EDP DISTRIBUTION AUTOMATION (R)EVOLUTION

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ABSTRACT

The economic growth and development of a country depends heavily on the reliability of the electric power supply.

Distribution automation (DA) can yield significant cost savings through measurable improvements to operational efficiency, reliability, service quality, and energy conservation – all of which can contribute to customer satisfaction. Distribution automation is also a key component of the smart grid.

Recent investments on distribution automation (supported on telecontrol and voltage-time automatic function) contributed to considerable improvement of the quality of service in Portugal.

Presently, 2.500 automated distribution devices are installed on the 60.000 km of overhead medium voltage (MV) lines and this number will rise to 4.000 by 2012. These are broadly categorized in two types: OCR1, load break switches with actuators and telecommunications that provide dispatchers remote operation and monitoring capability and OCR 2, devices with fault interrupting capability, designed to operate automatically based on voltage sensors and timers. The OCR 2 also has telecommunication capabilities like the OCR1.

The new focus will be supported by a DA pilot project, in order to evaluate the conceptual design developed by EDP and KEMA, integrating new distribution automation philosophy, new protection system guidelines, communications protocol standardization and the quality assurance process.

Analysis factors included overall economics (TIEPI/SAIDI/SAIFI savings), MAIFI and voltage sags monitoring, customers and EDP operations feedback, construction and maintenance issues, communications stability and component reliability.

PILOT PROJECT CONCEPT AND GOALS

During the course of this project, a DA vision, philosophy, strategy and roadmap documents were produced, in order to promote a clear focus to planning, telecommunications, dispatch and procurement. Specific recommendations for the roadmap were considered and the DA pilot project was the first step. Depending on the success of this trial, future decisions considering a large scale DA initiative will be better supported.

With the new DA concept, EDP will begin to utilize line reclosers.

The OCR 3 device, with similar technical characteristics as the OCR 2 device, will include voltage and current sensing and is intended to be used as a recloser or a sectionaliser, two different operating modes, and locally or remotely controlled. In the recloser mode the OCR 3 shall work as a circuit breaker with full protection and reclosing functionality, while in sectionaliser mode implements an automatic sectionalising function. Virtually any number of sectionalizers can be installed in a feeder since their opening will depend on a logic condition of fault current sensing followed by loss of voltage. The number of reclosers in series will be limited by the need to guarantee coordination with the existing feeder protection at the substation.

When sensing a downstream fault, the OCR 3 operating as a recloser will automatically perform a sequence of reclosing operations and lock-out if fault persists. Coordination with main feeder circuit breaker is achieved through time based coordination. The installation of selective circuit breakers along the MV feeders promotes more rapid fault isolation (and closer to its location) while restraining short term interruptions (MAIFI).

It will be possible for the reclosers on normally open points (NO) to close automatically after detecting loss of voltage from the normal power flow side or by order from the control centre. The OCR 3 devices (regardless of working as reclosers or sectionalizers) on the grid must automatically adapt to the new power flow direction thus adjusting their settings. So, for each OCR 3, there will be two groups of settings: normal power flow setting and reverse power flow setting.

This DA concept is designed to coordinate various OCR 3 in two different modes and configurations, in the same feeder, promoting network automation flexibility.

The automatic reconfiguration of the network is likely to increase the number of reclosing operations into faults and will transfer some faults into healthy feeders.

As a result, short term interruptions and voltage sags might increase but TIEPI will reduce due to automatic network reconfiguration.

A possible effective way to restrain the worsening of the MAIFI indicator (that will be tested in this pilot) is to use OCR 2 devices immediately downstream and upstream of the reclosers on the normally open points. Like this it will be possible to have automatic network reconfiguration with minimum transfer of faults to healthy feeders.

The next figure illustrates a feeder containing OCR 2 and OCR 3 devices. S1 and S2 are OCR 2 type devices. In this case all OCR 3 devices are operating as reclosers, but sectionalizers can also be included.

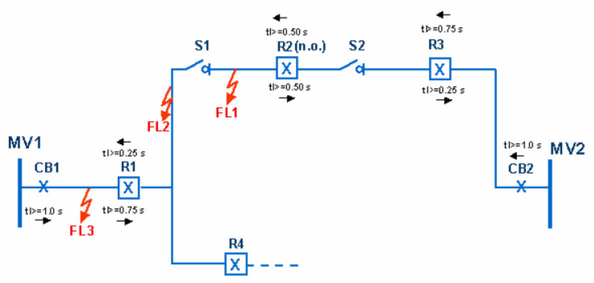

Figure 1 – Illustration of DA philosophy with automatic fault isolation and network reconfiguration

Only in presence of a fault on location FL1 there will be a possible fault transfer to a healthy feeder due to the automatic closer of R2 (N.O.). Considering a fault on FL2, after the automatic operations on the faulty feeder (R1 auto-reclose without success thus tripping and locking out; S1 opens due to the absence of upstream voltage), the automatic closer of R2 (N.O.) will supply clients between S1 and R2.

