Ti

TECHIMP SpA
Italy

TECHIMP **MONITORING** CASE STUDIES

LIST OF CASE STUDIES

- 20kV – 220Kv Power Plant – PD investigation
- MV and HV Power Plant – PD monitoring System
- HV Transformer – PD monitoring System

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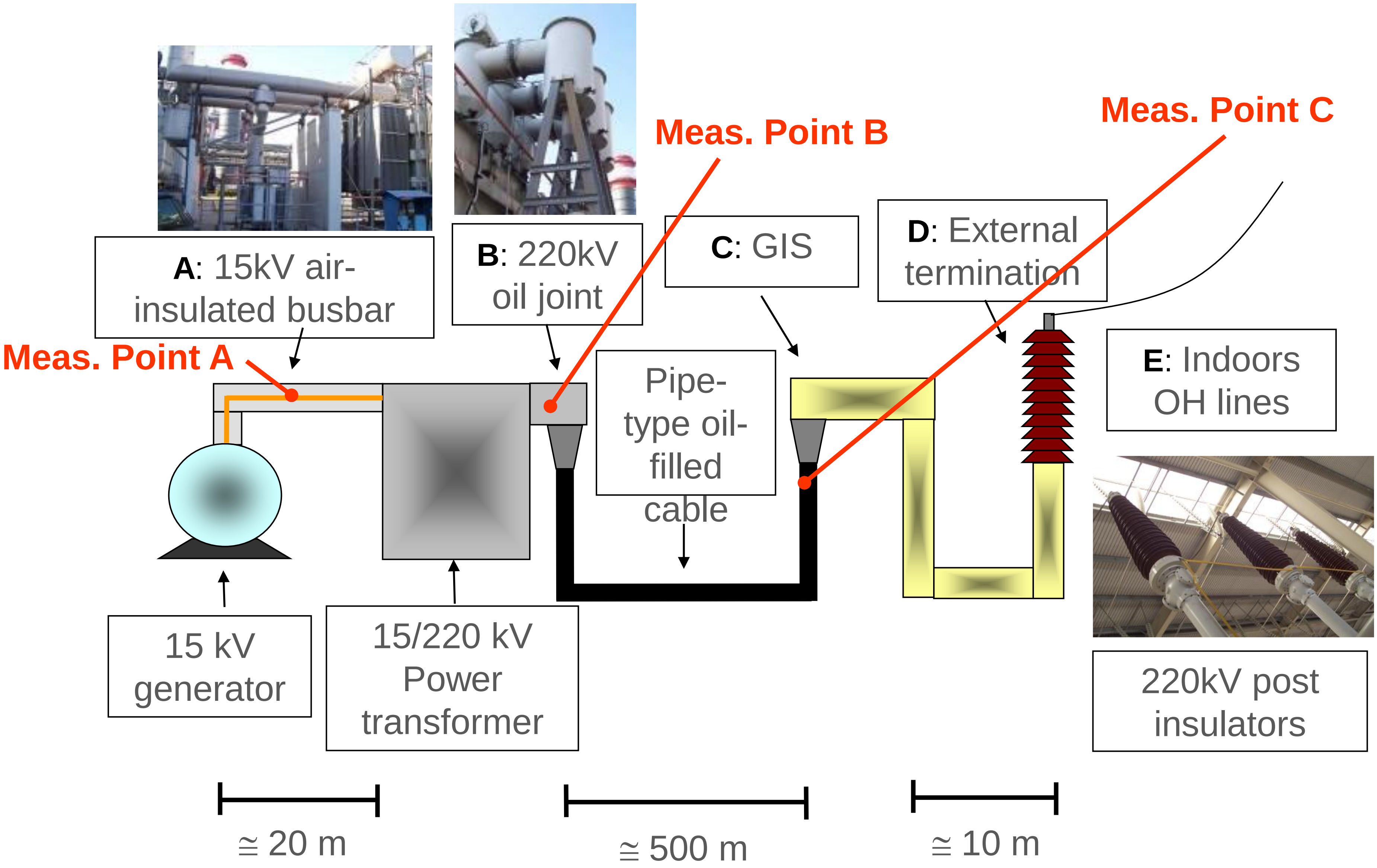
LOCATION	**EUROPE**
EUT	**POWER PLANT**
RATED VOLTAGE	**20 kV – 220 kV**
INSULATION	**VARIOUS**
LENGTH	
VINTAGE	
TYPE OF TEST	**OFF-LINE**

