MV/LV SUBSTATIONS – SOLUTIONS TO IMPROVE THE TECHNICAL QUALITY OF SERVICE

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ABSTRACT

The Technical Quality of Service has been a constant concern in EDP Distribuição. Between 2008 and 2010 the Portuguese Distribution System Operator (DSO) carried out significant efforts to improve the index that measures the quality of service in Portugal, the Average Interruption Time (AIT). Currently the focus is on reducing certain asymmetries that still persist between different areas.

In this context the need to carry out extensive works in secondary substations (MV/LV) has arisen. Taking into account the need for quick and less expensive solutions to the problems encountered in those secondary substations, several solutions were designed, aiming for a strong impact on results and simultaneously a quick implementation.

INTRODUCTION

The constant concern of EDP Distribuição (EDP Group), "Distribution System Operator (DSO) , with more than 6 million customers , over 400 HV/MV Substations , 60 thousand MV/LV Substations, 80 thousand km Network (HV/MV) and a LV Network about 140 thousand km", on improving the quality of service and on reducing asymmetries that persist between different areas of the country, took us firstly to study the electrical network as a whole, and only afterwards to endorse the problems of each of its components: substations, power lines and secondary substations.

The secondary substations do not have great visibility but considering the large number of these network elements, larger than 90000 if clients' secondary substations are considered, and its geographic dispersion, it would be expected that the performed interventions could produce relevant results on the quality of service.

For this analysis we have considered the Portuguese central coastal area (Leiria and Caldas da Rainha) ,which has 5595 distribution secondary substations (DSS) .

Technical Quality of Service

During the last four years, the AIT was reduced in 64% [1], (see figure 1).

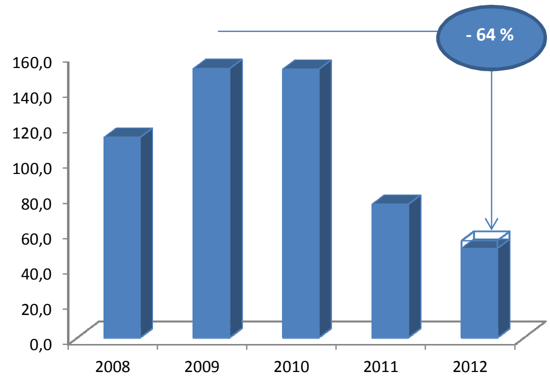

Fig. 1 – EDP Distribuição AIT (minutes)

In this work we will firstly describe the implemented solutions, comparing their advantages and disadvantages, and finally demonstrate how they are contributing to the presented results (see figure 2).

MV/LV SUBSTATION FAILURE MODE AND ROOT CAUSE ANALYSIS

MV/LV substation main failure modes, (see figure 2), and correspondent root causes are [2]:

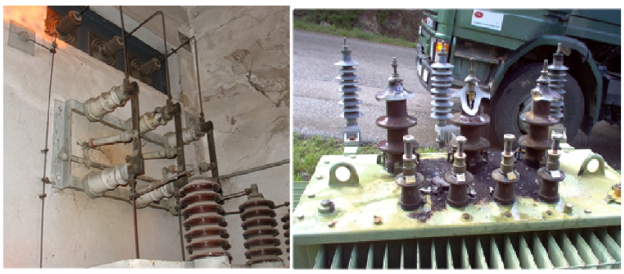

Fig. 2 – MV/LV Substations Typical Failure Mode

i) Building structure degradation: aging, deficient maintenance, vandalism and theft, sea and/or industrial pollution, deteriorated waterproofing, water infiltration;
ii) Power transformer local sparking, internal or external, or corona activity along the insulation surface: dirt wall bushings, animals, vandalism and theft, oil leak, insulating deterioration, inadequate load regime;
iii) Cells and busbars local sparking, internal or external, or corona activity along the insulation surface: dirt insulators, overheat, animals, corrosion, humidity, dielectric loss, manufacturing defect, premature aging;

The major interruptions in MV/LV substations are caused by insulator flashover, also on modular and enclosed MV switchgear.

The causes to these problems are local sparking or corona activity along the surface of the insulation. Discharges cause a slow deterioration of the insulator surface in the long term through three mechanisms: firstly through slow erosion by ionic bombardment of ions in the sparks, secondly by chemical degradation of the insulation material and thirdly from carbonization of the material surface.

Partial Discharges (PD), local sparking and corona discharges have enough energy to create O_3 and NO_2; the first degrades the polymeric materials and the last, combined with water (vapour or deposited by condensation), produces nitric acid that corrodes the metallic –steel and copper– surfaces and creates electrical conducting paths through insulator surfaces.

The pollution, acid condensation, etc. over the surface of insulators causes more degradation which causes more acid and ozone, creating a vicious cycle with flashover at the end, (see figure 3).

Fig. 3 – Example of severe degradation

FAILURE MITIGATION METHODS

This approach was divided into reliability solutions of short and long term that demanded from EDP Distribuição technicians' persistence and creativity.
We give special attention to an innovative solution, the RTV Silicone application, which will be explained in detail later.

