An approach to reduce MAIFI – the Quality of Service Indicator for Momentary Interruptions – the experience of the Portuguese DSO

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ABSTRACT

The main purpose of this paper is to show the approach developed by the Portuguese DSO (EDP Distribuição) to improve the Quality of Service Indicator MAIFI in Medium Voltage (MV) networks. To mitigate the effects of momentary interruptions and to troubleshoot their possible causes, it is automatically constructed an information report. This construction is based on sets of data gathered from several sources: weather conditions, type of fault (phase-to phase, phase-to-earth, etc.), fault locations provided by DMS and fault indicators installed over MV lines. Thus, the aggregated information allows to identify preliminarily possible causes: broken isolators, birds, trees located too close or near distribution lines, etc. Furthermore, the fault location information is a powerful tool to reduce areas to be inspected by the maintenance teams. The first results of this problem-solving oriented approach evidence the potential of its application: operational costs savings are derived from reducing the searching areas size to find root causes of momentary interruptions and sustained interruptions are avoided. Thereafter the indicators SAIDI and SAIFI can actually be improved.

INTRODUCTION

In the last two decades, the electric sector has been characterized throughout the world by the process of restructuring aiming to the liberalization of electricity markets. These changes in the sector led to the unbundling of the electric activities traditionally performed by a vertically integrated electric power company. Currently, the sector is organized in four main activities: generation, transmission, distribution and retailing. Generation and retailing are opened to competition while transmission and distribution are activities developed by natural monopolies tightly subjected to the regulation.

Accordingly, the role of the regulatory agencies for the distribution and transmission, besides to set the tariffs for each activity, is to guarantee the security, reliability and quality of supply delivered by the network activities. Regarding to the quality of supply, it is typically evaluated in three dimensions: continuity of supply, power quality and commercial quality. The continuity of supply is related to the number and duration of interruptions. Moreover, it is influenced by the investment level in the network (lines reinforcement, automated devices, network redundancy) and maintenance actions. The continuity of supply has been consistently in the agenda of the regulators, existing in the Portuguese Quality of Service Code standards to be met for SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index), as well as an incentive mechanism to improve the Quality of Supply (QoS). For the current period of regulation, the Portuguese Regulatory Agency (ERSE) introduced the indicator MAIFI (Momentary Average Interruption Frequency Index). Although it has not defined standards to be respected for this indicator, just its monitoring.

In order to continue with high performance, in terms of quality of service, EDP Distribuição has developed approaches to deal with short interruptions. Under the Portuguese regulatory framework, short interruptions are interruptions in which the supply to a customer is interrupted for a duration of 3 minutes or less ($1s < t \leq 3$ min). Nowadays, this type of interruptions is more noticeable than in the past due to the usage of a wide range of electronic appliances. Additionally, short interruptions may have a strong economic impact on industrial customers, causing unexpected breaks in their manufacturing lines.

To handle with short interruptions, it is necessary to understand in what conditions they occur and what type of faults are associated to them. On the other hand, the Portuguese electric distribution network is comprised about 80% by overhead lines, which are highly exposed to external agents, namely trees, birds and weather conditions, particularly lightning strikes. This means overhead systems are rarely reliable as underground ones. Furthermore, the Portuguese population is mostly concentrated on the coast, so that inside regions of the country are characterized by lower load density. Consequently, in that zones the medium voltage lines may have significant lengths, some with difficult access, which is a time-consuming process, increasing the search time.

Thus, taking into account the reasons described previously, EDP Distribuição has been developed an approach to mitigate the effects of the short interruptions and to avoid possible sustained interruptions.

In the following sections, it is described the framework of the distribution activity, its regulation and the methodology developed. The preliminary outcomes are presented as well.

EDP DISTRIBUIÇÃO

In Portugal, the electricity distribution activity occurs through the national distribution grid, consisting of a medium and high voltage network, and through the low

voltage distribution grids. The national distribution grid is operated through an exclusive concession, granted by the Portuguese state. This exclusive concession for the activity of electricity distribution is held by EDP Distribuição (EDP group).

