EDP DISTRIBUIÇÃO: SMART SOLUTIONS AGAINST THE THEFT OF POWER EQUIPMENTS

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ABSTRACT

In the last decade the price of copper has quadrupled; in the last year it has doubled compared to previous years. This price increase has contributed to the growing market of used and scrap, with copper being an attractive market worldwide. The theft of copper is not a phenomenon confined to the Portuguese market. The rocketing international price of this raw material, in recent years, has boosted this crime all over the world.

In Portugal, the theft of copper has already expanded to several regions and sectors of activity, but it is in the energy sector that its impact is more significant. The theft of overhead line copper conductors and other distribution network equipments containing copper has increased significantly between 2008 and 2011. Most of the increase has occurred in isolated and rural areas.

INTRODUCTION

EDP Distribuição (EDP D) is the Distribution System Operator (DSO) in Portugal and a member of the EDP Group Energias de Portugal. In Portugal, EDP D operates 80 thousand km of HV (60 kV) and MV (6 to 30 kV) networks, over 400 HV/MV and MV/MV substations and 60 thousand MV/LV Secondary Distribution Substations (SDS), with a total power capacity around 18.700 MVA. The LV distribution grid is about 140 thousand km long. At the end of 2011, EDP D had more than 6 million customers [1].

Copper is attractive to the electric utility industry because it is an excellent conductor of electricity, it resists corrosion, and in spite of recent price increases, it is inexpensive relative to alternate metals over time. Because of its properties of high ductility, malleability, and electrical conductivity, it has become the benchmark for almost all types of wiring. All over the world, utilities have become targets of copper theft because tons of copper are used in each electric utility substation, mostly in transformers. Utilities also keep large concentrations of copper wire at utility construction sites and storage yards, in the back of utility trucks, and in transmission and distribution lines [2].

STATE-OF-THE-ART

The accumulated losses in EDP D between 2010 and the first half of 2012 reached 30 million euros (about 12 thousand thefts). This sum represents the cost of labor and of replacement materials, excluding the value of the energy that was not sold due to these acts of vandalism (Figure 1 and 2).

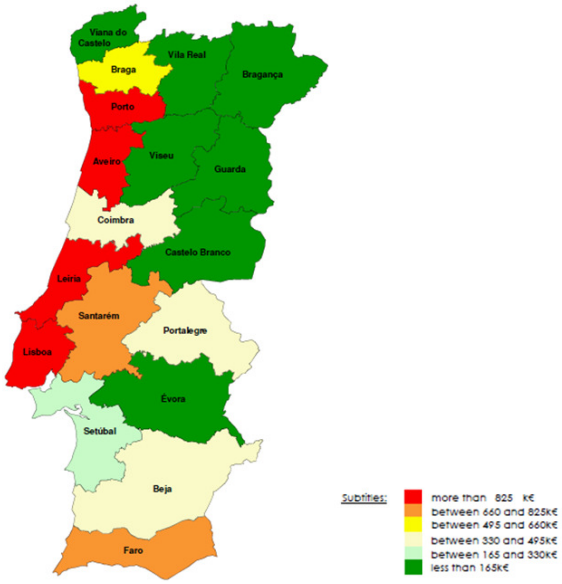

Figure 1 – National theft impact

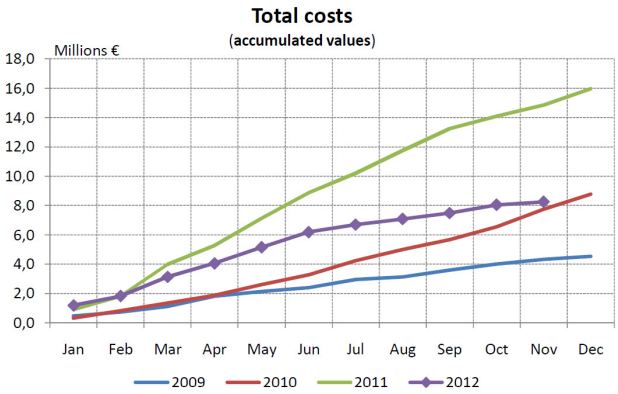

Figure 2 – Evolution of the thefts' total costs impact

PAST: CONSTRUCTIVE SOLUTION

As a DSO, which is fully committed to respond to the needs and expectations of clients, EDP D has been systematically adopting new constructive solutions [3] to mitigate the existing and the adverse consequences due to

the occurrence of thefts in distribution networks, including:

