EDP DISTRIBUIÇÃO'S ASSET MANAGEMENT TOOL SUPPORTED BY REAL TIME MONITORING

Hugo FERREIRA
EDP Distribuição - Portugal
hugo.ferreira@edp.pt

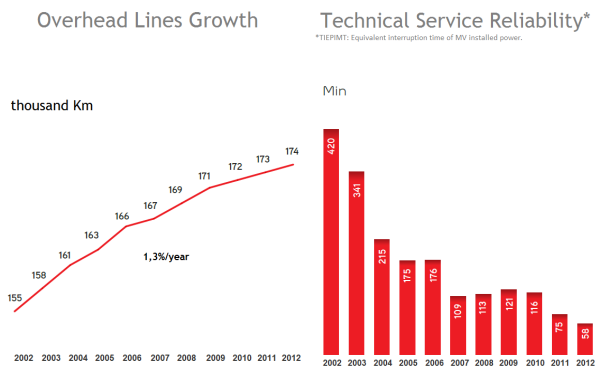
Pedro CARREIRA
EDP Distribuição – Portugal
pedro.carreira@edp.pt

Rui BERNARDO
EDP Distribuição - Portugal
Rui.bernardo@edp.pt

Jorge GOMES
EDP Distribuição - Portugal
Jorgemanuel.gomes@edp.pt

ABSTRACT

The development of the distribution network in the recent past has been marked by a reduction in its growth rate in terms of extension, as evidenced in Figure 1 a).



a) *b)*

Figure 1 – a) EDP Distribuição Overhead Lines Growth; b) Technical Service Reliability

This is due not only to the macroeconomic situation, which has conditioned the energy needs, but also to the very state of maturity of the extension of the distribution network. The quality of technical service has also had a marked improvement in the last decade, and its tendency to get closer to an optimum level (Figure 1 b)).

In regulatory terms, the scenarios are increasingly large regulatory requirement, from the point of view of investment optimization, operational efficiency and even higher levels of service quality. Based on PAS55 (Publicly Available Specification, published by the British Standards Institution) EDP Distribuição is implementing an asset management system, which will pave the way the implementation of innovative asset management policies and risk management practices. Supporting these new asset management system it is necessary to change the paradigm of maintenance that has been adopted so far. Predictive maintenance appears as a new factor that will able EDP Distribuição to act at the right time just before any failure happens, thus reducing the number of outages, improving quality of service and reducing costs. The online monitoring systems allow EDP Distribuição to respond to this challenge. Active Breather, online monitoring of primary and secondary substations and Park vector analysis of Power Transformer [5,6] are being developed by EDP Distribuição.

INTRODUCTION

EDP Distribuição, an EDP Group utility, is the main Portuguese electricity Distribution System Operator (DSO), managing 60kV, 30 kV, 15 kV, 10 kV, 6kV and 0.4kV networks in Portugal. With more than six million customers, 400 HV/MV substations, 65,000 MV/LV substations over a network that includes 80,000 km (49,712 miles) of HV and MV networks and 140,000 km (86,996 miles) of LV network, EDP Distribuição is continuously aware of innovative and competitive solutions that help to implement real time monitoring in order to explore and manage assets with high levels of reliability and efficiency and to contribute to a global asset management solution.

Until now EDP Distribuição has developed its maintenance activity based on policies that focus primarily on Time Based Maintenance (TBM) and Condition Based Maintenance (CBM). For each asset, maintenance manuals exist, which define on-site inspections and electrical tests, as well, as their periodicities. The information that results from the maintenance activity is loaded into the corporate systems and has allowed EDP Distribuição to establish maintenance plans for short and medium terms. However, it is not possible to follow in real time or regularly the health index of each asset.

OPERATION AND MAINTENANCE IN EDP DISTRIBUIÇÃO

For each asset EDP Distribuição has specified a maintenance program, which is based on visual inspections and electrical tests with monthly or five-year periodicities depending on the asset and its risk profile. The information that results from the maintenance activity is scattered into various corporate systems, allowing EDP Distribuição to control the maintenance program for each asset and establish maintenance plans. However, with this maintenance program it is difficult to have a global vision about the health index of each asset due to lack of operational information of each asset. So, spreading intelligence throughout the infra-structure is necessary to manage the relevant capabilities of scattered physical assets and to support the implementation of new asset management system compliant with PAS 55 (Publicly Available Specification published by the British Standards

Institution) (Figure 2) in order to consolidate asset management policies and further disseminate risk asset management practices. According to the new challenges arising from the implementation of this asset management system in terms of performance, cost and risk, it is necessary to change the paradigm of maintenance that has been previously adopted.