Concerning to the assets, EDP Distribuição operates 419 HV/MV substations and more than 3000 MV feeders, including 67063 secondary substations (MV/LV) and 82175 km of HV/MV network. A great part of the devices is operated remotely through a SCADA system.

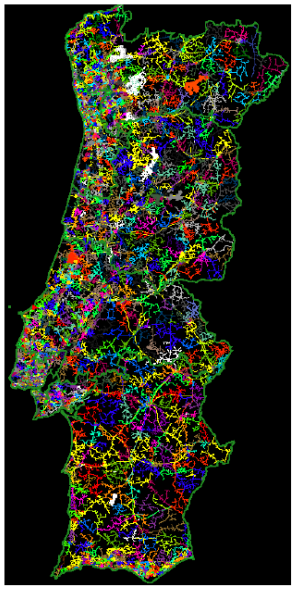

Figure 1 – Portuguese electricity distribution grid

QUALITY OF SUPPLY IN DISTRIBUTION SECTOR – PORTUGUESE CASE

In what to concerns to the quality of supply in Portugal, it has also three major components: continuity, power and commercial quality. The power quality is assessed through the evolution of the voltage wave frequency values, amplitude, harmonic distortion, imbalance and others. For this component of QoS, the Portuguese regulation follows the recommendations indicated in the EN 50160.

In turn, the commercial quality covers a series of subjects such as speed of customer service, response to various requests, reading of meters or the evaluation of customer satisfaction.

At last, the continuity of supply measures the number and duration of supply interruptions. The Portuguese Quality of Service Code defines the patterns to be fulfilled by the DSO, in terms of SADI and SAIFI. To compute the value of these indicators it is considered the sustained interruptions, which occurs when a customer is interrupted for a duration higher than 3 minutes. For SAIDI and SAIFI there are different patterns according to three zones: A, B and C. The first zone concerns to the capital of the districts or areas with more than 25000 customers, the second one reflects the areas with a number of customers from 2500 to 25000 and the last one, zone C, is linked to the remaining zones. Currently, Portugal presents quality of supply indicators at same level with the other European countries [1], namely, whether one considers the countries with similar network characteristics. Indeed, the Portuguese DSO has been made a significant amount investments leading to the reduction of 92% on the equivalent time of interruptions (TIE), since last fifteen years. Furthermore, the regulatory agency establishes a mechanism to improve the QoS, assessing the energy not supplied (ENS) and the SAIDI in the worst 5% of secondary substations. MAIFI have been also presented a decrease trend (Figure 2). Short interruptions are assuming relevance due to the increasing load sensitivity.

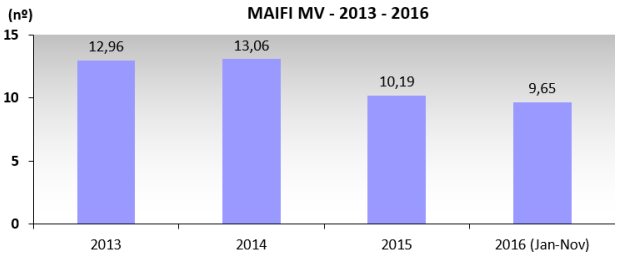

Figure 2 – Evolution of the MAIFI in EDP Distribuição

METHODOLOGY

A large part of the interruptions in a power system, mostly composed by overhead lines, is temporary [2]. Typically, these faults are solved by the reclosers automatisms. When it occurs a fault in a MV feeder, the circuit breakers go through a reclosing scheme to verify if the fault self-clear themselves. In sustained interruptions, the reclosers blocks at the final of the reclosing operation and the downstream devices isolate the fault. Otherwise, sometimes during or at the end of the reclosing cycle the service is restored. For instance, a set of birds bridges the gap across two live conductors (of an overhead power line), or in heavily wooded areas, where tree-line contact is likely, or even conductor clashing. In some cases, the short interruptions may be due to own assets of the distribution network. Despite of these situations may be framed in the scope of the asset management, the methodology developed is also able to be applied. It should be noticed that sometimes a sustained interruption is preceded by several short interruptions. Thus, the short interruptions may be represented as a symptom of a failure, and a sustained interruption can be avoided. These short interruptions can occur temporarily spaced, in a random sequence, once that they display themselves under certain conditions. Therefore, most of the causes are external and difficult to predict. However, it is possible to identify a set of conditions at the instant of time when the fault happens.

