Study Committee B1

Insulated Cable Systems

10868_2022

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

Ricardo GÓMEZ * (1), Ricardo REINOSO (1), Gonzalo DONOSO (1), Elena NOGUEROLES (1)

(1) REE Spain

Motivation

Checking the health state of the installations is not always easy or possible. Indirect parameters must be measured in order to estimate this state. Examples of parameters that can be monitored are:

- temperature along the whole circuit or in some points
- current measured in the sheaths
- mechanical vibrations
- partial discharges detected in the main insulation of the cables and accessories.

Choosing parameters to be measured and their optimum frequency of inspections is an important decision for utilities:
occasional measurements VS continuous monitoring.

Maintenance model of Partial Discharge (PD) inspection performed by the Spanish TSO in the past, and analysys for the present and future is shown.

Result: The commitment to PD monitoring.

Importance of PD measuring

PD measurement can offer very valuable information about the insulation state.
But management and analysis of the data coming from the measurement equipment is not easy:

- ✓ Signal filtering and 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, e.g., on the outside of the termination
- ❖ or internal cavity (the dangerous one).

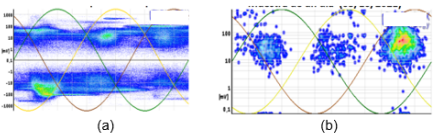

Figure 1. Example of PD signals before (a) and after filtering (b) for external surface discharge

Traditional Maintenance Model

Inspection model in the past included periodic inspections such as thermography, sheath test, PD measurements, etc. in all underground cable circuits.

PD were measured in all the elements of the underground cables, but only periodic short-term measurements (every 5 years and during 30 min.).

An analysis process was performed to study the efficiency of the periodic inspection of the traditional model. In the last 4 years:

- 2000 short-term PD measurements have been performed in circuits above 100 kV resulting in only 1 case with patterns of internal PD.
- 600 short-term PD measurements in circuits below 100 kV, with 5 detected cases with internal PD.

Consequently, some changes were introduced in the PD inspection strategy.

Strategy for present and future

IMPROVEMENTS IN PD INSPECTIONS

The main ideas to improve the traditional model are:

- Improvement of the PD inspection quality: continuous monitoring or temporary monitoring instead of periodic short-term measurements.
- Only selected underground circuits will have this type of inspection. Selection criteria based on:
  - ✓ Risk and importance of the circuits
  - ✓ Maintenance criteria.
- Training of company's own personnel to handle the PD equipment.

Figure 2. Training of company's staff on PD measuring equipment at a substation.

- Acquisition of more versatile and portable PD measurement equipment:

Figure 3. Portable PD equipment

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- Increase of number of circuits with PD monitoring: 1 (2014)➔36 (2021)
- Integration within maintenance control centre in the company (CMI2): management of alerts and alarms.

CHALLENGES DURING INSTALLATION

- Coordination of power outages in circuits.
- Power supply:
  - ✓ Connections to substation network.
  - ✓ Photovoltaic panels in transition towers.
  - ✓ Limitations in joint bays.

- Placement of the equipment: complete engineering project for each installation.

(a) (b)

Figure 4. a) Installation of continuous PD monitoring systems in a transition tower
b) Installation of portable PD monitoring systems inside a GIS substation.

- Analysis of sensor location to optimize measured length and cost.

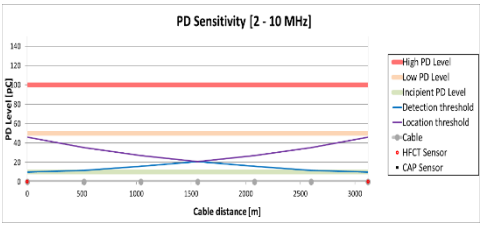


Figure 5. Analysis of sensor sensibility vs distance for a real circuit in operation.

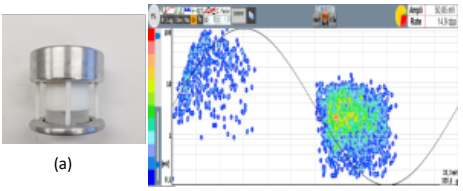
- Communication: big amount of data ➔ connection to internal telecommunication network.
- Cybersecurity: security protocols followed strictly.

Research: PD during transient overvoltage.

Modern research: PD can be measured during existing overvoltages in the network, due to:
- ✓ fast transients such as lightning or
- ✓ slow transients such as switching.