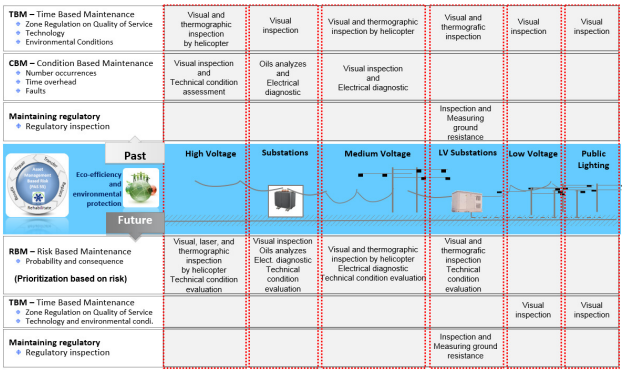


Figure 2 - EDP Distribuição maintenance planning according to PAS 55

Predictive maintenance enters as a new factor that will be able to act at the right time before the appearance of any failure, thus reducing the number of outages, improving quality of service and reducing costs.

INNOVATIVE SOLUTIONS

In line with these measures, EDP Distribuição has made efforts to implement: i) protection, command and control advanced system; ii) intelligent SCADA systems; iii) Work Force management solution; iv) data mining and v) asset management systems based in PAS55. All of these programs provide decision support tools in the development of investment plans, operational efficiency programs and maintenance of networks.

Taking in account asset management systems and taking advantage of the Smart Grid concept, EDP Distribuição identified a wide set of variables which coming from scattered physical assets can be useful to monitor in real time (Table 1).

Monitoring	HV Lines	Primary Substation	MV Lines	Secondary Substation	LV Lines
Corona effect	+	+	+	+	-
Infrared Image	+	+	-	-/+	-
Optical Image	+	+	+	-	-
LIDAR	+	-	+	-	-
Vibration	-/+	-/+	-/+	-/+	-/+
Acoustic	+	+	-	+	-
EMI (Electromagnetic Interference)	+	-	-	+	-
Inundation	-	+	-	+	-
Intrusion	-	+	-	+	-
Vandalism	-	+	-	+	-
Operation State	-	+	-	+	-
Electrical Variables	+	+	+	+	+
Chemistry Variables	-	+	-	+	-
Transient Variables	-	+	-	+	-

Table 1- Monitoring variables importance by asset

Also it was identified the Smart Sensor architecture to connect the sensors network to the upper layer system, as SCADA, WFM, Asset Management Systems, SAM, etc (Figure 3).

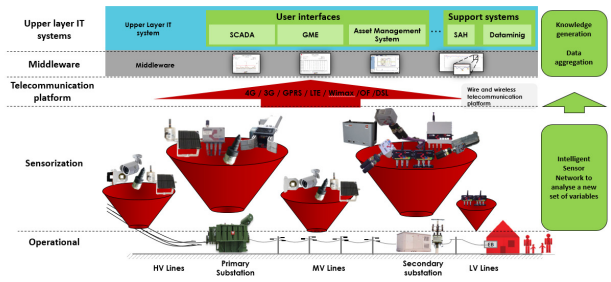


Figure 3 - Smart Sensor architecture to connect the sensors network to the upper layer system

In the following chapters it will be described some pilot project already implemented in EDP Distribuição.

ACTIVE TRANSFORMER BREATHERS

EDP Distribuição is testing a new type of air dryer in HV/MV transformers that uses special silica which can be regenerated (dried) resulting in an average lifetime of ten years. This air dryer is equipped with sensors that measure the temperature and moisture content of the air and when these parameters exceed predetermined values (indicating the silica is saturated), they activate a heater that dries the silica. The device has a data concentrator and communications capabilities that allow it to register and send to upper layer maintenance systems information regarding operation and silica condition by, in order to detect whenever it needs to be replaced (Figure 4).

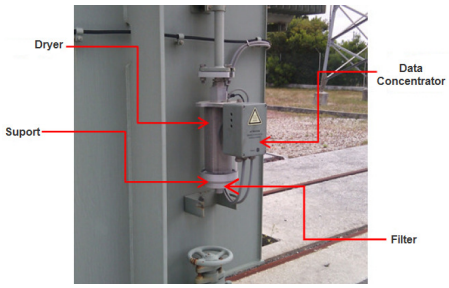


Figure 4 – Active Transformer Breathers

This project is in use at four HV/MV substations, each equipped with two transformers that are located in areas typically associated with high levels of air moisture. In each substation, one transformer is equipped with the new air drier while the second transformer has the conventional drier. EDP Distribuição is now in a position to compare both technologies in terms of effectiveness and maintenance costs.

