fault Passage Indicators (FPIs).
- Remote controlled FPIs
- Automation and remote control systems

These solutions can be used separately but also associated –in this 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 technico-economical choice, Fault Passage Indicators (FPIs) being a very economical solution to improve significantly quality of service, while remote control systems, with bigger investment, allowing even bigger impact.

Pole mounted reclosers used in Distribution lines are a very efficient solution to clear transient faults and isolate faulty sections (for permanent faults), however no utility is rich enough to install them on every branch.

A global approach

The network management involves remote control functionality.



MV distribution networks often have a tree structure mainly with overhead lines. The selection and placing of equipment and control system in these networks require careful planning to make the best of its performance. There are many possible ways (not exclusive) to place remote control points and FPIs on the network:

- retrofitting existing pole mounted or S/S switchgears with remote control, the difficult point being the motorization of the switchgears
- installing FPIs on existing pole mounted or substation switchgears,
- creating new remote controlled points (pole mounted or S/S) corresponding to the available power growth in the MV network,
- creating remote controlled network points, fitted with current measurement capability to improve network dependability without increasing the available power
- anticipating the expansion of remote controlled points by systematically installing motorised MV switches.

The global approach concept aims to increase the efficiency of the network management, in term of investment optimisation, reduction of minutes loss, reduction of customers concerned by loss of voltage and reduction of time to localise and reconfigure.

It involves a segmentation of the network into 3 levels. 3 types of substations will split the distribution network into 3 types of section

3 types of substations

Fault location and network reconfiguration scheme is defined from the use of 3 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

3 types of network sections

These 3 types of S/S split the network into 3 main sections:

- Small section edged by type 1 substations
- Medium section edged by type 2 substations
- Large section edged by type 3 substations

Each of these section may be characterised as follows:

- The faulty large section can immediately be isolated by the remote control centre. All customers in this section are not re-energised when the network is reconfigured: the larger the section, the bigger the number of customers with a long outage.

- The faulty medium section is immediately localised at the control centre. The maintenance crew is directly dispatched to the manually operated switch for opening. The result is that all customers in the healthy medium sections are supplied in a relatively short time.

- The faulty small section needs the maintenance crew to patrol the network. The time need to reach the faulty section and isolate it is rather long. Generally this section is as short as possible, and needs FPI function to be installed in each substation (underground cables) or at each branch (overhead lines).

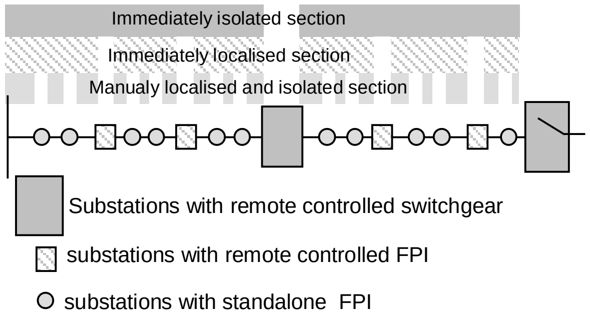
The most efficient scheme is to retrofit all S/S with a remote control unit, but this not an optimal situation in term of economical approach.

A trade-off is to mix the 3 types according to various criteria such as :

- Number of S/S on a feeder
- Number of customers in each section
- Importance of customers in each section (hospital, ministry , plant, ...)
- Accessibility of the S/S
- Data communication facilities for remote indication
- Motorization facilities in existing substation

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



A graduate solution

The concept of the definition of 3 main types of section give the advantage to simplify the investment analysis regarding the reality of the network.

A network could be equipped gradually according to progressive investment capability.

A first step is to place a FPI in all underground S/S. The benefit is immediately visible in term of time to locate faults, but also in term of saving assets.

- FPI are easy to install on an existing network
- The localisation of the faulty section is done by a patrol relatively fast
- There is no need to reclose the feeding circuit breaker on the fault.

A second or third step is to install fully remote controlled S/S. This operation give the benefit to quickly isolate the faulty section from the control centre. If this customer need is more important than to accurately locate the faulty cable or line, this step should be done first.