The occurrence of a fault on FL3 will cause CB1 (substation breaker) to trip and lockout, S1 will open on absence of voltage and R2 will supply all the clients downstream of S1. In order to re-establish the service to clients between R1 and S1, the operator at the control centre should manually open R1 and close S1, since he would know that CB1 only trips and locks-out for a fault between CB1 and R1.

Complementarily, FCI (Fault Current Indicator) devices will be used on simple and cheap basis, giving a visual signalling for field crews at or near the site and it does not have telecommunication facilities for costs reasons. FCI use reduces fault finding time process and service restoration.

This pilot will provide the perfect opportunity to compare DA possibilities.

Moreover, the OCR 3 devices fit without issues in the feeders that already include OCR 2 and these devices can even work as a team with the OCR 3 in order to achieve further feeder sectionalizing or even to make an important contribution on a step to automatic network restoration if adequately placed.

PILOT NETWORK SELECTION

The selection of the DA pilot network had to comply with several functional requirements: earth grounded MV network, stabilized in terms of recent years investments, reverse reconfiguration capacity and quality of service problems and was complemented with additional criteria to determine devices optimal number and location using KOLDA (Kema Optimal Location for Distribution Automation).

KOLDA [1] has been set up as a stepwise procedure, with steps that are partly heuristically based and partly calculated. It does not require access to a full Distribution Planning environment and the information needed to optimize a feeder is usually found on a single line diagram, to be supplemented with local knowledge about the region of the feeder in which to apply or optimize DA.

The general assumption is that DA-devices will be allocated based on economic feasibility, comparing investments with benefits in END. Since power is not changed by applying DA devices, reducing TIEPI and reducing END are linear consistent. Annual expected END is multiplied by a value of END to obtain monetary value (e.g. 1,50 €/kWh not distributed) and then transformed to a net present value, (NPV) in €. Thus, the value of END is also linear consistent with the TIEPI and END.

The following figure illustrates the steps taken into the validation of DA devices (number and location) as well as fault current indicators.

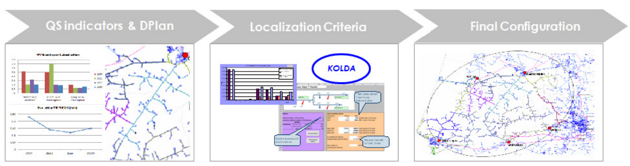

Figure 2 – DA devices and FCI validation

The pilot network will involve 5 substations in the centre of Portugal (Cantanhede, Tocha, Vila Robim, Alfarelos e Taveiro), 16 MV feeders (500 km), 25 OCR 3 and 60 stand alone fault current indicators (FCI) and will last for 6 months (2011).

The next figure contains a brief resume of quality service provided per substation, considering the events each feeder of the DA pilot had since 2007 till November 2010.

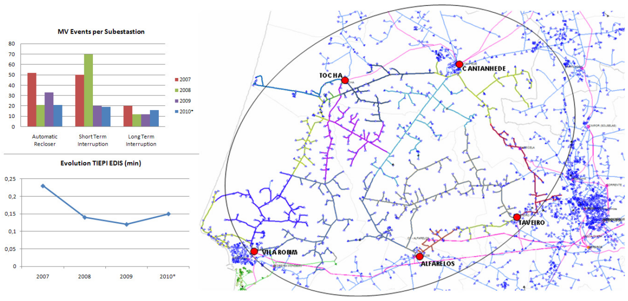

Figure 3 – DA Pilot Network

PROTECTION SYSTEM AND RECLOSING PRACTICES IMPACT

The application of the OCR 3 devices with protection functions (reclosers) along MV overhead lines is expected to have impacts on the current protection and reclosing practices of EDP.

The most obvious of these impacts has to do with the settings of the over-current protection, since the protection tripping time has to be coordinated with the downstream reclosers. In order to have a maximum of 3 reclosers in series, it is necessary to have the feeder protection at the substation trip in no less than 1 sec. Simultaneously, in order to guarantee coordination with protection of the HV system, it is not advisable to allow feeder protection tripping times greater than 1 sec.

EDP current practice of using different protection times depends on fault current. This is especially true for phase-phase faults where there can be up to three tripping stages depending on the value of the fault current. This protection philosophy is especially useful to mitigate the severity of voltage sags. For currents over 2 kA, EDP uses instantaneous tripping. If reclosers are applied along the feeders, then it is not advisable to use instantaneous over-current protection at the substation, since coordination with the reclosers will not be guaranteed. Although it is possible to implement current based coordination between the reclosers on the line and the feeder protection at the substation, there are practical issues, such as the need to update the settings every time there is a change on the upstream HV network or the difficulty to coordinate with reclosers that are installed close to the substation, that make this a hardly viable alternative.