Table 1 resumes the solutions that were implemented in Portugal central coast area between 2011 and 2012.

Mitigation Method	***2011***	***2012***
Live Cleaning	294	199
Electrical rehabilitation	393	434
Ventilation area regulation	68	57
Anti-Flash application	105	54
Structure rehabilitation	116	165
Constructive Type change	16	25
Technology replacement	43	119
RTV	36	44
total	1071	1097

Table 1 – Failure mitigation methods

Short term solutions

The short term solutions are characterized by their low cost and quick implementation. However, they are not responsible for a great efficacy; they help on results and allow a more complex and definitive solution to be studied and implemented.

Live cleaning
The live cleaning is a classical method used to clean the isolation coating, without interrupting the electrical power, on air insulated equipment. Its main purpose is to avoid the appearance of conducting films produced by moisture condensation over the dirt insulators. In the area of concern for this work, live cleaning has a special relevance due to industrial and saline pollution.
advantages**:** no interruption, low cost; known method
disadvantages**:** it demands special skills and specialized operators, impossible if insulators present discharge activities, does not allow deeper maintenance and tuning actions on switching equipment.

Electrical infrastructure rehabilitation
The electrical infrastructure rehabilitation consists of the replacement of electrical organs, or of parts of those organs, keeping the same insulating technology.
advantages**:** intermedium cost, quick intervention,
disadvantages**:** demands service interruption, it may not solve the problem's root cause.

Ventilation area regulation
On cabin type secondary substations the natural ventilation dimension is calculated considering the bigger power transformer at nominal charge and for the summer period.
The majority of the facilities have a transformer lower than the maximum and a charge regime lower than the nominal one. Therefore, the ventilation area is, most of the times, excessive, allowing moisture condensation over all surfaces in the cabin [3].
Using an algorithm that fits each facility, the ventilation regulation targets are adjusted to the ordinary charge regime. This is done through the partial obstruction of the

ventilation grid.
The ventilation grid obstruction does not allow excessive thermic heat dissipation imposing humidity levels within the facility, to be reduced without the need of additional heat sources.
***advantages*:** no interruption, low cost;
***disadvantages*:** static regulation;

Anti-Flash G142 e G144 varnish application

This technology consists of an insulating varnish application over the insulating material, recovering its special dielectric properties, keeping the facility working for a longer period without additional technical interventions.
***advantages*:** low cost, quick intervention, postpone the investment;
***disadvantages*:** low durability, needs interruption, applicable only to polymeric insulators.

Long term solutions

Long term solutions are more invasive and involve deep changes on assets.
Among these solutions we can mention building structures rehabilitation, cabin type constructive modification (to overhead type) and the technological improvement with the installation of compact cells, with or without integral insulating.

Concrete Structure Rehabilitation

The rehabilitation of concrete structures is, in some cases, simply preventing water infiltrations or improving urban landscaping; in other situations, depending on the cabin deterioration level, it was required a deep intervention that also contributes to improve the EDP image.
***advantages*:** decreases humidity levels, improves EDP images.
***disadvantages*:** intermedium cost, needs service interruption

Constructive type change.

Within rural areas, with lower charge profiles, cabin type facilities with severe damages have been replaced by overhead type structures. These last asset types, due to their simplicity, present higher levels of reliability.
***advantages*:** building concrete problems and electrical problems are solved, high cost;
***disadvantages*:** needs interruption, it may enforce changes on near power lines.

Technology Replacement

Older equipment has been substituted by newer improved technological versions with integral insulating and without any active area in direct contact with air.
***advantages*:** higher reliability, higher security, better operability;
***disadvantages*:** high cost, needs interruption.

RTV Silicone application, an innovative solution

That is an identical procedure to the above described anti-flash G142 and G144 varnish applications. It is slightly more expensive due to the higher material cost, but presents substantial advantages such as hydrophobicity (see figure 4) avoiding moisture condensation in a continuous film.

EDP Distribuição began field trials with RTV silicones in 2002, continuing with RTV application in the most environmentally critical HV/MV substations.

In the beginning, LABELEC, the R&D EDP branch, supported EDP Distribuição in the choosing process of the best RTV silicone available at time.

The chosen brand was CSL Silicones Inc. The latest applications were made only with Si-Coat 570
The main Si-Coat characteristics, in the applier's point of view, are:

- Mono-component product
- Hydrophobicity;
- Recovering of contaminant agents regaining loose hydrophobicity

Prior to Si-Coat application it is fundamental to ensure that all traces of electrical activity, all pollution contaminations and all grease or oil are removed.

The application is made according to strict ambient rules, being the most important the atmosphere temperature above +5 ºC, dew point at least 5 ºC below atmosphere temperature and wind speed less than 2 m/s.