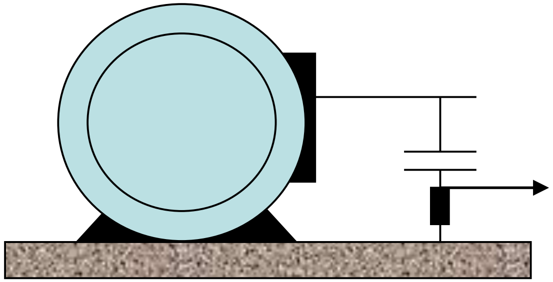
CASE STUDY

Off-line PD detected in Power Plant

PD measurement setup



- Meas. Point A: PD signals detected thorough couplers (80 pF) installed at generator terminals and 10 meters away from generator terminals.



- Meas. Point B: PD signals detected thorough bushing taps of the transformer

- Meas. Point C: PD signals detected thorough HF CT connected around the grounding leads of the cable sheath

GIS Cable Terminations

PD measurement results

Example of measurement results in one phase

Meas. Point A

Generator coupler

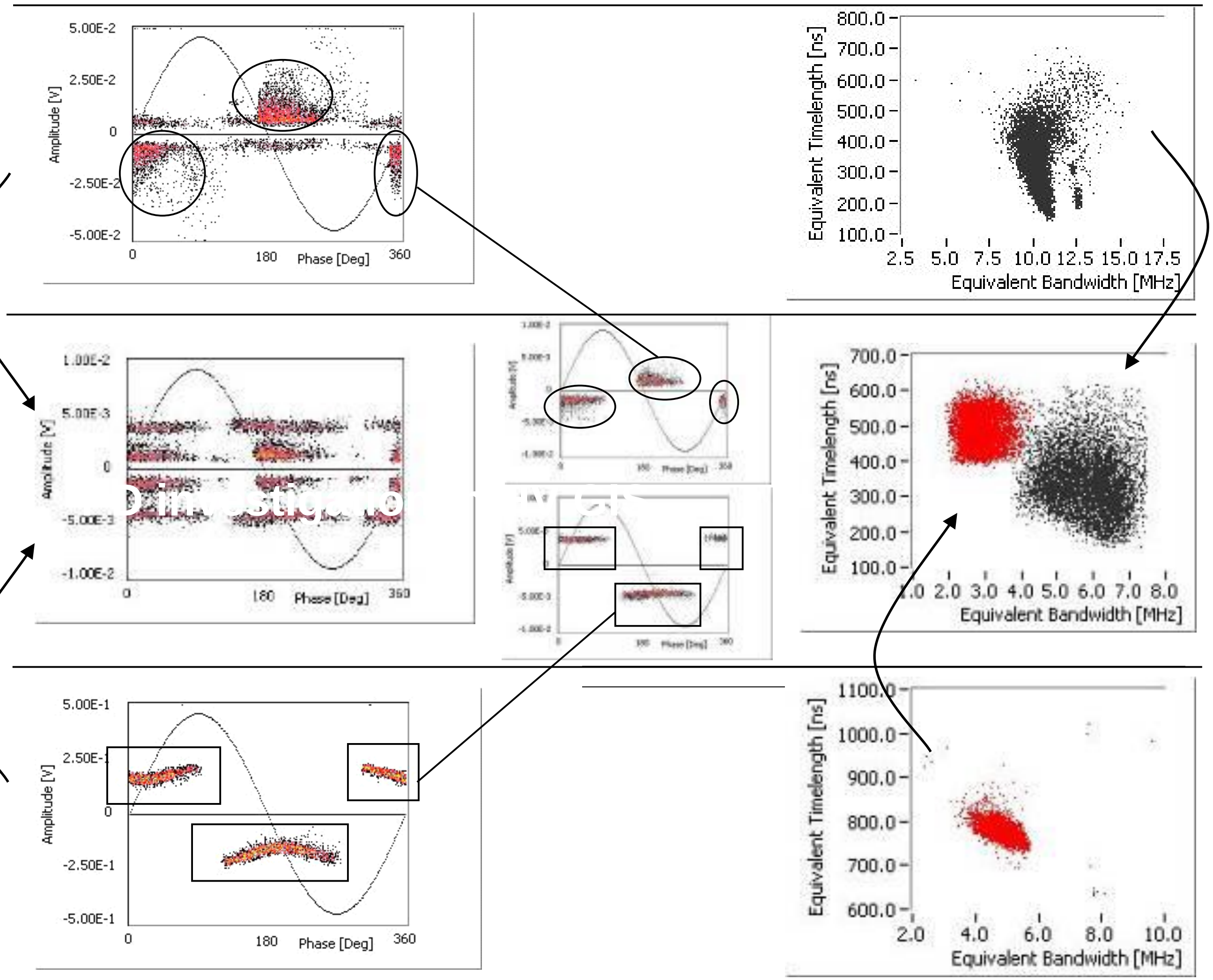
Meas. Point B

Transformer bushing

Same phases
Lower magnitudes
and frequency
content at xform

Meas. Point C

Cable terminations



Conclusion: The generator is affected by PD; disturbances are injected into the system through the cable termination, the transformer is PD free!!

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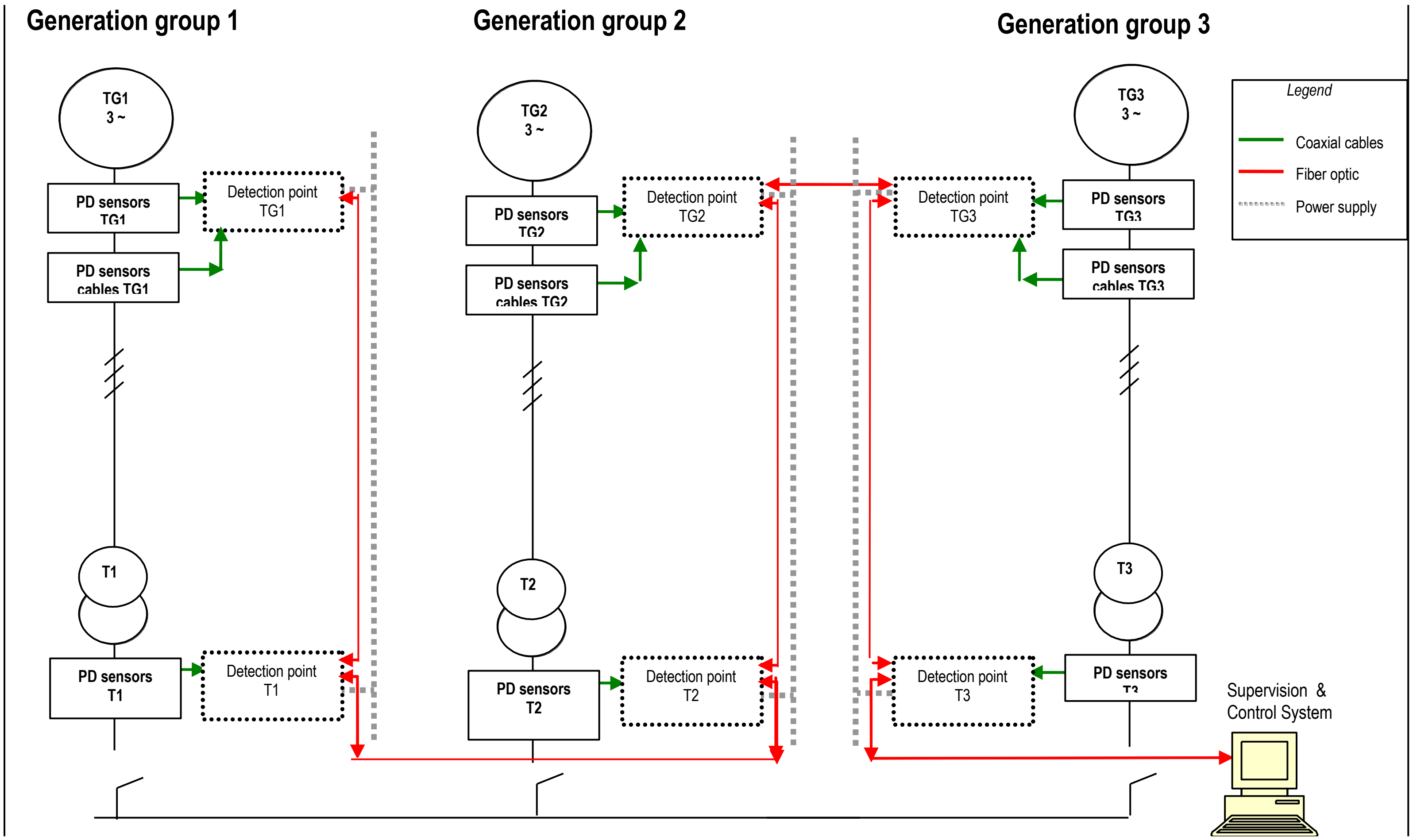
LOCATION	**SOUTH AMERICA**
EUT	**POWER PLANT**
RATED VOLTAGE	**VARIOUS**
INSULATION	**VARIOUS**
LENGTH	
VINTAGE	
TYPE OF TEST	**ON-LINE**