Based on it, the Spanish TSO has performed composite testing in the HV laboratory:
New PD measurement instrument has been implemented: immune to interference caused by the overvoltage itself in synchronism with the grid sinusoidal voltage.

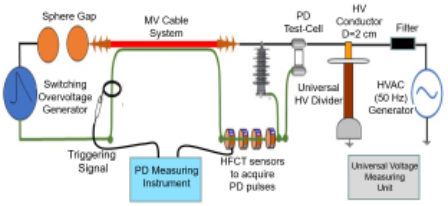
PD pulses will allow the construction of a phase-resolved PD (PRPD) pattern similar to conventional PRPD patterns recorded in continuous PD measurements.



(a) (b)

Figure 6. a) Small PD test cell (5 cm height and 5 cm diameter) with a cavity-type insulation defect inside
b) Phase-resolved PD pattern generated by the test cell at 6 kV.

The composite test voltage was measured by a universal measurement system (an universal HV divider and an universal voltage measuring instrument) as shown in Figure 7.



(a)

(b)

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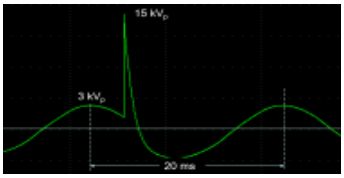
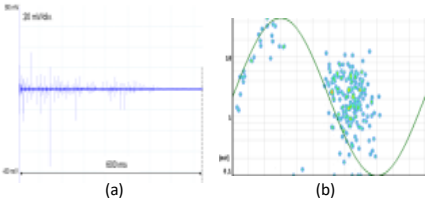


(c)

Figure 7. a) Schematic circuit of a composite voltage test
b) Implemented testing set-up in HV Laboratory
c) Composite voltage waveform measured by the Universal Voltage Measuring Unit.

Partial discharges in the "test cell" generated by a switching overvoltage were acquired by an HFCT type sensor and processed by the new developed measuring instrument. Figure 8.a shows the record of a PD pulse train for 600 ms (30 periods of 20 ms) and in figure 8.b the corresponding phase-resolved pattern generated by the switching overvoltage.



(a) (b)

Figure 8. a) PD Pulse train generated by a switching overvoltage, b) Phase resolved pattern of PD pulses from a pulse burst caused by a transient overvoltage

Defect recognition:

The phase resolution PD pattern of a PD pulse train caused by a single switching surge may be sufficient to recognize a cavity-type defect in solid insulation because its PD pattern, shown in Figure 8. b), is similar to the PRPD pattern shown in Figure 6.
However, overlapping PRPD patterns caused by multiple switching surges (e.g. 7 or 10) give PRPD patterns much easier to recognize as a “cavity type” defect, as shown in Figure 9 and in comparison with Figure 6.

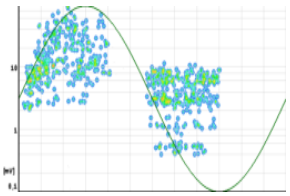


Figure 9. Phase-resolved pattern of PD pulses for pulse bursts caused by several (e.g. 7) transient overvoltages of the switching type.

Consequently, synchronized PD measurements during transient overvoltages, e.g. due to the switching operations, is a very efficient method for the early detection of insulation faults in high voltage networks.

Continuous monitoring benefits

- Improvement in the quality of the measurements
- Information available in real-time, so faster reaction is possible.
- Saving in periodic measures and travels.
- Synergies between different monitoring project (other useful parameters).

Future of monitoring

- Increase number of PD measurement equipment at selected circuits.
- Automatic analysis and interpretation of PD measurements using artificial intelligence must be promoted. The Spanish TSO is sponsoring an artificial intelligence tool.
- Research to solve the current limits for PD monitoring:
  - ✓ units with low power consumption as most joint bays do not have power supply
  - ✓ PD measurements in HVDC circuits are currently not enough developed.

Conclusion

- After analysis, the current strategy includes selection of critical underground circuits and installation of PD monitoring systems.
- the commitment of the Spanish TSO to PD monitoring has covered:
  - ✓ Important investment in PD measurement equipment
  - ✓ Training of internal staff and
  - ✓ Centralizing the PD information at the maintenance control centre (CMI2).
- For the future, some challenges must be faced to expand PD monitoring network:
  - ✓ PD measurement synchronized with transient overvoltages due to switching operations.
  - ✓ Automatic analysis and interpretation of PD measurements using artificial intelligence
  - ✓ Research of technological solutions for the current limits for PD measuring.