The effectiveness assessment relies on periodic oil analyses that help to compare moisture evolution in oil for

the different drier technologies. These analyses are compared with the transformer load diagrams in order to determine the effect of load imbalances which can affect the transformer breathing rhythms and mask the effectiveness of the driers. From the data recorded to date the new drier is seemingly as effective as the conventional drier but the main benefit has been the reduction of maintenance costs associated with silica replacement (Figure 5).

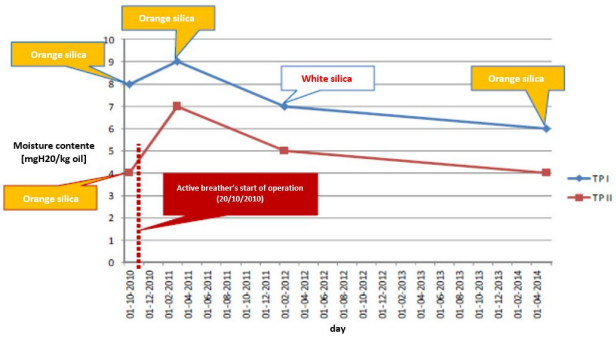


Figure 5 - Moisture content evolution (TP 1 with traditional transformer breathers

As the active breathers allow utilities to become more aware about silica condition, the risk of having oil excessively exposed to moisture (due to silica saturation) is reduced, which represents a lower aging rate for power transformers.

Also, the communications capabilities that can be associated to active breathers may be an interesting complement to a Smart Grid architecture, as the one EDP Distribuição has been developing at Évora's InovCity, providing real-time information about the devices operation and about the condition of the silica (a tiny but critical component for the power transformer lifetime).

ON-LINE MONITORING OF PRIMARY SECUNDARY SUBSTATIONS.

EDP Distribuição is developing a pilot project with a national consortium (ENEIDA and the Faculty of Sciences and Technology-University of Coimbra) to develop and test innovative and pioneering sensors to monitor critical parameters identified as strategic. The market does not offer as a standard solution, namely HV and MV circuit breakers, HV switchgear and HV/MV transformers installed in primary substations (Figure 6). The circuit breaker monitoring focuses on the collection of transient electrical current data during switching and vibration data. This provides a pattern signature for each device and early signs of mechanical malfunction can be detected via comparative analysis with the real-time data available from the previously recorded signature. The sensors installed at switchgear are monitoring the contact wear on the moving parts and their temperatures, in order to detect persistent hot-spots.

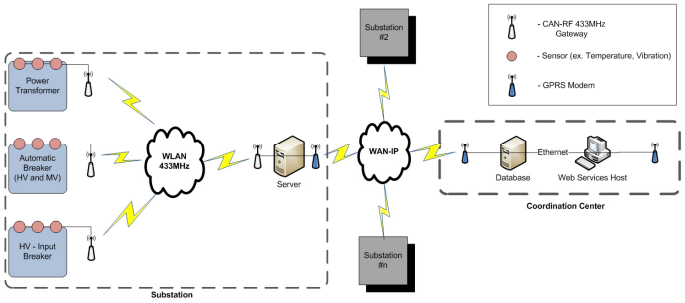


Figure 6 - Smart sensor network tested by EDP Distribuição

Powering the smart sensors installed in primary substation switchyards presented a challenge in order to avoid using batteries. Thus, the smart sensors can be installed with appropriate energy harvesting and storage devices, by resorting to super -capacitors being charged by small 8 x 8 cm solar cells (Figure 7).

Figure 7- Wireless smart sensor powered by energy supplied by PV solar cells

The criterion that was recently adopted for the health assessment of the electromechanical equipment in a substation corresponds to a window centred in the up-to-date determined average value of the relevant variables, allowing for a margin of ± σ (standard deviation), which represents a margin narrow enough for a serious evaluation.

Given the low number of events recorded at the substations under observation, namely circuit breaker operations, the respective reference figures still lack statistical significance and, therefore, no message warnings and alarms have been set for this equipment.