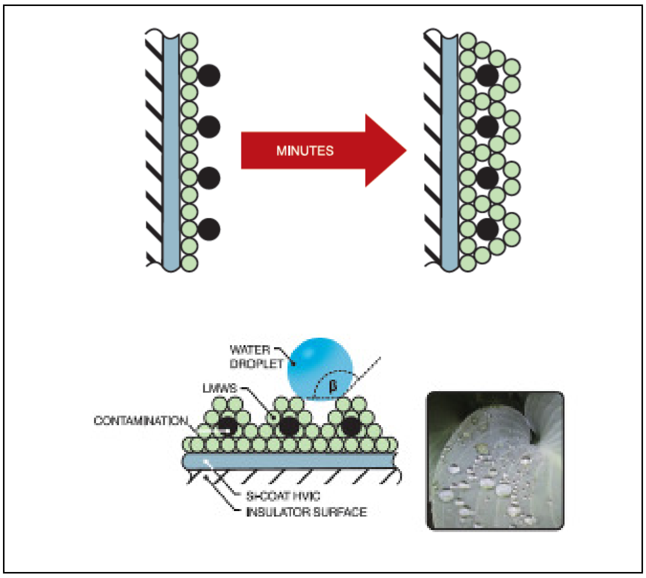

Fig. 4 – Recovering of contamination agents and regained hydrophobicity as stated by SCL Inc [4].

The application is made with an airless spray machine because thinners or solvents to decrease viscosity of Si-Coat are not allowed to be added.

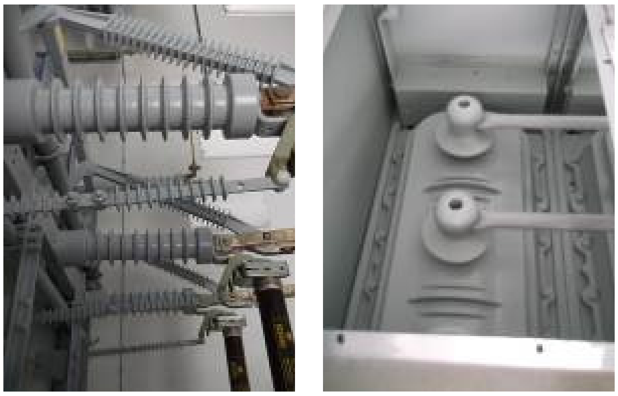

Fig. 5 – Final results

In the end, the applicators ensure that there is a layer of, at least, 0.35mm of dry RTV over the insulators surfaces. After application the insulator surfaces are rehabilitated and all surface electrical activity is stopped: no noise, no smell, no overheat, avoiding further degradation (see fig 5).

As part of the value of this application, it must be stressed out it has a 10 year warranty, which provides added security for EDP Distribuição.

RESULTS

Through the years 2011 and 2012, a set of actions were taken and, along with them, it was possible to register their merit as shown on table 2.

Method	Costs	App time	Durability	Reliability
Live Cleaning	Low	Low	Low	Med
Electrical rehabilitation	Low	Low	Med	Med
Ventilation regulation	Low	Low	High	Med
Anti-Flash	Low	Low	Low	Med
Structure rehabilitation	Med	High	High	Med
Constructive Type change	High	Med	High	High
Technology replacement	High	Med	High	High
RTV	Med	Low	High	High

Table 2 – Failure mitigation methods merit

Within the same period, and taking as reference the electrical interruptions occurred during the year 2010, the incidents with origin in DSS were analyzed. There is an important and generalized reduction in outages from 100% to 60%, but, in the geographical region of interest, this reduction is bigger: it has fallen to 1/3 of the original value (fig. 6).

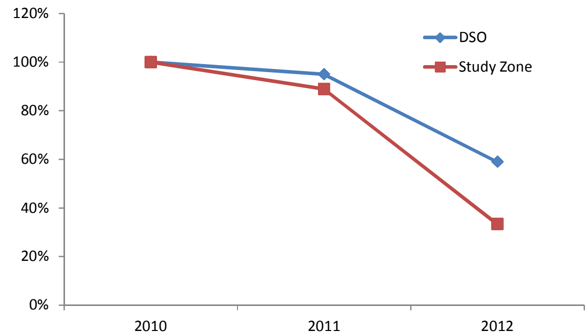

Fig. 6 – DSS outages reduction

The reported results are only related with incidents that are originated in DSS. However, in an indirect way we can assume that the implemented solutions do contribute to the improvement of AIT and SAIDI indices, because the incidents registered were then less complex and quicker to solve, and of MAIFI index, which is also due to transitory incidents on those facilities.

CONCLUSIONS

The reported results were consistent with expectation and are quite motivating. DSS are important structures of the power network and it is important to view them with a different perspective.

For the future it is important to define the most appropriate set of solutions and to improve the efficacy of their implementation aiming to eliminate PD, discharges due to corona effect, reduce the characteristic O_3 and/or NO_2 smell and condensation.

REFERENCES

[1] EDP Distribuição Energia, SA, DDC\QS,2012.

[2] The Institute of Asset Management,2008, *PAS 55,* BSi British Standards.

[3] Francisco Noronha Távora, 1997, *Redes de Distribuição de Energia Eléctrica,* ESTG, Leiria, Portugal, cap. 7.

[4] The Science of Si-COAT® HVIC, Parts 2 & 4