

PIONEER EARTH SYSTEMS REMOTE MONITORING FOR SECONDARY DISTRIBUTION SUBSTATIONS

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ABSTRACT

EDP Distribuição is currently focusing on implementing sensorization solutions for its assets, having in mind their importance for the grid operation, their financial value and their maintenance needs. This strategy, conjugated with the comparison between Portuguese regulation regarding the maintenance of secondary distribution substations and the regulation of other similar European countries, are the support basis for the system implementation here described. The system uses a sensor to measure the earthing system impedance values of the secondary distribution substations, allowing the online monitoring of these values through a Remote Supervision System (RSS). With this, it is possibly to register and analyse the values of the earthing systems and their variability throughout the year, which results in a more precise knowledge of the asset condition, supporting the possibility to shift the maintenance strategy from Preventive to Predictive. Furthermore, by studying and comparing the measurements of the earthing systems registered with this solution with the ones registered with the regulated method, it shows that different methods can be used to perform these measurements accurately.

INTRODUCTION

In Portugal, Distribution System Operators (DSO) are required by regulation to perform annual inspections on secondary distribution substations (preventive regulatory based maintenance). These inspections include the measurement of earth impedance, which must be performed on specific months (from June to September), for more than 65.000 secondary substations currently in operation. The degradation of earthing circuits or deviations from its standard values has implications on energy quality and quality of service as well as on ensuring the protection of people and assets.

A comparison with similar utilities showed that, among the countries analysed, only Portugal and Belgium imposed an annual regulatory period for these measurements. Furthermore, only Portugal and Spain specify a method, in their regulation, for the measurement of earth impedance. Additionally, the EN 50522 standard, which specifies the requirements for earthing systems design and erection of

of electrical installations, has increasingly been adopted by European countries.

The combination of these factors led to the necessity of finding a smart condition based maintenance solution. As the main DSO operating in Portugal, EDP Distribuição pushed for the development and demonstration of such solution, with the collaboration of Eneida Wireless and Sensors, that provided the expertise on sensors and their integration over communication networks, and EDP Labellec, the laboratory center of EDP Group, that has the expertise in equipment testing and certification and earthing measurements .

This solution should allow for a deeper knowledge concerning earth impedance variability throughout the year, in different regions, based on alternative approaches for automatic and remote monitoring. It should also show that different methods can be used to perform these measurements accurately. With the development of this solution, EDP Distribuição is aiming for the increase of quality of data, as well as to start a negotiation for a regulatory update with the purpose of reducing the annual volume of onsite measurements by two thirds.

APPLICATION SCOPE

The primary purpose of this EDP Distribuição project is the measurement of the earthing systems impedance values. In this project, the application of this solution is limited to compact ground level secondary substations with separate neutral and equipment earthing.

This system was installed in five secondary distribution substations located in the operation area near Coimbra. All secondary distribution substations are compact and they were selected in order to have one of each of the following criteria:

- Earthing systems impedance values (20Ω is the maximum regulatory value allowed by the Portuguese regulation):
 - Lower than 5Ω ;
 - Between 5Ω to 20Ω ;
 - $\approx 20\Omega$.
- Significant earthing systems impedance variations registered between 2013 and 2014;
- Geographic location (inland and coast).

The secondary substations where this system was implemented are resumed in Table 1, according to the selection criteria. Figure 1 represents the geographic location of these assets.

SECONDARY SUBSTATION		SELECTION CRITERIA					
		R<5Ω	5Ω<R<20Ω	R>20Ω	ΔR [2013/2014]	Inland	Coast
CDN 0090			X		X	X	
CNT 0024				X		X	
FIG 0253			X		X		X
SRE 0019				X	X	X	
SRE 0015		X				X	