This paper presents a methodology developed by EDP Distribuição to handle with short interruptions. It is based on the construction of a report, gathering automatically the data from several sources: weather conditions, type of fault

(phase-to phase, phase-to-earth, etc.), fault locations provided by DMS (Distributed Management System) [3], fault indicators installed over MV lines and interruptions time.

The goals of this approach are defined in the following points:

- Make a prelaminar diagnosis using the information provided in the report, identifying a possible cause;
- Minimize the zone to be inspected by the maintenance teams;
- Avoid future sustained interruptions;
- Improve MAIFI;

Proposed Methodology

As it was described above, data is gathered from several sources, as it is illustrated in the next figure.

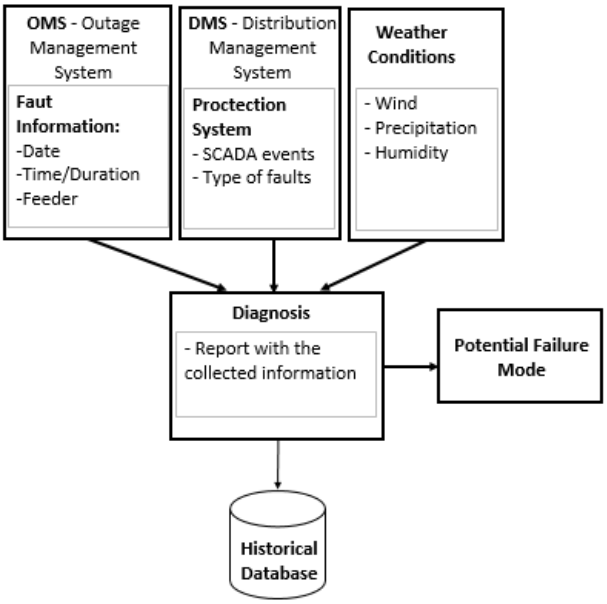

Figure 3 – Flowchart of the proposed methodology

This approach has four main steps:

- **Selection** – Within the set of all MV feeders, it is needed to identify the ones that in the last days/weeks had a significant number of short interruptions (it's possible to choose different values). It is defined a trigger to obtain the list of MV feeders to be analyzed. Normally, in terms of time window, it is selected the last three weeks. To select the feeders, it's used the Outage Management System (OMS) data, in which all occurrences in the feeders are registered.
- **Data Collection** – The available data have different sources and a large quantity. The data for the type of faults come from the DMS system, since that all events of the circuit-breakers and protection system are saved there. Still, the DMS has also the information provided by fault location and fault passage indicators. The available information on the internet about the weather measurements are used. The approach assumed consists in the usage of geographic coordinates from primary substations and meteorological stations. The weather measurements (precipitation, wind and humidity) at the instant time of the interruption are determined considering the meteorological station closest to the primary substation. In fact, a MV feeder may have a significant length and the weather conditions may vary along its path. It is difficult to have a wide coverage of meteorological stations. However, this approach shows suitable once that the purpose is to have some knowledge about the conditions. Therefore, a MV feeder is represented by a single point located in the primary substations HV/MV.
- **Generate the information short interruptions report**: Using the data collected in the previous point, the report is automatically generated through a routine programmed in Excel/VBA. Then this information report is send to a specific maintenance team, in order to identify the cause location. The great advantage of these methodology is to provide a diagnosis report including the possible zone of the fault, and a possible cause. This report jointly with experience of the field teams are undoubtedly an added value.
- **Feedback and historical database**: The processes should finish with the feedback information given by the maintenance teams. When the field actions are completed the maintenance teams inform about what cause was identified and what type of action was made to solve it. Obviously, the field actions may be inconclusive. Afterwards, all cases detected are characterized to supply a database. This database will allow to obtain increasingly accurate diagnoses, considering the history of the MV feeders.

CASE STUDIES AND RESULTS

This section presents some examples in which the approach described previously was applied.

