A SYSTEM DEVELOPMENT PROMOTING RELIABLE ACCESS TO ELECTRICAL ENERGY (PROJECT OACIS)

Pedro PAULO
ARGL -EDP Distribuição – Portugal
pedrosilva.paulo@edp.pt

Maria Luisa SERRA
ARGL - EDP Distribuição – Portugal
marialuisa.serra@edp.pt

Paulo CAMPOS
ARGL- EDP Distribuição - Portugal
paulo.campos@edp.pt

ABSTRACT

Project OACis main aim, is to reach high quality standards in MV energy distribution network through its improved performance. This objective tends to be usual in liberalization processes, mainly in very dense urban areas (Great Lisbon Network Area-ARGL- has more than 1,5 million inhabitants in an area with 566 km2, where the underground cable distribution network is almost 90% in a total of 4,5 thousand km and where areas served by overhead lines are gradually becoming Urban areas).

The main topics are related to performance requirements, results and benchmarking, addressing a big challenge on real improvement of MV network quality and continuity of service in a short period of time. Our experience shows that it is very important to focus on clear, quantifiable and ambitious medium term objectives. The sustainability and disruptive jumps are possible if the Project uses right analyses and development techniques to improve the performance of MV network.

The analysis method applied was supported, firstly, on an internal best practice performance evaluation and benchmarking, in order to allow the comparison of data based on real values for interruptions per km for different type of network. In a second phase, gap analysis between significant areas helped to define the most effective way to achieve our goals (i) for different distribution networks key drivers (Substations Usage factors (ii),HV and MV structures) identifying Reliability correlation Indices in small areas (default rates, interruption time).

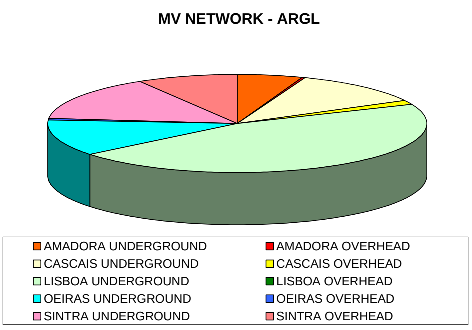
The project integrates also Conditioned Based Maintenance (CBM) strategies, based on diagnosis methods for different configurations and Network structures (Visual and Thermographic inspection, Partial Discharge, Ultrasounds, outsourced Emergency generators). Simultaneously with Diagnosis registration we followed other network symptoms (Overload, Voltage drop).

The investment and maintenance processes design, allowed the improvement of MV circuits performance and identification of new equipment specifications as well as Network architectures with new solutions on Compact and project refurbishment (technology, ventilation, noise).With fundamental importance was the detailed analysis of all defaults in MV distribution Network and undertaken actions to avoid future failures, through the use and development of IT control systems, combining several key tools in order to focus a reference performance in energy distribution.

INTRODUCTION

From a geographic perspective Great Lisbon Network Area (ARGL) supplies services to five municipalities with different realities containing urban and rural areas. The urban areas are characterized mostly by underground cable distribution networks and rural ones by a mixed configuration of overhead lines and underground cables. Both MV network types are mostly operated in open ring, but different structures, imply different approaches for real improvement of the service quality (TIEPI) related with maintenance and investment processes.

These municipalities integrate Lisbon Metropolitan Area, where in last years we noticed a significant growth of energy needs. The rural areas are becoming urban and new underground cable networks are gradually replacing overhead lines. Overhead lines represent about 10 % of the network and are mostly located in Sintra and Cascais close to the coastal line.



In ARGL OACis project, when launched, strives to increase the quality standards facing customer's expectations, in order to improve quality and continuity of service which is a major concern in Electrical Utilities especially with market liberalization and the introduction of incentives/penalties regimes. To accomplish this main objective, it is critical to improve MV network reliability. The main effort undertaken is in the reduction of the Equivalent Interruption Time for Power Installed (TIEPI).