The choice depends on the importance given to outage duration and number of customers affected by a loss of voltage.
The installation of such functionality in a substation is easier if it has been defined before the substation installation for new networks.
For existing S/S, adaptable control unit could be used, but generally the better solution is to add new substation with remote control facility at strategic point of the network.

<u>In a third or second step</u>, FPI connected to the control centre have to be added in order to decrease the number of customer victim of loss of voltage, by reduction of the size of the isolated section.

An other aspect to optimise the investment and increase the efficiency of the network management is to take care of the functionality of the electronic components.

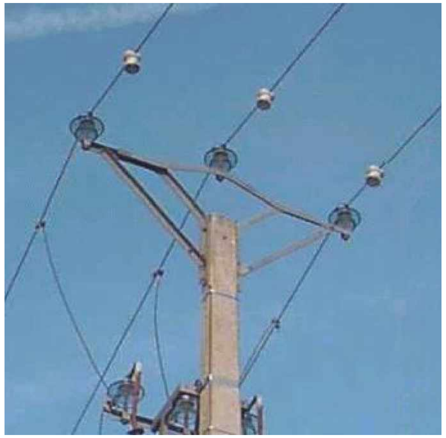
II - Fault Passage Indicators

<u>Standalone FPIs</u>

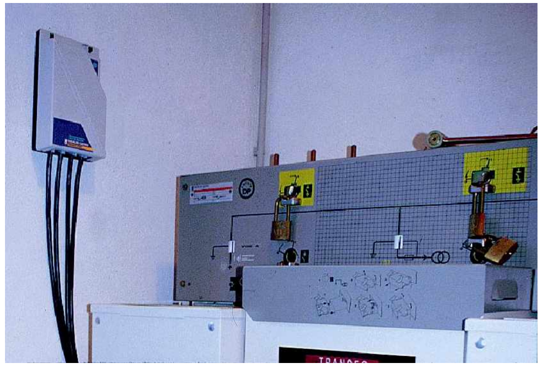
The Fault detection function must be seen as a part of the network protection plan. So, depending on local specificity of line and cable distribution, the setting should be adapted for a better accuracy of the function. consequently, the FPI function have to be fully programmable. Obviously, it is also a key economic factor as it allows stock management optimisation.

The FPI range should be used either on underground cable network or overhead lines (pole mounted or clip on the line).

On underground cables, FPIs can be either wall-mounted on existing switchgears (RMUs or others) or delivered embedded in the RMU panel.



OH: Clip on Fault Passage Indicators



UG : wall mounted FPI

OH : pole-mounted FPI

UG: FPI embedded in the RMU panel

Remote controlled FPIs

Overhead lines

Clip-on FPIs

When utilities started to think of dreaming of getting the output of clip-on overhead FPIs (in case of network fault) directly at the SCADA, some manufacturers have simply added a radio chip inside their existing clip-on FPI, that was sending a short range radio signal to a radio received located on a direct line of sight at 10 meters from it. This radio receiver was closing a contact upon fault occurrence and opening it upon MV return. The contact of the receiver was connected to a digital input of a small RTU that was forwarding the signal to the SCADA.
At first, this simple solution seemed to fill the need.

Since then, users have discovered that this technical solution was not finished for it lacked three main features:

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

Some manufacturers have covered the gap, by offering more than what initially required. By designing a system where the FPI and the receiver use a bi-directional radio communication system, and where the receiver is based on a true RTU fitted with a data communication interface (RS232, GSM/ GPRS, .), it has become possible to offer what was missing:

§ Alarm upon wireless link (short range communication) failure
§ Alarm upon battery low level
§ Load measurement

Plus more:

§ Remote FPI configuration (fault thresholds, etc.)
§ More than 3 FPIs connected to a receiver.
§ Time stamped recording of all events from FPIs and receiver