CASE STUDY

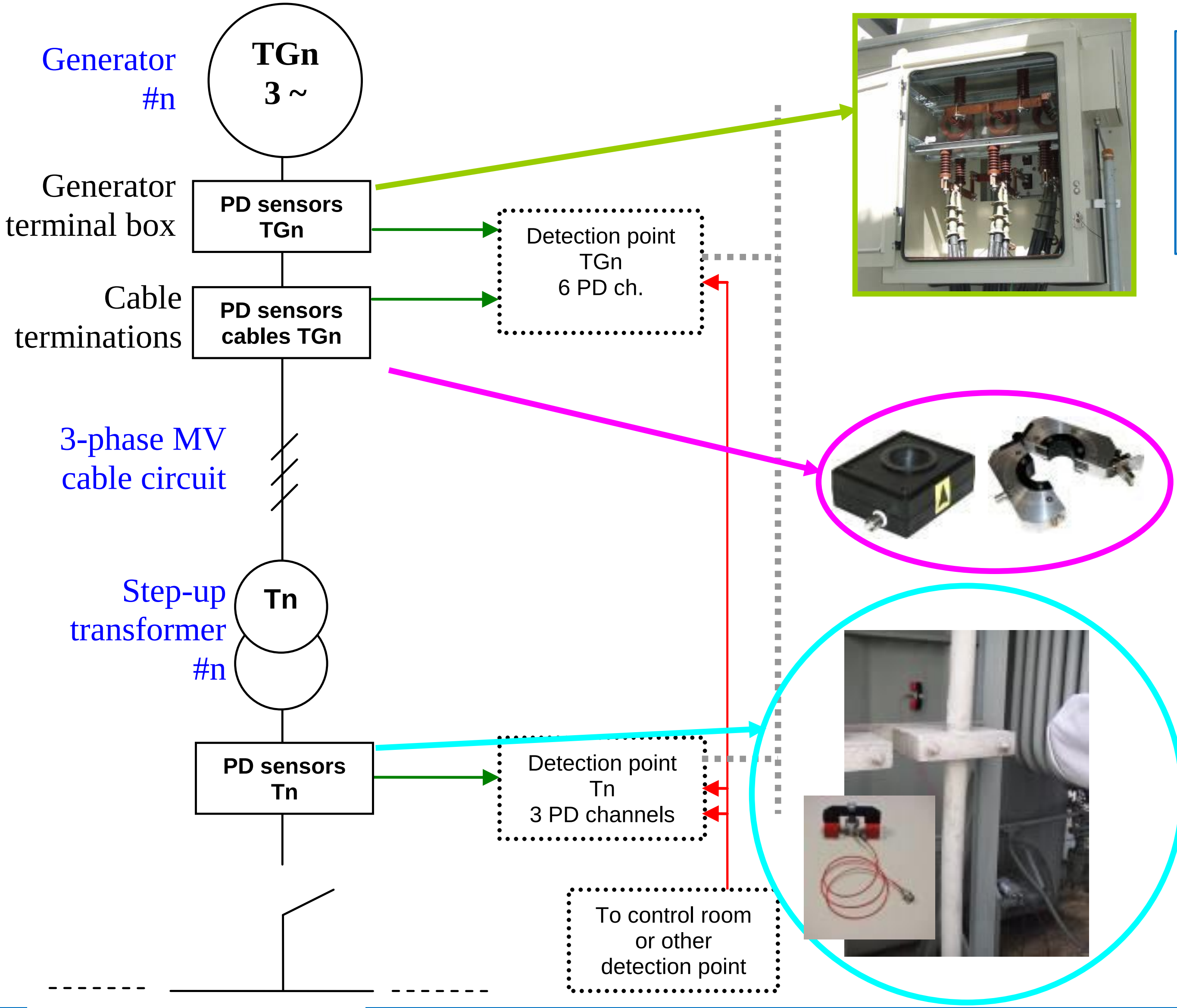
On-line PD detected in Power Plant

Permanent PDM systems installed in a power plant controlled from remote via internet

Generators, MV cables and transformers under monitoring



PD Sensors layout more detailed (sensors)



SENSORS FOR GENERATORS:

- 3 Couplers located inside generator terminal box

PD SENSORS FOR CABLES:

- 3 HFCT's wrapped around cable ground leads or directly around MV cables

PD SENSORS FOR TRANSFORMERS:

- Antenna or acoustic sensors in case
- Voltage tap adapters in bushings

Permanent PDM systems installed in oil refinery, controlled from remote via internet

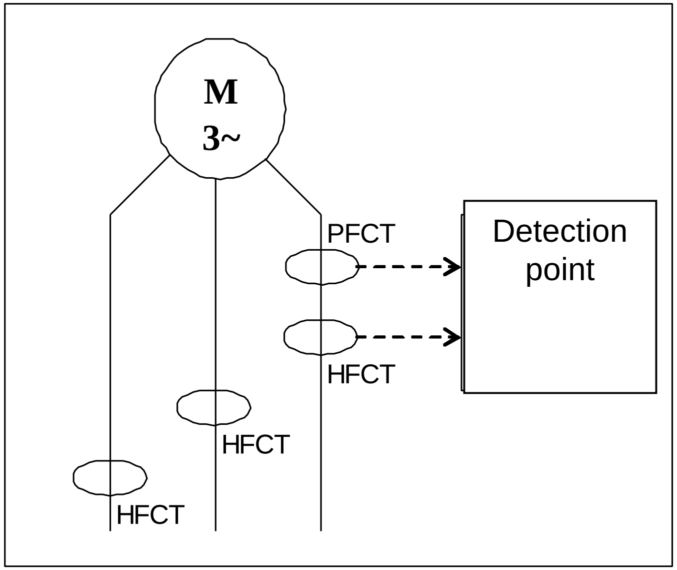
REFINERY: generators and motors under monitoring