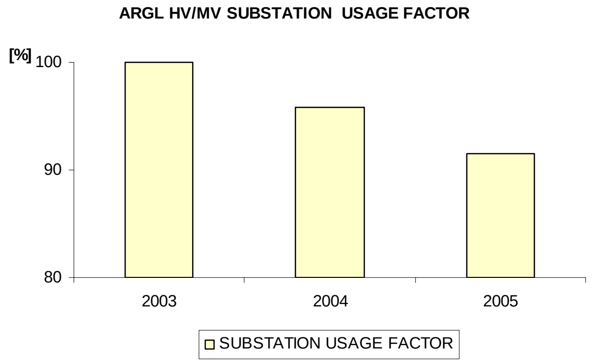
The quality measured by (TIEPI) is defined by the effects of outages verified in a geographic area in a certain period of time, concerning the outages number, duration and affected power installations related to the total installed power for the considered geographical area.

$$TIEPI_{MV} = \frac{\sum_{j=1}^{k}\sum_{i=1}^{x} DI_{ij} \cdot PI_j}{\sum_{j=1}^{k} PI_j}$$

DI_{ij} – Interruption Time *i* in delivery point *j* [min]
PI_j – Installed power in delivery point j – Delivery point considered are MV/LV Substations [MVA].
k – Total quantity of delivery points in the considered geographic area.
x – Number of interruptions in the delivery point j.

The plan has to consider energy needs due to the costumer's growth and consumption increase, implying a continuous expansion of network, upgrade and construction of new HV/MV substations, and take in new strategies to manage MV network. All these are important factors that OACis project follows closely.

Investment impacts made in the past years in the construction of new HV/MV substations can be measured by the usage factor of these installations, which was reduced in 10 % due to the application of improved network architecture.

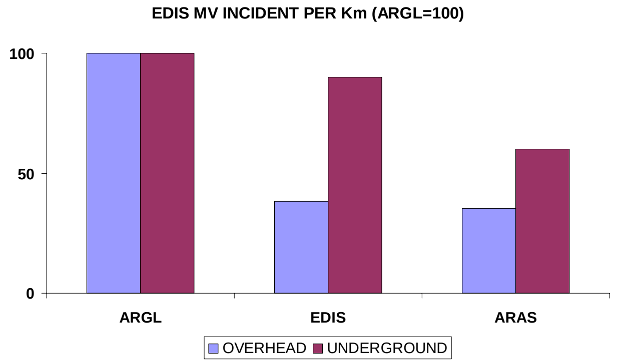


BENCHMARKING - BEST PRACTICES

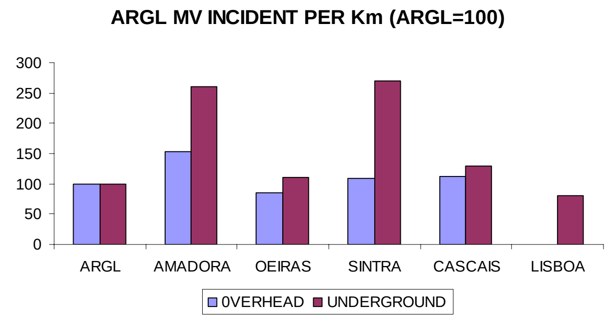
Among other programs, the investment on MV network led to the development of techniques in order to improve the network performance.

OACis project started with an internal benchmarking analysis of incidents in other geographical areas of our company, in order to eliminate conceptual misunderstandings. The analysis, was mainly directed to the incidents ratio in MV underground and overhead lines. These installations contribute greatly in the number and duration of the outages verified in ARGL.

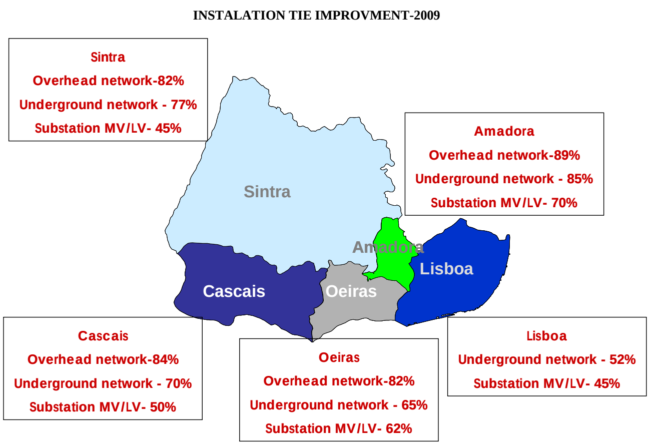
Considering total utility network dimension and total number of outages verified in it, we calculated the overhead and underground cable indices: incident per km.