As result of this pilot, it was identified an interesting set of variables with quick-wins information, others without so much interest because it needs further academic interpretation and others without any interest because it must be correlated with other variables or can be replaced by other method such as Park vector analysis (Table 2).

SENSOR		DECISION	
Asset / Type	Sensing	Interest	Proposal
Transformer	Vibration		To consider the Park vector analysis
	Temperature		
	Analysis based on motor current variation (On Load TAP Changer status)		
HV/MV Switchgear	Breaking current		To be considered
	Opening time		To be considered
	Motor load profile		To be considered
	Operation status (open/close)		To be considered
	3 phases breaking time deviation		To be considered
	Vibration		Requires academic study to create knowledge that supports default data generation
	Protection relay reaction time		To be considered
Substation	Infrared image sensing		To be considered
Substation	Corona effect		Requires academic study to create knowledge that supports default data generation

Table 2- Primary Substation innovative and pioneering sensors to monitor critical parameters identified as strategic

EDP Distribuição is also collaborating with the University of Coimbra to develop a real-time diagnostic system for power transformers. The system measures the primary and secondary currents and voltages of the monitored transformer in order to detect incipient faults occurring in windings or in the core, through Park vector analysis in addition to the degradation of the contact resistance of the transformer on-load tap-changer (OLTC) (Figure 8). This technology has been successfully applied to industry for diagnosing faults in motors and variable speed drivers for the last 20 years and is now being adapted to static machines like power transformers. Currently EDP Distribuição has an experimental version of this system running as a pilot in two primary substations.

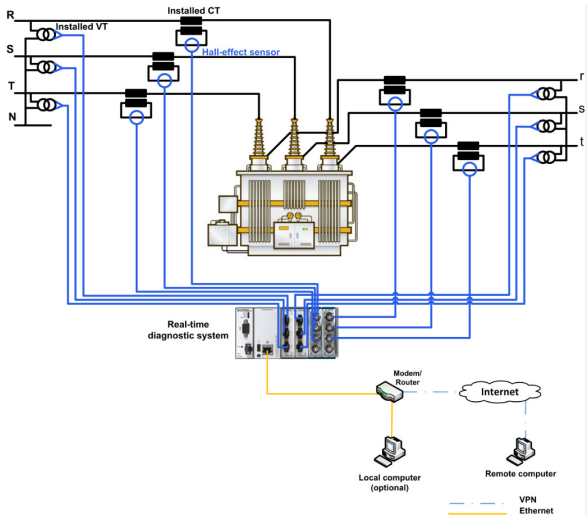


Figure 8- Architecture of the EDP Distribuição's system for Park vector analysis

ON-LINE MONITORING OF SECONDARY SUBSTATIONS.

Currently EDP Distribuição secondary substations have been in service for more than 30 years in a standalone mode. These substations are more disperse across the inland Portuguese territory and have more vulnerable equipment than primary substations.

EDP Distribuição, Faculty of Sciences and Technology-University of Coimbra, ENEIDA and EFACEC (InovGrid project partner) developed and tested innovative and pioneering sensors to monitor critical parameters identified as strategic. The market does not offer as a standard solution, namely breaking and switching equipment and the transformer in addition to environmental parameters inside the secondary substation (air temperature and humidity measurements, fire and flood detection, access control, transformer theft detection, Automatic Test of the water pump and blow fuse detection by current inspection sensor) (Figure 9).

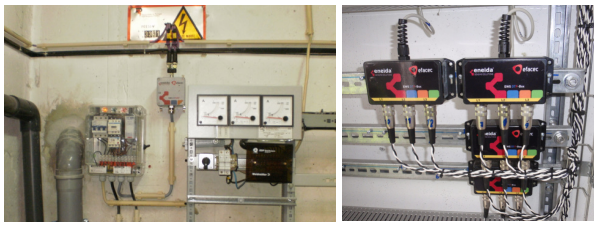


Figure 9- Automatic test of the water pump sensor in an underground substation and blown fuse detection by current inspection sensor

This project was successfully incorporated in the communications architecture developed for the Smart Grids initiative of EDP Distribuição (Figure 10). The distribution transformer controller (DTC), the INOVGRID project's device, installed in a secondary substation is responsible for collecting data coming from the consumers and for transmitting it upwards (to BTGrid, the INOVGRID's remote platform) which acts as a gateway for the data coming from the sensors.