Table 1 - Selection criteria per secondary substation

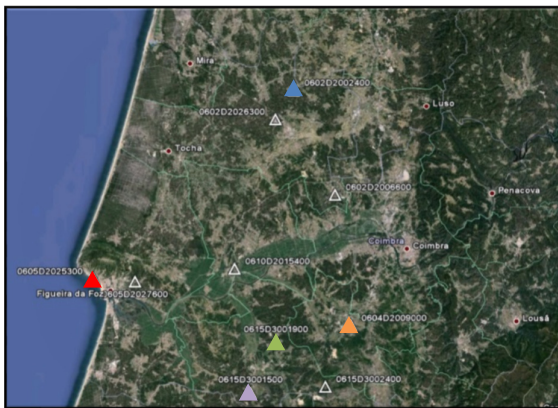


Figure 1 - Geographic location of the selected secondary substations (matched color from Table 1)

TECHNICAL SOLUTION

This system was conceived to measure the neutral and protective earthing values using the Clamp-on method with the possibility of adjusting the measurement frequency and with remote and automatic online monitoring. One of the main technological issues was the fact that the system should be installed inside the secondary distribution substation enclosure.

This system incorporates three components, as shown in Figure 4:

- **Monitoring equipment:** it measures the earthing circuits using the clamp-on method. See Figure 3 for an example of this equipment.

- **GPRS communication interface:** it allows the interaction and data transmission from and with the monitoring equipment.
- **Remote supervision system:** it manages the data flow from the GPRS communication interface. Registers all data from the measurements and generated events on a database and displays this information using a graphic interface that allows for the rearrangement of its parameters.

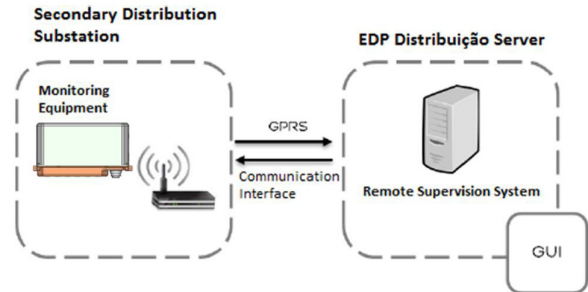


Figure 2 - Earth systems remote monitoring functional architecture

Monitoring equipment solution

The Clamp-on monitoring equipment has three blocks, that are installed as shown in Figure 3:

- Neutral earthing measurement unit (EWS DTEC-rg);
- Equipment earthing measurement unit (EWS DTEC-r);
- High voltage relay (I/O rel).

This method of measurement is based on the electromagnetic induction principle. Using a toroidal coil inductor (T_{ind}), where K is its transformation factor, a specific voltage (V_{inj}) is applied, generating a current (I_{ind}) in the earthing circuit that can be measured by another toroidal coil (T_m). Using Ohm's law, it is possible to calculate the impedance of the earthing circuit:

$$V_{ind} = \frac{V_{inj}}{K}$$

$$V = Z \cdot I \rightarrow Z_{cir} = \frac{V_{ind}}{I_{ind}} = \frac{V_{inj}}{K \cdot I_{ind}}$$

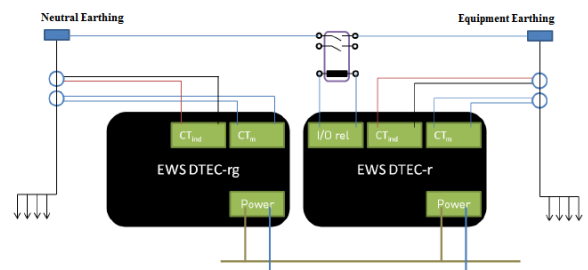


Figure 3 - Installation schematic for Clamp-on measurement equipment



Figure 4 - Monitoring equipment installed in CNT 0024

SYSTEM VALIDATION AND RESULTS

For all five secondary distribution substations where this system was installed, three different measurements sets were collected monthly, during a period of one year.

The earthing systems remote monitoring equipment (RME) registered the earthing impedance values daily, every two hours. Based on these values, available at the remote supervision system, as shown in Figure 5, a monthly average value was obtained.