- making the switches in secondary substations inaccessible;
- welding the metallic structures that support the power transformer in secondary substations (Figure 3);

Figure 3 – Power Transformer welded to the metallic structures

- installing devices that prevent thieves from easily climbing the poles (Figure 4);

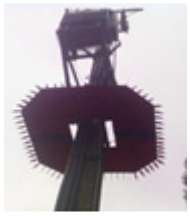

Figure 4 – Example of devices that prevent thieves from easily climbing the poles

- establishing earth connections using aluminum, instead of copper.

Besides, all these technical solutions, that have limited geographical scope, EDP D, with other affected companies, has been focusing in awareness of civil society and Government authorities for the negative impacts in national economy, with measures that have huge geographic scope:

- involving National Security Forces (Police) in relevant joint action;
- instilling the awareness and the cooperation of the public opinion;
- influencing new laws and market rules for all actors in the chain, namely storekeepers, scrap dealers, foundries and recyclers.

Putting aside the measures taken to gain awareness of the civil society and the Government authorities, many of the other constructive solutions had poor results and did not prove their efficiency in the fight against thefts of power equipments.

So far, the evolution of Smart Grids has been mostly driven by objectives of both smart metering and energy efficiency. One of the main advantages of the Smart Grids is the utility information network, which enables more real time operational intelligence, as well as connectivity and observability further down into the grid and across the electricity supply chain. These functions allow prompt detection of thefts of SDS assets which are relatively more vulnerable equipments that exist in large numbers scattered throughout the territory Portugal.

PRESENT: "CAMPO SEGURO"

Located in central Portugal, the "Campo Seguro" project involves national authorities, security forces (Police) and technology manufacturers in the development of a regional pilot platform to fight against thefts in agricultural areas which concentrate most of these acts of vandalism.

In "Campo Seguro" project, EDP D installed 225 smart low-cost sensors (Figure 5) in outdoor aerial power transformers mainly used for power supply to the agricultural infrastructure in Santarém area, the district most affected by this problem. The sensor is equipped with 3-axis accelerometer, which can measure the static acceleration of gravity in tilt-sensing applications, as well as the dynamic acceleration resulting from motion, shock, or vibration. It has GPS tracking and fault energy detection.

Figure 5 – Smart low-cost sensors

Using the wireless public network (GPRS/GSM), the sensor sends status information and alarms to the local police management crisis room. At the same time, the sensor sends text messages to EDP D dispatching premises, which interact with police in order to foil fault alarms and avoid unnecessary intervention (Figure 6).

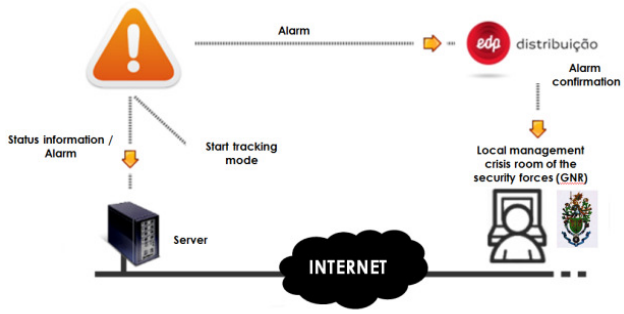

Figure 6 – "Campo Seguro" Communication Topology

It was necessary to use reverse engineering in order to optimize algorithm alarm activation and to minimize fault alarms. The sensor, installed in aerial outdoor power transformers on the top of the poles, is exposed to dynamic acceleration. Therefore, it was necessary to identify the acceleration profile (alarm triggers to generate warnings and alerts when the specified criteria are met) (Figure 7).