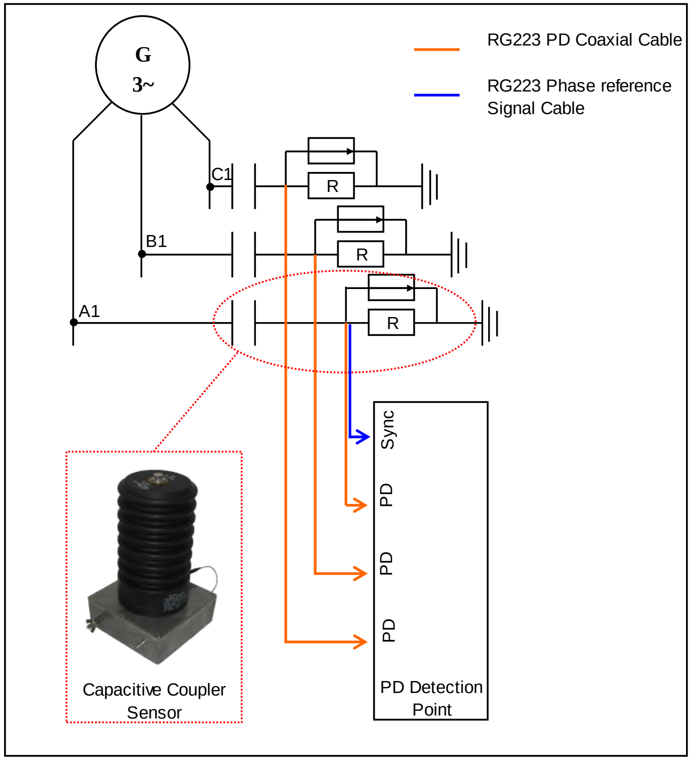
SENSORS FOR MOTORS:

- 3 Couplers located inside motor terminal box, where room is enough,
- HFCT's around incoming MV cables.

SENSORS FOR GENERATORS:

- 3 Couplers located inside generator terminal box

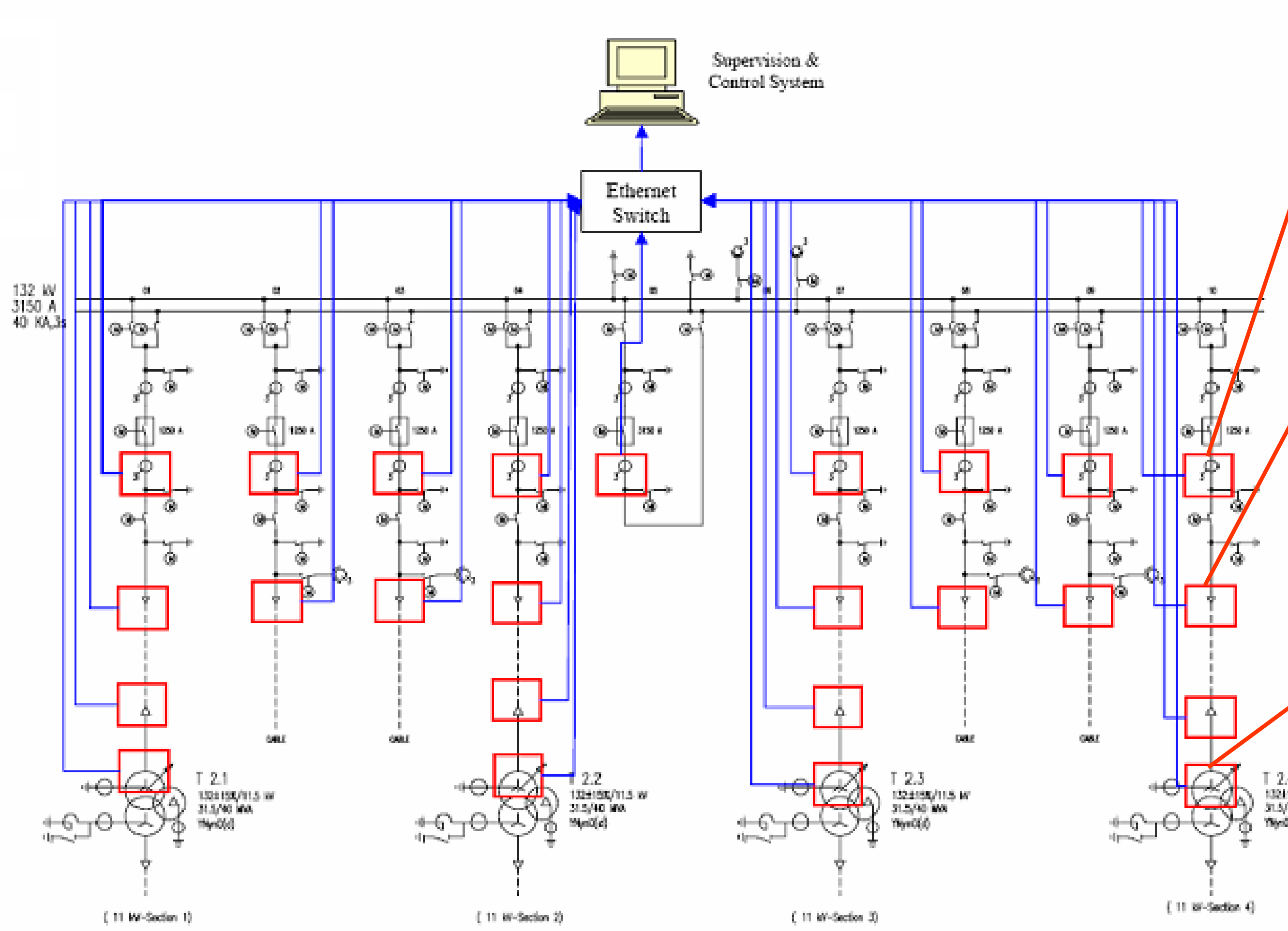




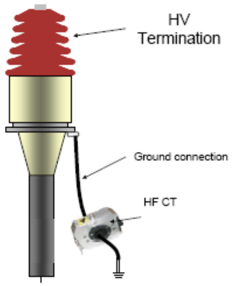
PD monitoring setup

Permanent PDM systems installed in HV electrical substations, controlled from remote via internet

PDM layout : detection points installed on GIS, Cable Terminations and Power Transformers.



