

## Study Committee D1 Materials and Emerging Test Techniques Paper D1-PS1-11049

### Requirements for Artificial Intelligence Platform addressed to Automatic Assessment of Insulation Condition of Indoor and Outdoor Installations through PD Monitoring

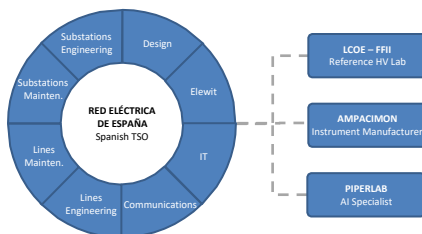
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#### Motivation

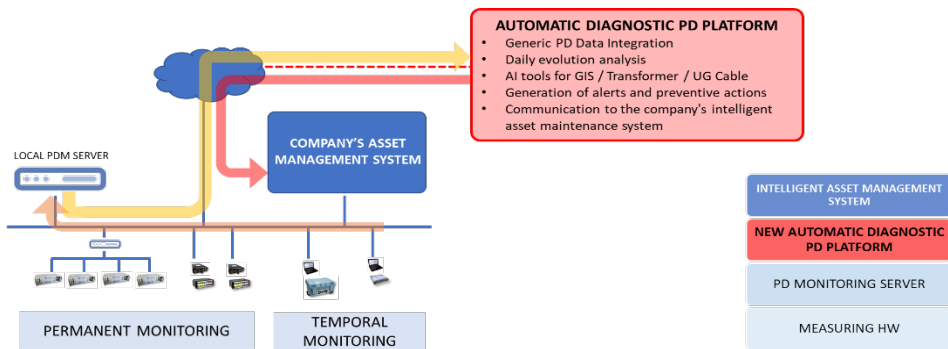
Partial discharge monitoring in electrical installations to assess the insulation condition of different assets is being widely applied by many electricity companies in the world. However, there are no complete automatic solutions that allow simultaneous monitoring of the main different elements of high voltage installations: GIS substation, power transformer, cable and measuring transformers with different measurement technologies working from 1 MHz to 3 GHz, and that in the event of an insulation defect trigger automatically an alarm signal with information on the type of defect, its emplacement and severity, without the need for human interaction.

#### R&D Project



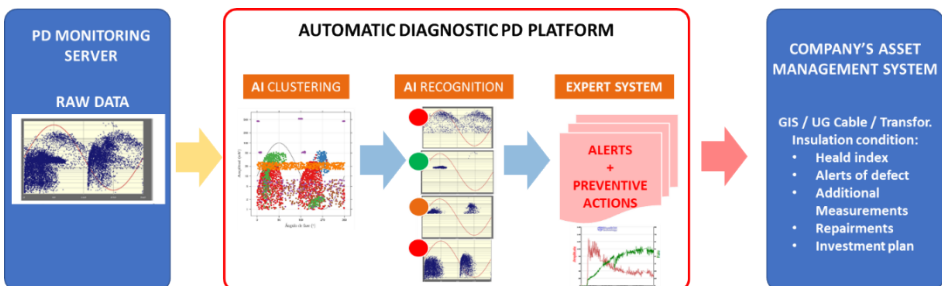
#### ARTIFICIAL INTELLIGENCE PLATFORM

The new platform includes AI tools to carry out the diagnosis done currently by high qualified diagnostic engineers.



#### Platform structure

As modern platform design with high scalability and integration has been chosen a cloud solution design, been able to be deployed in a flexible storage solution. All the data collected by continuous or temporal monitoring systems must be centralized in this new platform to be diagnosed with AI tools that will be learning and retrained from all the accumulated new data.



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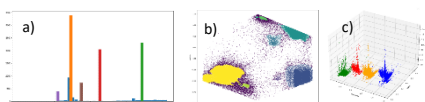
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### DEVELOPED AI TOOLS

















#### 1. Signal processing tool for automatic PD clustering

- a) Localization
- b) Ratio between phases
- c) Pulse wave shape parameters

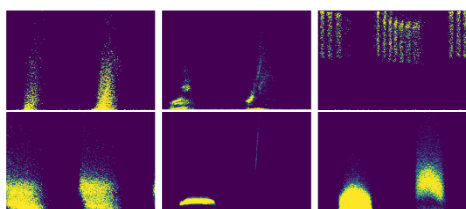


#### 2. Neuronal network for automatic PD pattern recognition

- a) PRPD pattern recognition from HF sensors
- b) PRPD pattern recognition from UHF sensors

	Type 1 Mobil Particles In SF6	Type 2 Surface in SF6	Type 3 Protrusion In SF6	Type 4 Floating Potential In SF6 or in air	Type 5 Cavity	Type 6 Internal Surface	Type 7 Corona In Air	Type 8 Surface in Air
HFCT								
UHF								

Convolutional neural network (CNN) is used to classify the different defects with the linear and logarithmic representation of the PRPD.



