REE´s commitment to partial discharge monitoring in its underground cable network

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SUMMARY

The measurement of partial discharges (PD) is a reliable tool for ascertaining the state of insulation of high voltage equipment, especially insulated cable systems, as well as for preventing faults in these installations.

The efficiency of this tool is greatly increased when the information is obtained on a continuous basis as opposed to the usual spot inspections, because the analysis of the state of the insulation is closer to reality. The information obtained is used to feed the company's asset management system, integrated in the platform SAGA (Advanced Management Asset System, in Spanish).

Technological advances in partial discharges and monitoring have allowed us to deploy equipment that sends data from each cable circuit, through the REE (Red Eléctrica de España) network, to the Integrated Facilities Maintenance Centre, located at REE headquarters, where the group of experts in Line Maintenance analyses the information. The main purpose of the analysis is to classify the origin of the partial discharges detected and focus on those ones that come from an internal defect. Once identified and located a signal that may be dangerous for the cable insulation, a maintenance action has to be decided in order to prevent the installation failure.

In 2020, the Spanish TSO has made the forward leap from having a pilot project for monitoring PDs in one circuit to having a significant number of circuits monitored all around the geography of Spain. There are 36 circuits sending PD measures online continuously. Additionally, REE has 6 portable devices that measure temporarily, with the capacity to cover around 150 circuits per year. The installation has been carried out in coordination with the different departments and regional areas of the Installations Maintenance Management Area of REE.

Some challenges appeared in the process of installing the PD sensors and equipment:

- Outages of the circuits: Programmed outages of the circuits were arranged in order to install the PD sensors.
- Power supply: Connection to the substation power network was performed where available, while different autonomous systems were found where necessary.

- Space for the stable equipment: complete engineering projects had to be redacted to look for the best location and connection option in every set up performed inside a substation.
- Communications: Connection to the REE telecommunication network was necessary, due to the amount of data generated in the PD equipment (the use of Internet of Things technology was not an option)
- Cybersecurity: the security standards and communications protocols of REE were followed strictly.

Monitoring allows us to have greater control and manage maintenance based on the risk and criticality of the facilities. Based on the data analysed, decisions can be made to prioritise maintenance tasks and thus reduce the time that circuits are unavailable, in addition to anticipating any faults that may occur.

In the future, the number of permanently monitored facilities is expected to continue to increase, as part of REE's Power Line Monitoring Strategy, which includes other parameters like sheath current, temperature, mechanical vibration, etc. At the same time, continuous efforts are being taken to be aware and apply the most suitable monitoring technologies available in the market.

KEYWORDS

Partial Discharge, Monitoring, Cable Systems, Preventive Maintenance.

1. INTRODUCTION

One of the main difficulties of a maintenance team in charge of cable systems (underground or submarine cables) is that checking the health state of the installations is not always easy or possible. Indirect parameters must be measured in order to estimate the remaining life or to predict whether a circuit will likely suffer a failure in a short or mid-term. Examples of these parameters are the temperature of different parts of the circuit (along the hole circuit or in some points), the current measured in the sheaths, the mechanical vibration or the partial discharges detected in the main isolation of the cables and accessories.

Another important decision for a maintenance team in every utility is choosing which parameters should be measured and what is the optimum frequency (time between punctual measures or monitoring) to perform the different inspections in order to optimize the resources dedicated to preventive maintenance.

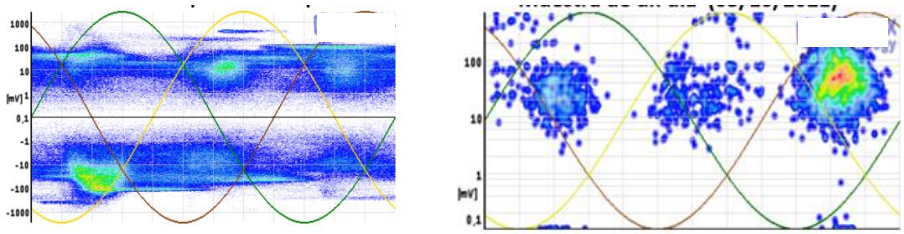
In this paper, the traditional maintenance model of Partial Discharge (PD) inspection in the Spanish TSO is presented as well as the commitment of the company to PD monitoring, showed in the inspection strategy for the present and the forecast and challenges seen for the future.

2. IMPORTANCE OF PARTIAL DISCHARGE MEASURING IN CABLE SYSTEMS

Based on the experience of several years managing the maintenance of the cable systems of the Spanish TSO (with a cable network of more than 2.000 km), one of the analysis results of the maintenance team is that Partial Discharge inspection is, at this moment, the most reliable tool to know the state of the isolation of the cable and accessories (the main problem in the case of internal cause failures). Therefore, PD can be a very useful tool to prevent failures in the circuits before they occur, that is one of the maintenance objectives.