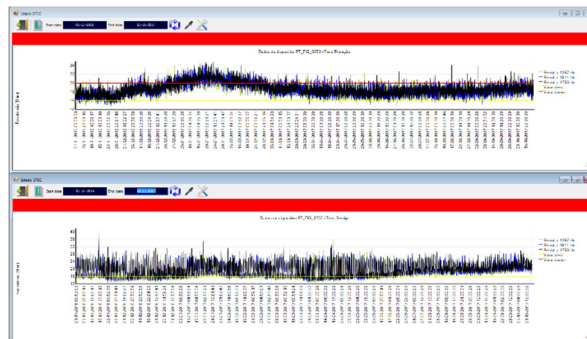


Figure 5 - Detail of the remote supervision systems for secondary substation FIG 0253

To validate the earthing values obtained with the Clamp-on method, EDP Distribuição measured onsite the earth impedance values monthly and used the method specified by regulation (three-pole method). Additionally, every 4 months, the earth impedance values were measured, also using the three-pole method, by EDP Labelec (Labelec). These measurements were registered in the same period as the ones measured by EDP Distribuição.

Figure 6 and 7 show the graphs with the results for secondary substation SRE 0015. These results were

registered between November of 2016 and October of 2017. In June, it was not possible for EDP Distribuição to measure the values of the earthing systems for all five secondary substations. EDP Labelec performed measurements in November 2016, March 2017 and July 2017.

The labels in the graphs below are:

- EDP D: EDP Distribuição monthly three-pole measurement;
- Labelec: EDP Labelec three-pole measurement;
- RME: Remote monitoring equipment average of the daily measurements.

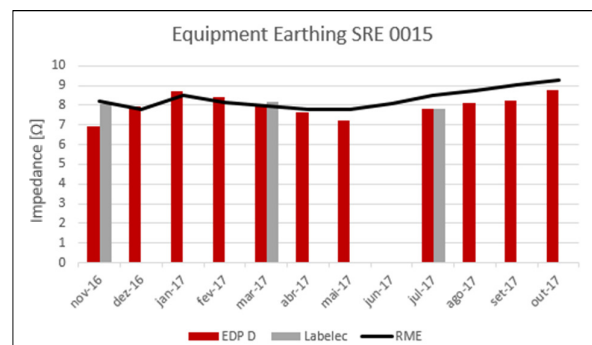


Figure 6 - Equipment earthing impedance values for SRE 0015

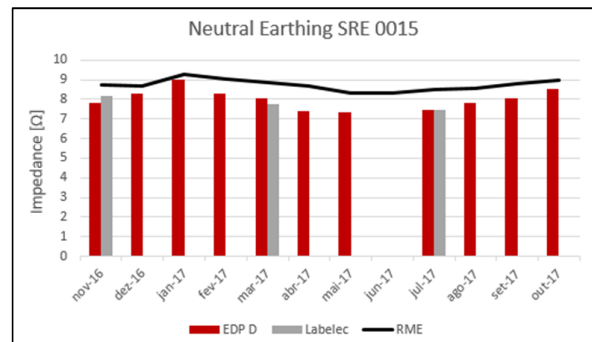


Figure 7 - Neutral earthing impedance values for SRE 0015

For secondary substation SRE 0015, with earthing impedance values well below 20Ω , the variations registered between the maximum and minimum values for the three different sets of measurements do not go above 1Ω and the difference between maximum and minimum for each set of measurements does not go above 2Ω , as shown in Table 2 and 3.

Equipment Earthing SRE 0015			
[Ω]	RME	EDPD	Labelec
Max	9,25	8,79	8,20
Min	7,77	6,91	7,79
Δ [Max-Min]	1,48	1,88	0,41

Table 2 - Maximum, minimum and variation for SRE 0015 equipment earthing per method

Neutral Earthing SRE 0015			
[Ω]	RME	EDPD	Labelec
Max	9,29	9,00	8,16
Min	8,34	7,35	7,49
Δ [Max-Min]	0,96	1,65	0,67

Table 3 - Maximum, minimum and variation for SRE 0015 neutral earthing per method

As for secondary substation FIG 0253, with earthing impedance values close to 20Ω, the results can be seen in Figure 8 and 9.