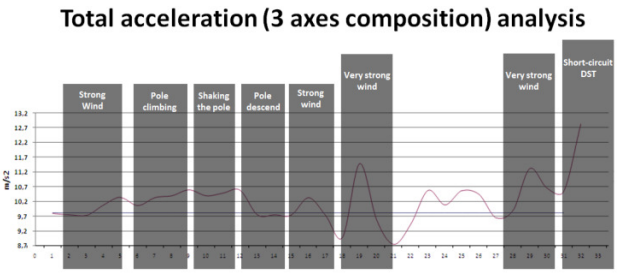

Figure 7 – Total acceleration analysis

Oscillations with 8 cm of amplitude and 4 Hz of frequency were identified on the top of the pole under normal conditions. Based on field tests and laboratory simulations, a trigger of 3,003 m/s^2 was pre-configured without jeopardizing efficacy on motion detection by sudden stir (sudden rotation and acceleration).A logical algorithm with the 3-axis accelerometer was implemented with the objective of minimizing false alarms, taking advantage of the fault energy detection.

The alarm status is only activated by the conjugation of both 3-axis accelerometer and fault energy detection.

Technical and economic Analysis

Until now, the project has been considered in an engineering sense to evaluate its technical feasibility. To enable decision-making, on an economic basis, a tool has been developed to determine the theft reduction BEP, which was achieved with just 3% of theft reduction considering a 6 year study. With a reduction of 15%, the NPV is 355 k€ (Figure 8).

Simplified assumptions		
SDS theft average cost		12.752,00 €
SDS total theft between 2008 e 2010		143
SDS theft per year		48
Total cost per year		612.096,00 €
Benefits considering only 15% of theft reduction	15%	91.814,40 €
Discount rate		10%
B/C needed reduction to NPV=0		3%
CAPEX (225 smart low-cost sensors)		64.800,00 €
OPEX (Telecomunication cost per year)		4.200,00 €

Year	CAPEX (a)	OPEX (b)	Total cost (a+b)	Total cost with refresh rate (10%)	Annual benefits	Annual benefits with refresh rate (10%
0	64.800,00 €	4.200,00 €	69.000,00 €	69.000,00 €	91.814,40 €	91.814,40 €
1	- €	4.200,00 €	4.200,00 €	3.818,18 €	91.814,40 €	83.467,64 €
2	- €	4.200,00 €	4.200,00 €	3.471,07 €	91.814,40 €	75.879,67 €
3	- €	4.200,00 €	4.200,00 €	3.155,52 €	91.814,40 €	68.981,52 €
4	- €	4.200,00 €	4.200,00 €	2.868,66 €	91.814,40 €	62.710,47 €
5	- €	4.200,00 €	4.200,00 €	2.607,87 €	91.814,40 €	57.009,52 €
Total			90.000,00 €	84.921,30 €	550.886,40 €	439.863,21 €
					Net Present Value	354.941,91 €

Figure 8 – "Campo Seguro" economic analysis

FUTURE: INOVGRID

The InovGrid project, EDP's smart grid project (Figure 9), is ultimately aiming to develop a set of functionalities and new devices to install in the field which will enable the equipping of the current electric power distribution grid with a level of intelligence to respond to the challenges of the new paradigms of the electrical system. In this context, this project will grant the SDS with a set of new functionalities associated with managing the electric power distribution grid.