Sensor for GIS



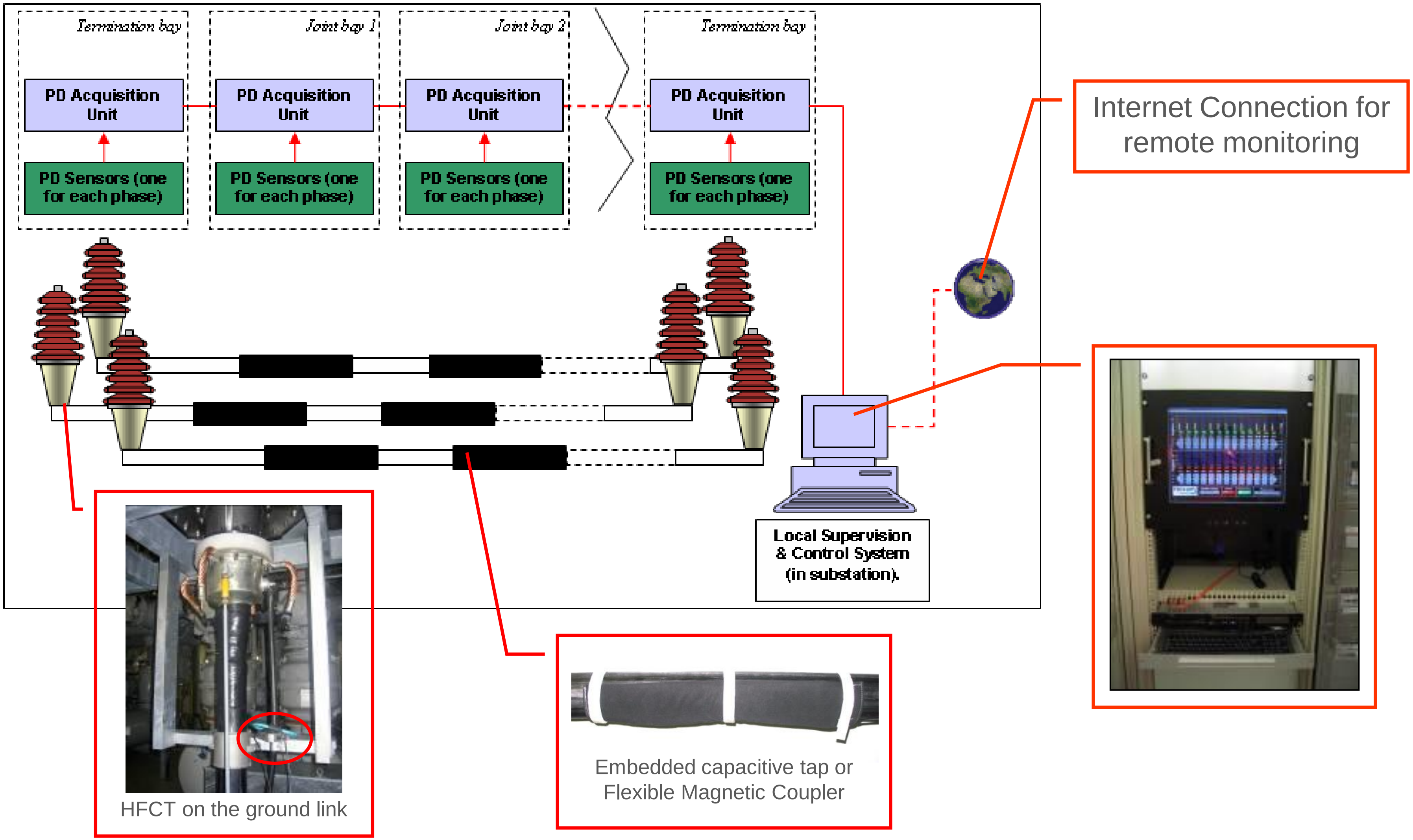
Sensor for Cable terminations

Sensor for Power Transformers

PD monitoring setup