Identical benchmarking was made inside ARGL. As a result it was possible to measure the potential contribution of each area to ARGL network global performance.

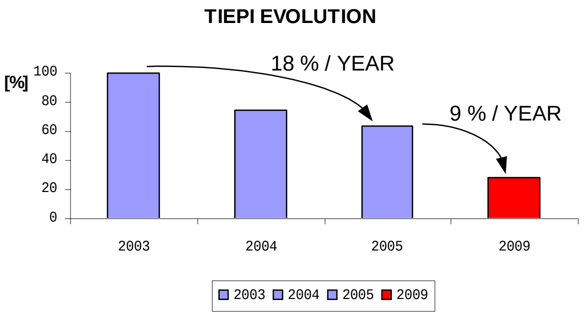


The analyses of internal ratios, made it possible to define priorities related with investment and maintenance programs that focus on main improvements in overhead lines, underground cables and also project refurbishment of older installations.



This comparison, led us to conclude, that it was also important to observe worst performance lines. Bad performances are usually associated to lines with usage factors above 80%, with great number of obsolete installations or with a few numbers of remote controlled installations. These cases were considered as a main priority in the definition of investment programs proposals.

After analysing relevant ratios, ARGL objective was defined for a five year period (2009). The conclusion of this program pointed to a potential 50% improvement of TIEPI.



NETWORK EXPANSION ANALYSIS

Nowadays ARGL network is characterized by two MV levels, 10 kV that represents 90 % of the network and a 30 kV underground cable network that is currently under use and being gradually converted to 60 kV distribution network. The underground cable network is mostly composed by XLPE cables, technology widely used since the 80's and is gradually replacing the paper oil impregnated cables, some in service for about 50 years.

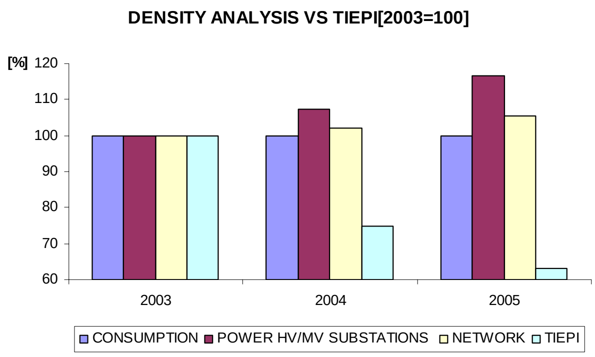
In overhead distribution network we have mostly copper and alloy composite lines supported in concrete supports. Copper overhead lines are gradually being replaced by alloy composites with larger sections.

New strategies and architecture for distribution network were important to improve quality indices. In urban and dense areas MV networks have an open ring conception; the power is rated (n-1) in case of an outage of the main supply line. The elimination of low cross section cables was also focused.

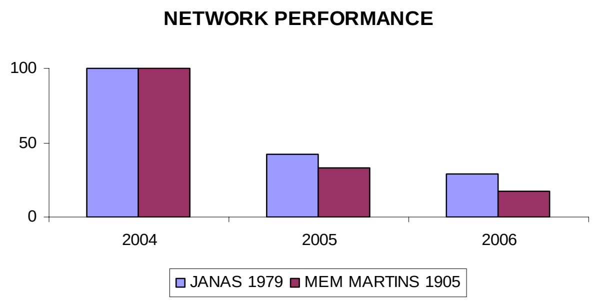
For rural networks the reference was the same: building networks with open ring configuration when possible, decreasing the sensibility of MV overhead lines to atmospheric phenomena and choosing the optimal route avoiding wooden areas. To improve network performance the replacement of main overhead lines located in wooden areas and in new urban areas by underground cables or by other overhead lines through a different route in a non wooden zone was decided. In this process the involvement of the costumers, land owners and local institutions was very important. In cases, were it was impossible to improve the route of overhead lines, investments were made to guarantee the safety from obstacles, ensuring service and reinforcing the transport capacity of the line.