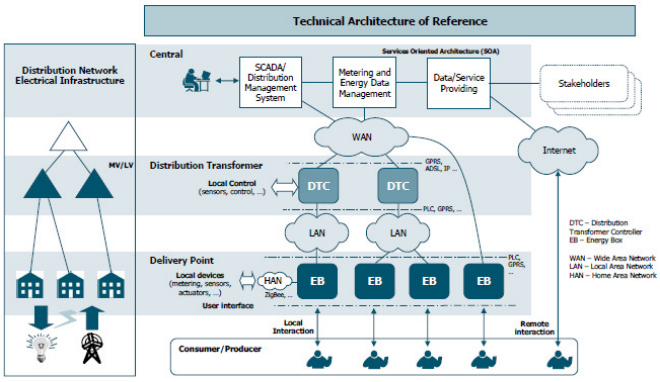

Figure 9 – Inovgrid Topology

In the context of the InovGrid project, EDP D invited the University of Coimbra, Eneida, and EFACEC- given their expertise and industrial background on smart sensors and the respective integration over both cabled and wireless communication networks (Figure 10) -, in order to specify and demonstrate innovative original produced sensors and a systems platform for the overall monitoring condition of SDS.

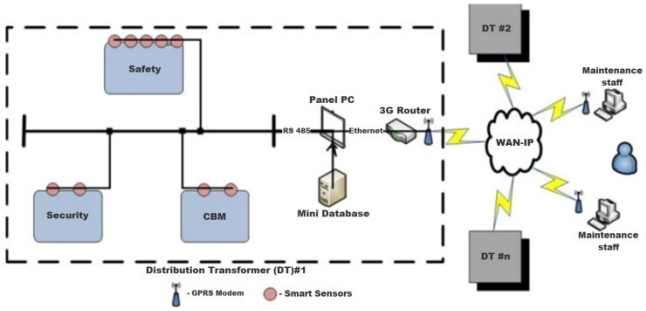

Figure 10 – Network topology of monitoring condition of SDS assets

Taking advantage of the Distribution Transformer Controller (DTC), which has the metering information concentrator as its principal function, a fully modular platform was developed that has a number of different, independent and self-contained smart devices. Adequately located throughout a SDS, this platform would promptly detect the intrusion through doors and ventilation grilles or detect any transformer removal (Figure 11 and 12).

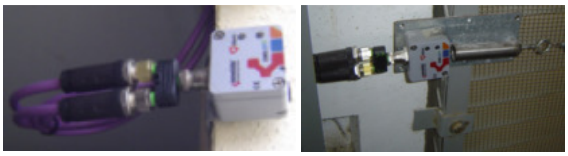

Figure 11 – Intrusion sensors: doors (left) and ventilation grilles (right)

Figure 12 – Transformer theft sensor

The solution was integrated in BTGrid (Figure 12), which is the new SCADA solution for the LV distribution grid. BT Grid provides both alarm and warnings corresponding to instant detection of theft to the staff in charge.

Figure 13 – BTGrid: Aereal PT synoptic

CONCLUSION

Copper theft is a widespread problem closely linked to economic circumstances. There is no evidence that sabotage or the destabilization of Portugal's electrical grid has been a motivation in any of the copper theft cases to date. Copper wire theft is not likely to cease entirely as long as copper prices remain sufficiently attractive to would-be thieves. However, the combined efforts of electric utilities, lawmakers, scrap metal dealers, local law enforcement and of the public opinion have succeeded in reducing the problem and driving a wedge between copper price increases and comparable increases in copper theft [2]. The efforts made by EDP D in several areas have resulted in a reduction of 12% in the number of thefts between 2011 and 2012, contradicting a growth of 100% a year.

In terms of involvement of the security forces in technical security projects, it is very important to take into account the theft solution credibility. False alarms will discredit the solution. With the 3-axis accelerometer it is possible to detect motion by sudden stir (sudden rotation and acceleration). Nevertheless, the experience shows that the association with fault energy alarm is the most important to minimize false alarms. Also, in order to detect alarms caused by planned or maintenance intervention, it was decided to implement a methodology that ensures that all alarms are previously confirmed by the LV dispatching center.

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