#### 3. Alert and alarms criteria for automatic insulations diagnostics

Each PD activity obtained will be analysed according to the following criteria:

- type of behavior of the defect
- precision of the defect location
- type of sensor that detected the defect pattern
- type of defect that has been recognized
- equivalent amplitude and rate

### FUNCTIONAL REQUIREMENTS

- PROCESSING AND STORAGE
  - o Automatic diagnostic capabilities with AI
  - o Tools to train AI with new knowledge database
  - o Generate diagnostic alerts for each monitored sensor with customizable configuration
  - o Identity assessment system for different users
  - o Data must be stored a minimum of three years
- COMMUNICATION REQUIREMENTS
  - o Ability to collect data from different PD providers in standard protocols
  - o Outbound communication to send processed data through IEC61850 and other protocols
    - Type of alert
    - Evolution of amplitude and rate
    - Recommended actions
    - Type of defect
    - Type of activity behaviour
    - Criticality of the defect
    - Location
    - Starting time and accumulated uptime
- USER INTERFACE REQUIREMENTS
  - o Configuration of the diagnostic system
  - o Browsing by diagnosed system
  - o Alert lists
  - o Details and evolution of each defect or sensor

### NON-FUNCTIONAL REQUIREMENTS

- Containerization for easy deployment using flexible storage
- HMI based on a web application for visualization of the processed data
- Able to receive and store all the data sent by the data sources until processing
- Able to be installed both on-premise and in the cloud to be used as a SaaS.
- Able to collect data from any PD monitoring technology after adapting the collection process and the automatic clustering with available parameters
- All security requirements of the user utility

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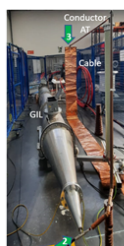
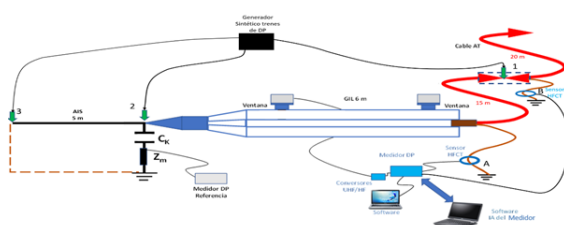
### LABORATORY FACILITIES TO PERFORM QUALIFICATION TESTS TO AI PLATFORMS

#### PD generation

- HV + Test cells (GIS-Cable-AIS)
- Synthetic PD generator

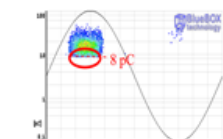
#### Testing Workbench

- GIL section 7 m long and 0.5 m in diameter
- Power cable 35 m long 12/20 kV with an intermediate splice
- Bare conductor 5 m long
- 2x UHF sensors in each window of the GIL
- 2x HFCT sensors in the earth connection of the cable terminations
- Noise generator
- PD reference measuring system
- Power transformer is planned to be connected to the cable end currently opened

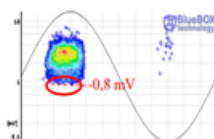


### QUALIFICATION TEST

1. Sensitivity Tests in the GIL using test cells and high voltage
2. Noise rejection test
3. Defect recognition
  1. PD pattern recognition of type defects using test cells under high voltage stress
  2. PD pattern recognition of type defects using PD pattern generator
4. PD Location
5. PD pattern clustering when different PD sources are generated
6. Alarm tests



Reference Measurement System



HFCT Sensor

### CONCLUSIONS

PD monitoring platform that collects data from different PD measurement systems based on different HF, VHF and UHF technologies is being developed. The data acquired by the platform is processed to intelligently diagnose the insulation health of the HV facilities. In the event of detecting an insulation defect, activating an alert or alarm signal depending on the criticism of the defect.

A set of qualification tests have been designed to be able to evaluate the effectiveness of the platform when operating with different measurement systems from different manufacturers.

The results obtained are promising and they could contribute if there was a development of international standardization in the definition of requirements and qualification tests for this type of platform for assessing the insulation condition of the HV facilities of the power grid.

#### Validation of Automatic Clustering + Defect Recognition

Defect Type	#1	#2	#3	#4	#5	#6	#7	#8	#9
Case 1	2%						100%	50%	25%
Case 2	25%	2%						100%	50%
Case 3	50%	25%	2%						100%
Case 4	100%	50%	25%	2%					
Case 5		100%	50%	25%	2%				
Case 6			100%	50%	25%	2%			
Case 7				100%	50%	25%	2%		
Case 8					100%	50%	25%	2%	
Case 9						100%	50%	25%	2%