Regarding phase-ground fault protection, EDP uses a fixed time setting for the protection at the substation, for which it is possible to implement time based coordination with the reclosers along the feeder. However, EDP is also using a sensitive earth fault protection to detect high impedance faults. This protection is set for tripping at 2 A current and is based on a dedicated very inverse tripping characteristic. Sensitive earth fault protection is also offered by the recloser manufacturers and the viability of the coordination between the reclosers and substation feeder protection can be tested during the pilot project and discussed with the manufacturers. The objective is to conclude about the use of this function also at the reclosers or keep it only at the substation (statically, this high impedance faults represent a minor percentage of the universe of faults).

Finally, there will be also impacts in current reclosing practices. Presently, auto-reclosing cycles start instantaneously by the detection of fault current (between phases or to ground), i.e. reclosing does not depend on the circuit breaker tripping on a definite time basis. If reclosers are present along the feeder, this will mean that the reclosing cycles at the substation will start before the reclosers operate, thus causing the recloser application to lose interest. In order to overcome this issue it is necessary that the reclosing cycles at the substation are triggered by the circuit breaker tripping.

Once again, the pilot project presents the perfect opportunity to assess the impacts of these changes both on reliability indicators and power quality aspects such as voltage sag severity. One interesting aspect is that faults close to the substation are expected to take longer to eliminate than before thus originating more severe voltage sags. The trade-off between improving reliability indicators (that actually have regulatory targets) and having more severe voltage sags should be shown during this experience and analyzed.

TELECOMUNICATIONS DECISION

Most DA devices on the EDP medium voltage networks communicate with the control centers through VHF radios. This technology is low cost and suitable for small-scale pilot applications, but does not have enough bandwidth and reliability to support a large DA initiative.

EDP also uses GPRS (General Packet Radio Service), oriented for the mobile data service on the 2G and 3G cellular global communication system (GSM). It has inherently more bandwidth than VHF, but requires the use of repeaters which can become overloaded and can drop messages during periods of high message traffic.

To address both issues (protocol and communication technology), EDP decided for the adoption of a standard protocol, the IEC 60870-5-104, used in Utilities of European Countries in SCADA networks. Following the development of network technologies, IEC 60870-5-104, which covers transmission over TCP/IP, is nowadays growing in use for communications between RTU's and Control Centers. EDP specified a Protocol Implementation Document (PID), expressing the requirements needed for this DA application.

A lot of utilities are now using/planning a high-speed telecommunication network to all their substations and to use IP based communication.

Combining the communication channel for more than one purpose is cost effective and efficient.

For the wireless TCP/IP transmission, EDP decided to support the DA initiative in GPRS technology, not only because of the low cost of GPRS modem's and data communication, but also because of the telecommunication infrastructure itself, required to have country wide range.

During this pilot, EDP will also test if a public operator can deliver the wireless requirements needed for the success of this pilot, namely: availability, security, maintainability, compatibility, flexibility, expandability, reliability, capacity, performance.

MARKET SOLUTIONS PORTFOLIO

Current technology is acquired in a restrict market of suppliers.

The new DA approach will allow to broad this supplier market by acquiring off-the-shelf solutions (besides some specific software development for local automatic functions) provided by world class suppliers.

In the framework of this pilot, acquirement, quality assurance and supply chain processes of different suppliers will be evaluated.

EDP expects more aggressive supplier's competition in order to achieve cost reduction, reduce delivery time and improve overall quality.

IMPLEMENTATION PROGRAM

The table presented bellow resumes the macro activities of this DA pilot.

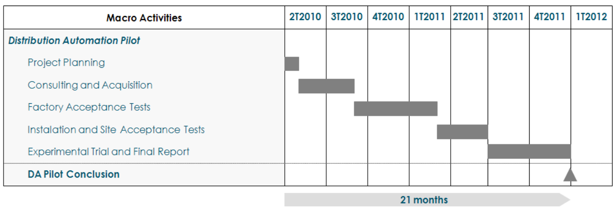

Figure 3 – Implementation Program

CONCLUSIONS

EDP and stakeholder's expectations involve the achievement of higher standards of quality of service, thus providing focus for a philosophy change in distribution automation.

Our expectation is to determine if this conceptual design has the positive translation into normal network operations and if the real achievements can support a decision for subsequent country roll-out.

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[1] Increasing quality of supply of EDP through optimal and strategic distribution automation design, 20th CIRED International Conference, 8-11 June 2009 (R. Oliveira, G. Bloemhof, A. Blanquet)

[2] Fault Current Indicators Specification for MV Overhead Lines, 9/08/2010 (M. Morgado)

[3] Specification Pole Mounted Recloser and Controls OCR 3, 15/09/2010 (M. Morgado)