On the other hand, PD measuring is not always easy or even possible, depending on the type of installation. PD inspections are a significant expenditure and measure equipment systems (and their installation) entail an important investment for the company, so the case study must be done, taking into account the possible benefits of making each expense.

Besides, although PD measuring can offer very valuable information about the isolation state, the management and analysis of the data coming from the measure equipment is not easy. Filtering of the signals and a correct interpretation of the PD parameters must be done to identify if PD exist in the installation and, if so, if the PD corresponds to corona, external surface discharge of internal cavity (the dangerous one).



(a) (b)

Figure 1. Example of PD signals before (a) and after filtering: external surface discharge (b).

3. TRADITIONAL MAINTENANCE MODEL

The traditional maintenance inspection model in the company included periodic inspections (different parameters) in all the underground cables. In particular, PD were measured in all the elements of the underground cables (where possible), but only making punctual measures and only once every five years.

An analysis process was performed within the Maintenance Department to study the efficiency of every periodic inspection of the traditional model. Therefore, some changes were introduced in the PD inspections, because low level of inspection in all the cables meant very low profitability (the benefits obtained were rare). In general, those inspections were useless to prevent or avoid failures in the installations.

4. CURRENT STRATEGY

4.1. General improvements

To solve the weakness detected in the traditional PD inspection model, the current PD strategy includes the following ideas:

- Improve the quality of the data coming from the PD inspections: monitoring or long-time measures instead of punctual measures.
- Reduce the number of elements to inspect with long-time PD measures. Only selected underground circuits will have this type of long-time inspection. The selection criteria is based on the risk and importance of the circuits for the company and on maintenance criteria.
- Training of a crew inside the company that can handle the PD equipment. This provides benefits to the strategy, as the internal crew can perform necessary works faster (decreasing the time of unavailability of the circuits), gives more know-how to the company and more value to the staff. Moreover, internal training reduces the dependency from external providers and their associated costs.

Figure 2. Training of REE staff on PD measuring equipment at a substation.

- Acquisition of more versatile and portable PD measure equipment. PD devices with a multiplexer are sometimes prioritised, as they allow measuring several circuits with only one equipment and installation (saving costs).

Figure 3. Portable PD measure equipments

- Increase the number of PD measure equipment: from one circuit measured in a pilot project near Madrid [1] in 2014 to 36 measuring points along all the Spanish geography in 2021.

During the installation of the PD monitoring systems, different tasks had to be arranged:

- Outages of the circuits: Programmed outages (or other kind of interventions) of the circuits were planned in order to install the PD sensors and external and internal staff were working coordinated (always in collaboration with the regional areas of the Installations Maintenance Management Area of REE). When necessary, an outage of a few hours is usually enough for this kind of installation.
- Power supply: Connection to the substation power network was performed where available, collaborating with the Substation Maintenance Department, while different autonomous systems were found where necessary. Inside a substation, an standard AC socket has been used to obtain the power supply. In terminations located at transition towers installing photovoltaic panels (and batteries) is also an option to get the necessary power.
- In joint bays, the absence of power supply is usually a limitation for installing PD monitoring systems. Providing alternative power supply systems could be impossible (in non-accessible joint bays) or too expensive (using energy harvest systems). And the consequence of this limit in measuring is that only some parts of the length of the circuits can be measured. Sensors (measuring points) must be installed optimizing the measured length and costs.

Figure 4. Installation of PD monitoring systems inside a GIS substation.

- Space for the stable equipment: complete engineering projects had to be redacted before installation to look for the best location and connection option in every set up performed inside a substation. Sensor sensibility will vary depending on each circuit configuration, so it is very important studying the best place to connect them.