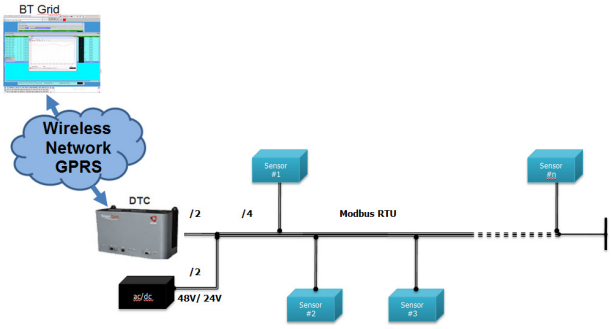


Figure 10- Incorporation of sensors' communications with the INOVGRID project of EDP Distribuição

Overhead Secondary Substation

SENSOR			DECISION	
Evaluation Criteria	Asset / Type	Sensing	Interest	Proposal
Equipment operating status	Transformer	Analysis based on motor current variation (Ruptor status)		Do not consider
	Fuses	Current detection in LV output circuits (Fuse status)		To consider the solution based on current analysis
Security	Intrusion	Door status		To be considered
	Theft	Transformer detection		To be considered

Indoor Secondary Substation

SENSOR			DECISION	
Evaluation Criteria	Asset / Type	Sensing	Interest	Proposal
Equipment operating status	Transformer	Vibration and external temperature analysis		To consider the solution based on CAPEX and OPEX analysis and secondary substation history
	Fuses	Current detection in LV output circuits (Fuse status)		To consider the solution based on current analysis
Safety	Ambient air	Temperature and relative humidity variation analysis to be associated with fire sensing		To be considered
	Fire sensing	Temperature variation detection		To be considered
Security	Intrusion / Theft	Door status / Transformer detection		To be considered

Underground Secondary Substation

SENSOR			DECISION	
Evaluation Criteria	Asset / Type	Sensing	Interest	Proposal
Equipment operating status	Transformer	Vibration and external temperature analysis		To consider the solution based on CAPEX and OPEX analysis and secondary substation history
	Fuses	Current detection in LV output circuits (Fuse status)		To consider the solution based on current analysis
Safety	Ambient air	Temperature and relative humidity variation analysis to be associated with fire sensing		To be considered
	Fire sensing	Temperature variation detection		To be considered
	Flood detection	Water level detection		To be considered
	Water pump test	Analysis based on pump status and current consumption		To be considered
Security	Intrusion / Theft	Door status / Transformer detection		To be considered

Table 3- Secondary Substation innovative and pioneering sensors to monitor critical parameters identified as strategic

As result of this pilot, an interesting set of variables were identified with quick-wins information, others without so much interest because it needs further academic interpretation and other without any interest because it must be correlated with other variables or can be replaced by other system solution (Table 3).

CONCLUSION

The recent significant advances in different technological areas – sensors, microsystems, wireless networks, and web service programming has made it feasible to bring industrial maintenance to higher levels, by bringing together maintenance, operation and engineering, through the whole life cycle of assets. The key to this policy lies in the ability to monitor, in real-time, a number of variables that describe the operating status and condition of equipment that being critical to the respective process operation, should be subject to more sophisticated maintenance criteria: Condition-Based Maintenance (CBM) and, in the long-term, other forms of predictive maintenance based on Risk Management criteria, as preferred by most utilities.

Aligned with this challenge, EDP Distribuição is developing different pilot projects to test new real-time sensor solutions specifying and demonstrating innovative and pioneer smart sensors for real-time monitoring of a number of new variables of critical assets in primary and secondary substations.

Capabilities that enable gathering, analysing, and supporting human decisions – while they do not start sending out worksheets represent a valuable tool for the purpose of high-level asset management increasing the amount of intelligence dispersed throughout electrical grids. These solutions deserve being designated as 'Smart'. Also, EDP Distribuição has been testing active breathers in power transformers. These devices include a special silica that allow regenerations and a system that automatically perform such regenerations (as a function of time or silica condition), representing potential reduction of operational costs and of environmental impact in silica substitutions. The results obtained by EDP Distribuição confirm the predicted reduction in operational costs and show that these devices, besides having a technical performance very similar to the conventional driers, may contribute to a longer lifetime of power transformers, since they may help to prevent situations in which silica is maintained in service beyond its saturation point. The implementation of the new active breathers was considered economically viable depending on both silica replacement periodicity in the standard breathers and investment costs for the new active breathers.

Finally, closing the gap between the birth of this idea and the manufacturing of the end product was successfully accomplished as a result of fruitful co-operation between industry, both the manufacturer final consumer and Academia.

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