Other important network elements are MV/LV substations. In ARGL we can find a lot of different type of installations, some of them very old and obsolete. A fault in one of these installations can provoke great damage in the energy supply. Therefore the replacement of equipments or adaptation of old installations to new SF6 technology is gradually being done.

Considering an increase in energy consumption, substation power and network extension; the flexibility of the constructed network when interrupted contributes to the improvement of service quality.



An example of significant results was verified on the two worst TIEPI lines of the project.



In three years TIEPI was reduced about 80% to these worst lines.

CONDITION BASED MAITENANCE (CBM)

Condition Based Maintenance (CBM) is also an important part of OACis project to improve quality of electricity supply. This maintenance method combined with preventive maintenance is replacing Corrective Maintenance with great benefits. These methods can increase the network reliability because it is possible to find the location of weak points and to decide, which and when they can be repaired before breaking down. This method brings major benefits, not just economic ones but also those foreseen to customers. Repair before breakdown reduces operational costs and customer claims, increases availability and reliability, postponing major investments and promoting smaller interventions.

Overhead Lines CBM

Regarding overhead lines, the CBM main methods used are visual inspections (VI) and thermo graphic inspection (TI).

The visual inspection is an important and experimented method that covers annually almost 70 % of the ARGL on overhead network. This annual campaign makes possible to inspect the state of overhead network concerning its establishment conditions. The main problems detected are corrosion of steel parts, broken and fissured isolators, broken and fissured supports and distance changes between active parts and obstacles, like trees and new buildings.

The corrosion problems are related with the establishment conditions of overhead lines that are in most cases very close to the coast line. To minimize this problem, new lines are designed using alloy composite conductors that contain higher resistance to salt water moisture. Overhead line supports used in these cases are made of concrete with a special resin that reinforces their resistance to weather phenomena's.

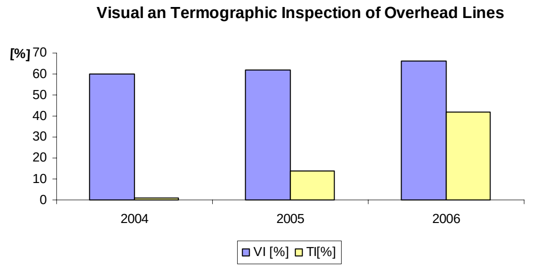
Some of ARGL overhead lines are established in municipalities with high urban growth, so in annual inspection we detect new buildings and obstacles in the safety corridor, which in some cases violate the safety distance from active parts.

The most critical situation detected in these visual analyses are lines established in wooden zones that are very close to growing trees. In these cases, small projects are automatically developed, to define a new route or simply place higher supports or/and cut some branches to guarantee safety distances for operation.

Sometimes those solutions are impossible to implement because the lines are established in environmentally protected areas where is totally impossible to cut trees and we don't have conditions to built underground lines due to geographic irregularities. Route changes may imply intensive study and high investment. In these cases, to avoid failures we apply silicone rubber tapes and tubes to isolate and seal the critical zones. This technology is also applied to Avifauna protection.

Visual inspection is an important method to analyse and schedule tasks before fault. However there are some limitations in diagnosing failures that can't be seen at eye sight.

To enhance the diagnostic process, since 2003, we started applying MV overhead lines and thermo graphic inspections. Thermo graphic examinations can detect problems related with bad connection and isolation by the detection of abnormal temperature behaviour in overhead lines parts. OACis objective is to extend Visual and Thermo Graphic inspection to almost 70 % of ARGL overhead network.



Combining both methods, based on the reports, we prioritized and scheduled tasks that increased the quality and efficiency of network and minimized outages contributing to TIEPI improvement.

Underground Cables CBM

Underground network behaviour concerning the number of outages in ARGL, has an important role in TIEPI value. To reduce this value a wide CBM program was defined by OACis project to guarantee the reliability of power supply.

The main target to be achieved is the reduction of outages verified in the worst MV underground circuits considering the number of isolation defects verified annually (Worst Cables).