Example 1

For the first example, it is presented a situation caused by birds. A MV feeder presented some interruptions in the last

months August and September, as it is indicated in the Table I.

Table I - Conditions for the short interruptions of example 1

Date	Hour	Wind (km/h)	Precipitation (mm)	Type of Fault
03-09-2016	18:37	24,1	0,0	Phase-to-Phase
02-09-2016	03:56	6,4	0,0	Phase-to-Phase
29-08-2016	18:50	20,9	0,0	Phase-to-Phase
29-08-2016	19:18	16,1	0,0	Phase-to-Phase
27-08-2016	08:08	9,7	0,0	Phase-to-Phase
22-08-2016	19:22	16,1	0,0	Phase-to-Phase
20-08-2016	08:03	6,4	0,0	Phase-to-Phase
20-08-2016	08:21	6,4	0,0	Phase-to-Phase
09-08-2016	19:59	19,3	0,0	Phase-to-Phase

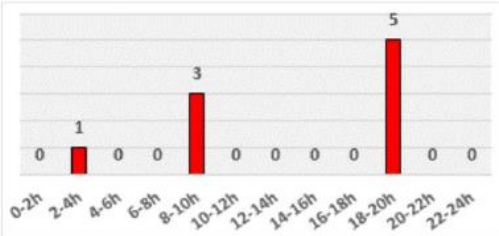

Figure 4 - Chronological distribution of the short interruptions for the example 1

A fault phase-to-phase can be associated to the conductor clashing or even to birds, bridging the gap across two live conductors. The report showed that the interruptions occurred without the presence of wind. Therefore, our conclusion indicated that the cause could be birds. In fact, observing the chronological distribution of the interruption, it is possible to conclude that the short interruptions are concentrated at the daylight hours. This corresponds to the typical activity of the flock of birds. For these short interruptions, the fault passage indicators signalized a zone allowing to restrict the search area. The maintenance teams confirm these diagnosis and measurements were taken in order to mitigate the impact of the flock birds.

Example 2

A second example is presented regarding to a tree that came into contact with a MV overhead line, in windy periods. The events of the protection system showed that the faults are phase-to-earth with a high value of fault resistance. In terms of weather, the short interruptions occurred with windy conditions. The automated switch captured the passage of fault, reducing the area to be searched. The team filed detected a tree close to the MV line, confirming the initial diagnosis.

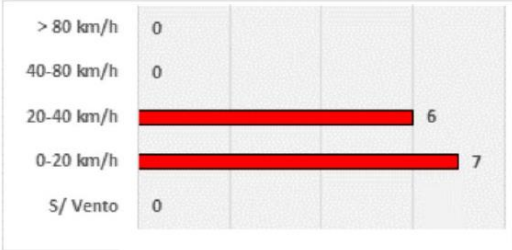

Figure 5 -Short interruption under wind conditions for the example 2

Example 3

Another successful example is showed concerning to an indoor secondary substation MV/LV. The MV feeder presented short interruptions, when the weather conditions were characterized by high humidity and moderate rain. The maintenance teams determined a cracked insulator (probably caused by a lightning strike), which was responsible for the interruptions. Moreover, the system protection indicated phase-to-earth faults and the fault location tool indicated a possible area.

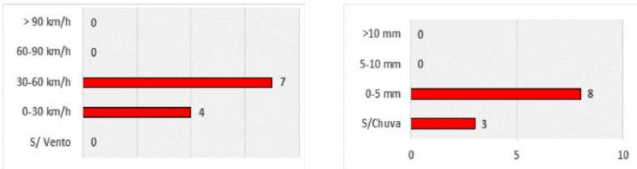

Figure 6- Wind (left) and precipitation (right) conditions for the example 3

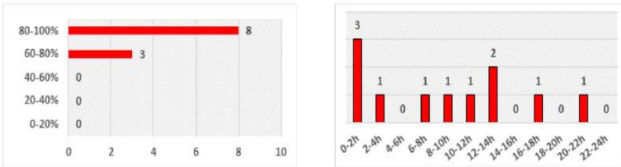

Figure 7 - Humidity conditions (left) and chronological distribution (right) of the short interruptions for the example 3