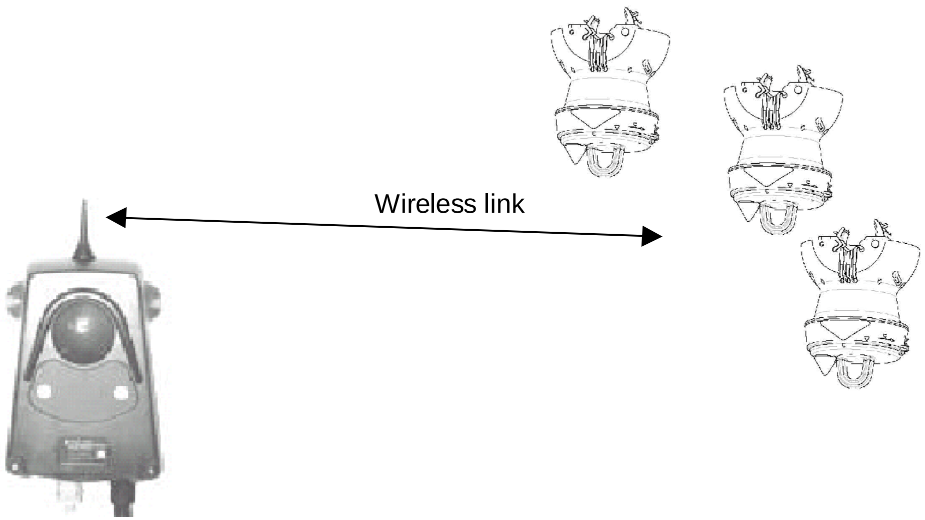
Pole mounted FPIs

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 reports the alarm to the SCADA.
However, it is not able to manage more than one MV line, even when located near a branch, the data communication system cannot report the information from the main trunk and the nearby branch: from a remote communication point of view, it is not optimised.
In addition, it cannot measure the load on the phase conductors, so the link cannot be optimised in that aspect as well.

Underground cables

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

In order to simplify the communication function, it is recommended to use remote controlled FPIs that use a solution compatible with the remote control unit one (same protocol and same data communication media).



III - Remote control

In a remote controlled S/S, electronic components have to perform the following functions:

- RTU : communication with control centre
  - Storage and time-stamping for events and measurements
  - Support the range of protocols (IEC, DNP3, etc.)
  - Various data communication media (GPRS, GSM, PSTN, Radio,.)
  - Local & remote configuration of all components of the control cabinet.
  - Remote downloading of software update and S/S configuration
  - Concentrating facility for existing IEDs (protection relay, power measurement devices, etc.)
  - Protocol communication tracing system (to find why the link to the SCADA does not work, in case that happens)
- Backed-up Power Supply for :
  - Switchgear motorisation
  - Modem
  - CPU
- FPI function including
  - Direct acquisition from Current Transformers
  - Phase overcurrent and Earth fault thresholds
  - Load and/ or power measurement facility
  - Remote threshold settings
- Interface with the switchgear
  - Ready to connect
  - Capacity from 1 to numerous feeders
- Local control and maintenance facilities

Such a control cabinet may be build from standard components: however, the cost of such a solution is not cheaper than a specially designed control cabinet (ISCU or Integrated Substation Control Unit), and its reliability may be questioned. Given the impact of a failed equipment on the network, fully tested units from complete control cabinet manufacturers are more attractive, for they guarantee

- A safety installation
- A simplified commissioning
- A comprehensive maintenance
- To be tested a whole at the factory.
- The full EMC compatibility.
- The minimum wiring and cabling, which dramatically increase the quality, the reliability and the availability of the control system.

Integrated **S**ubstation **C**ontrol **U**nit for 4 feeders.

IV - Conclusion

It is now clear that in all developed countries, delivering electricity with high level of quality and availability becomes a priority challenge.
From years and years the utilities have experimented various solution. It is now time to take advantage from all these experience.
It appears clearly that the remote control and the 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 a particular attention.
The introduction of Fault Detection and network monitoring and control needs to be driven with pragmatic and optimised actions.
The cherry on the cake when using Remote controlled FPIs and ISCU fitted with load measurement, is that utilities can easily optimise their power generation and chase non-technical losses.
The global concept described here synthesise the experience cumulated from various utilities world wide. (France, Spain, UK, Australia, Canada,…).
The components which must be associated to such a concept, such as ISCU, remote controlled FPIs, … are available on the market.