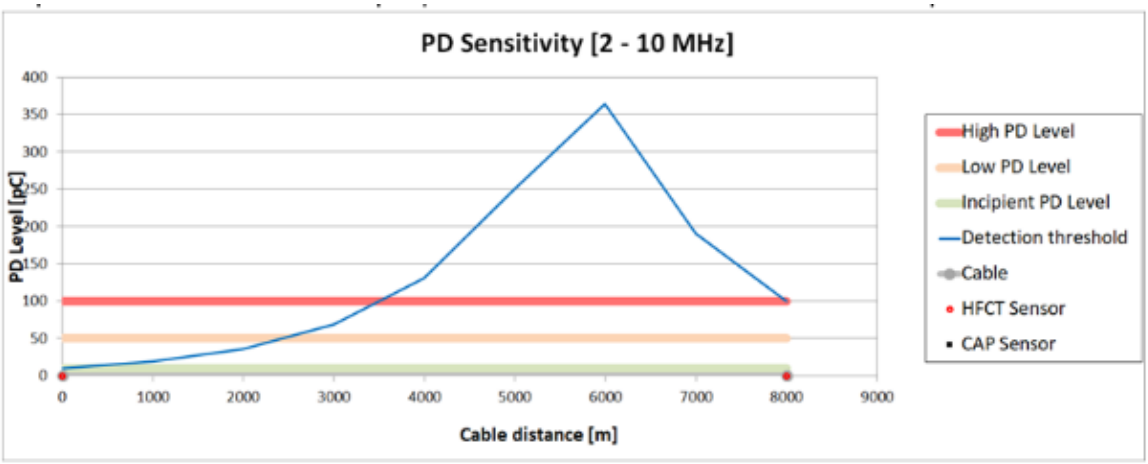


Figure 5. Analysis of sensor sensibility vs distance for a concrete circuit.

- Communications: Connection to the REE telecommunication network was necessary, due to the amount of data generated in the PD equipment (the use of Internet of Things technology was not an option). Collaboration with Communications Department was a must. Alternative communication systems are more expensive (or non-feasible).
- Cybersecurity: the security standards and communications protocols of REE were followed strictly.

5. CONTINOUS MONITORING BENEFITS

This change in the PD inspection strategy has been done to take advantage of the monitoring benefits found for this parameter.
There is a significant improve in the quality of data, going from useless data (in general) to detailed, reliable and useful data.

Monitoring means having the information available in real-time, so measures are obtained faster. This is interesting to prevent possible failures (better response time) and to prioritise maintenance tasks. Monitoring also implies a saving in punctual inspections and travels and can entail a reduction of cost due to unavailability of the circuits.

Monitoring projects in the company must follow an evaluation process defined in the monitoring strategy. To ensure the efficiency of the installed systems and to evaluate the impact of monitoring, cost-benefit analysis must be done for every project.

Within the company, there are synergies between different monitoring projects that are changing and modernizing processes. In general, all these projects require the collaboration of different departments (Lines, Substations, Design, Communication, Regional Areas, etc.). For this reason, the impulse to PD monitoring can be used to increase monitoring of other useful parameters, like sheath current (REE has already experience of pilot projects [1] [2]), temperature, etc.

6. INTEGRATION WITHIN MAINTENANCE CONTROL CENTRE IN THE COMPANY

There are several control centres in the company and one of them is dedicated to the maintenance of the installations, the CMI2: Integrated Facilities Maintenance Centre (in Spanish), located at the REE headquarters in Madrid [3]. The CMI2 control is designed as a place to receive information of the installations (lines and substations), analyse those inputs and take maintenance decisions. At the CMI2, alerts and alarms coming from monitoring systems are managed with different software and connected to the target staff.

In order to have centralized the reception of monitoring information, collaboration with Communication department has been a must to fulfil the challenges of cybersecurity. This integration is necessary also to make possible the scalability of the monitoring of parameters.

7. FUTURE OF MONITORING

The commitment of the company on partial discharge monitoring for the next years is also clear. The number of PD measure equipment will increase and will be installed at selected circuits.
The heath index values and accuracy will be better in underground circuits when monitoring is performed, and these values will be used in the Asset Management System (SAGA in Spanish), to optimize the maintenance task of the underground lines.

Automatic analysis and interpretation of PD measures using artificial intelligence should be promoted or even sponsored, so scalability of PD monitoring can be done. In this sense, PD alerts and alarms must also be generated in an automatic way.

Additionally, investigation on solving the current limits for PD measuring have to continue (supply of power in joint bays, PD in HVDC circuits, etc.).

Beyond PD measures, the installation of PD monitoring systems may be an opportunity to expand monitoring of another parameters, like sheath currents, taking advantage of the synergies of the installation of PD monitoring systems.

8. CONCLUSSION

After analysing the maintenance inspections along several years, PD has been identified as a relevant parameter of useful information and a significant change has been performed in the maintenance PD inspections strategy by the Spanish TSO. The current strategy includes selection of critical underground circuits and installation of PD monitoring systems.

In this sense, the commitment of the company to PD monitoring has covered an important investment in PD measuring equipment, training of REE staff to handle internally the equipment and centralizing the PD information at the maintenance control centre (CMI2).

For the future, some challenges must be faced to expand PD monitoring network: the automatic analysis and interpretation of PD measures using artificial intelligence and the research of technological solutions for the current limits for PD measuring.

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