This program includes Tan Delta (Loss Factor) and Partial Discharge measure, using Very Low Frequency (VLF) 0,1 Hz offline testing equipment. VLF testing reproduces a stress inside the cable close to that caused by AC voltages requiring much lower charging power. With this method it is possible to use smaller and easy carried voltage supply to perform tests in longer cables, when compared to equivalent AC 50 Hz testing equipment.

Tan Delta factor is a global value that helps to justify cable replacement by measuring the loss factor. It is also an important value to define ageing and contamination of the isolation of the tested circuit.

The Underground Cables CBM program also includes performance tests to new cables before their connection to MV network (New Cables) as a complement of the existent commissioning tests.

Considering the Worst cables selection, we verified problems related with partial discharge critical behaviour, and high Tan Delta loss factor values for different step voltage evolution, typical of aged circuits. Sometimes we found problems, like the presence of water treeing and moisture.

For these circuits we created a short time intervention program and undertook actions for replacing critical identified partial discharge accessories (Splices and terminations) and repeated the tests for the circuits were

high values of tan delta and critical presence of water treeing problems were detected (Non linear or abnormal variation in the different voltage steps Tan Delta curve).
Considering ARGL underground network cable types evolution, some ARGL circuits are mixed circuits combining PILC and XLPE technologies. The tan Delta measures for these cases can induce high values due to the main difference of the loss angle for the two different technologies. Some mixed circuits are included in the worst cable program where we verified high values of Tan Delta loss factor value.

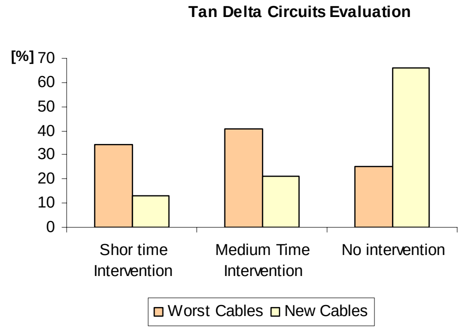
For these cases we created a medium time intervention program with the main objective of controlling the growth of Tan Delta Value in time by new Tan Delta and partial discharge testing scheduled.

In this intervention program was also included some XLPE cables where we verified high values for Tan Delta. Considering we were testing the worst cable selection we should expect worst results.

Defining standards for cable replacement considering our universe of cables was a difficult decision mainly because some high values of tan delta could be acceptable because of cables high length, technology and number of installed accessories (joints). Our experience in testing high tan delta value circuits led us to a main conclusion: better than analyses of tan delta value for a circuit, is the analyses of its growth in time.

The high Tan Delta value is mainly related with problems in accessories assembling and with water ingress in cables, with dangerous contribution to premature ageing and the appearance of water treeing in XLPE cables. These main causes were detected in laboratory analysis of replaced parts.

As a result of the Short time intervention actions we obtained major improvements in the values of tan delta and partial discharge behaviour.



The use of Tan Delta and partial discharge testing equipment, in the commissioning tests of new cables proved to be a good solution because it is possible to identify major problems mainly related with bad assembling of accessories and laying condition of the cables.

The detected errors can be repaired before the circuit's connection to MV network preventing future faults. This test also provides important initial value of Tan Delta, to analyse its growth in time and identify major problems in the MV underground cables.

The errors detected in the analysis of replaced parts defined the need of recycling the contractor's workers knowledge in assembling the MV underground network accessories. Actually all MV underground network workers have to attend special formation course and EDP accreditation document.

CONCLUSIONS

Quality of electricity supply is one of the most important factors to company's performance. OACis project was created to guarantee this main objective in ARGL.

One way to measure the quality performance of one utility is evaluating its TIEPI and network key drivers. Comparing similar utilities and internal ratios it was possible to establish ambitious objectives to ARGL focusing **50% improvement of the TIEPI.**

MV network expansion based on three major points produce significant benefits.

First, by improving project definition we can avoid a lot of obstacles with MV network performance. Second, a careful choice in accessories quality increases reliability of MV network. Third, it is very important to ensure the execution quality with a process of personal certification.

Using CBM techniques in overhead and underground network reduces operational costs and customer claims, increases availability and reliability, postponing major investments and promoting smaller interventions.

REFERENCES

[1] Council of European Energy Regulators, 2005, "Third Benchmarking Report on Quality of Electricity Supply"