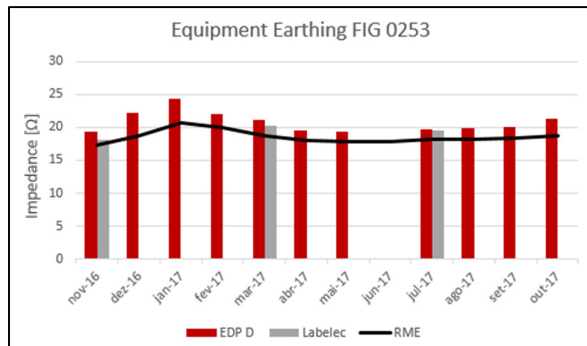


Figure 8 - Equipment earthing impedance values for FIG 0253

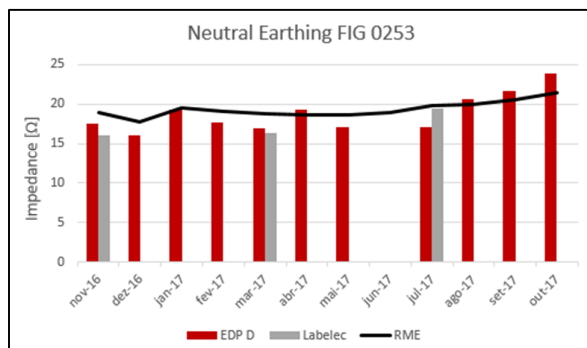


Figure 9 - Neutral earthing impedance values for FIG 0253

In this case, the variations registered between the three different sets of measurements, throughout the year, are higher (the highest difference reaches around 4Ω). Moreover, for each set of measurements the differences between maximum and minimum values are also more significant, as shown in Table 4 and 5.

Equipment Earthing FIG 0253			
[Ω]	RME	EDPD	Labelec
Max	20,76	24,40	20,20
Min	17,23	19,40	18,10
Δ [Max-Min]	3,54	5,00	2,10

Table 4 - Maximum, minimum and variation for FIG 0253 equipment earthing per method

Neutral Earthing FIG 0253			
[Ω]	RME	EDPD	Labelec
Max	21,42	23,80	19,50
Min	17,70	16,10	16,01
Δ [Max-Min]	3,72	7,70	3,49

Table 5 - Maximum, minimum and variation for FIG 0253 equipment earthing per method

CONCLUSIONS

The analysis of results obtained during the one year period showed that for earthing systems with impedance values near the 20Ω threshold, the earth values registered by the remote monitoring equipment, using the Clamp-on method, are within the same order of magnitude as the ones registered onsite, both using the three-pole method. Thus, having in consideration the criteria of the secondary substations selected, it was concluded that the Clamp-on method offers a secure range of accuracy of measurement, offering an alternative solution other than the three-pole method. This can be particularly useful for urban secondary substations where this method is very impractical due to space and ground limitations.

However, as earth impedance values increase, the remote monitoring equipment loses sensibility and the values registered are consistently lower than the ones measured by EDP Distribuição and Labelec. This is a result of the sensors range used. Since the earthing system values should not be higher than 20Ω, the sensors were dimensioned accordingly.

Despite this offset, the variation curve of the values registered by the remote monitoring equipment during the one year period is consistent with the variation curve of the values measured onsite. In addition, for each of the three sets of measurements, the amplitude of the respective variation curve is lower for the secondary substations with lower earthing systems impedance values.

Final results are in line with the initial assumptions of the project :

- Clamp-on method offers an accurate alternative for measurement of the earthing system impedance values, considering the selection criteria of the secondary substations selected for the project;
- If earthing systems are not damaged by others or by high corrosive soils, their impedance value does not register significant changes throughout the year, which is aligned with the intention of adapting the regulation towards higher levels of operational efficiency;
- By monitoring earthing impedance values online, in some cases, it is possible to detect when the earthing systems are damaged (e. g., by theft), as well as to identify when they are deteriorating.

This can support a predictive maintenance strategy.

REFERENCES

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- [3] IEEE Std 81-2012 – Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System