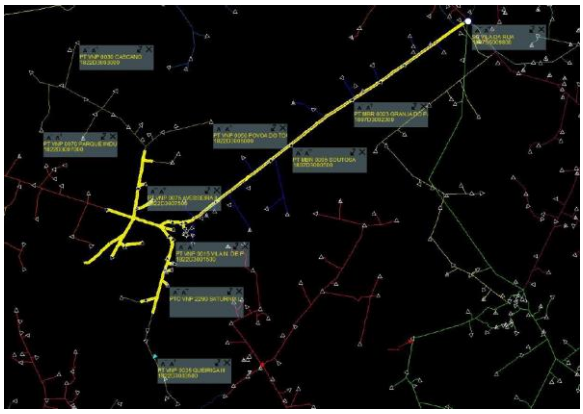

Figure 8 - Fault Location for the example 3

CONCLUSIONS

Short interruptions can occur temporarily spaced, in a random sequence, once that they display themselves under certain conditions. Therefore, to obtain a location for the cause is challenging.

With the analysis and organization of weather measurements, type of fault data and interruptions time, it was possible to discover patterns between these factors and potential causes for short interruptions. Given the network length and the secondary substations MV/LV number, per feeder, collect the DMS data (fault location and fault passage indicators) it's essential to reduce areas to be inspected. This information, which is transmitted to the field teams, allows them to focus on looking for the potential failure (Table II), and consequently contribute to the success of these task.

Furthermore, the report that is automatically generated through a routine programmed in Excel/VBA could be finished in a few minutes. Previously, to generate the same information it would take a lot of effort and time. Thus, the report can be send easily to the maintenance teams, after the selection step.

Table II - Potential Failure mode

Potential Failure Mode:	Potential cause of failure:	Visual inspection:	Short-circuit type:	Comments:
Two conductors get closer or touch each other (condutor clashing)	Wind or birds	Distribution line Struture Types; Sag; Flock of birds;	Phase-to-phase short-circuit, clear of earth	Birds - Vertical or Delta conductor configuration; Short interruptions occur during the daylight; Wind - Horizontal conductor configuration;
Trees and branches coming into contact with overhead lines	Wind or Wind+Rain	Distance betwen trees and overhead lines	Phase-to-earth or Phase-to-phase-to-earth short-circuit	Heavily wooded areas, where tree-line contact is likely
Jumper get closer or touch the cross-arm or the pole	Wind	Jumper wire (deadend/tension insulator)	Phase-to-earth short-circuit	
Annealed wire, to conductor binding, (used on pin type insultors)	Wind	Pin type insulator and annealed wire	Phase-to-earth short-circuit	
Insulator failure	Rain or Rain+Humidity	Outdoor secondary substations (MV/LV) and overhead lines	Phase-to-earth short-circuit	
	Humidity	Indoor secondary substations (MV/LV)	Phase-to-earth or Phase-to-phase-to-earth short-circuit	
Larg stick nest bridges the gap across two live conductors	White stork	Poles	Phase-to-earth or Phase-to-phase-to-earth short-circuit	White stork presence

FURTHER DEVELOPMENTS

The report establishes the weather conditions at the time the feeder short interruption occurs. Nevertheless, it will be necessary to know if with identical or worst weather conditions, short interruptions didn't happen in other periods. The idea is to confirm the feeder behavior, when subjected to the same weather conditions.

With the maintenance teams equipped with digital schematics it'll be easy to communicate the area that need to be inspected and also the potential failure mode.

REFERENCES

[1] CEER, Benchmarking Report 5.2 on the Continuity of Electricity Supply Feburay, 2015.

[2] K. V. R. Gadiraju and M. R. Vallem, "Methods for reducing momentary interruptions in distribution systems," *2012 IEEE Power and Energy Society General Meeting*, San Diego, CA, 2012, pp. 1-6.

[3] N. Pereira, C. M. Pinto, M. Louro, P. Viegas, A. Leitão and D. Cabral, "Integration of fault location in a smart grid operating system," *22nd International Conference and Exhibition on Electricity Distribution (CIRED 2013)*, Stockholm, 2013, pp. 1-4.