Permanent PDM systems for HV cable systems

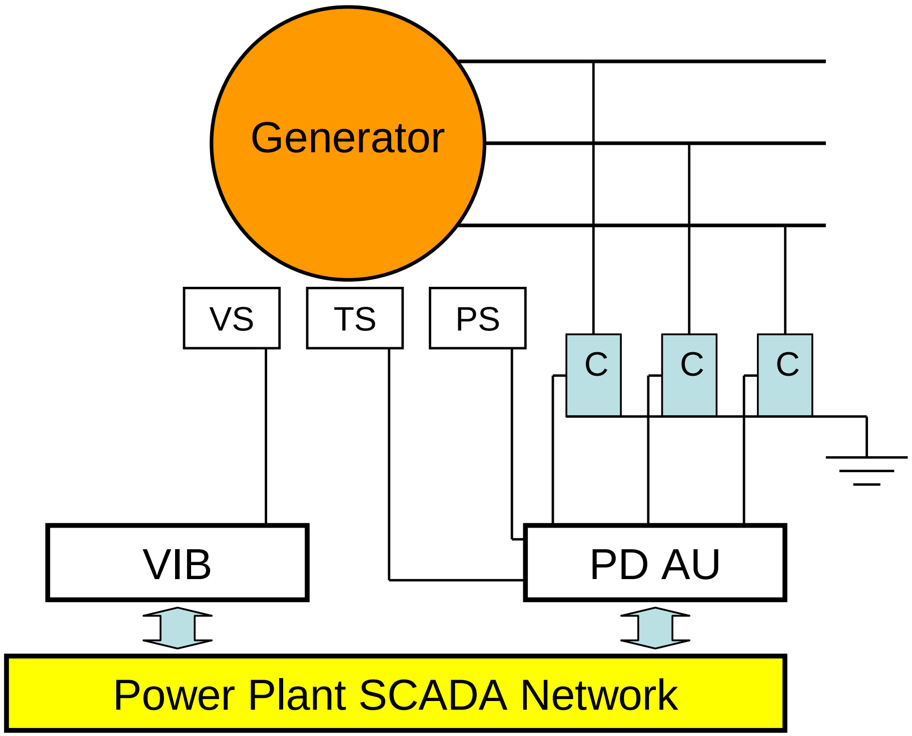
PDM layout: EHV cable system under monitoring



PD monitoring setup - Generator

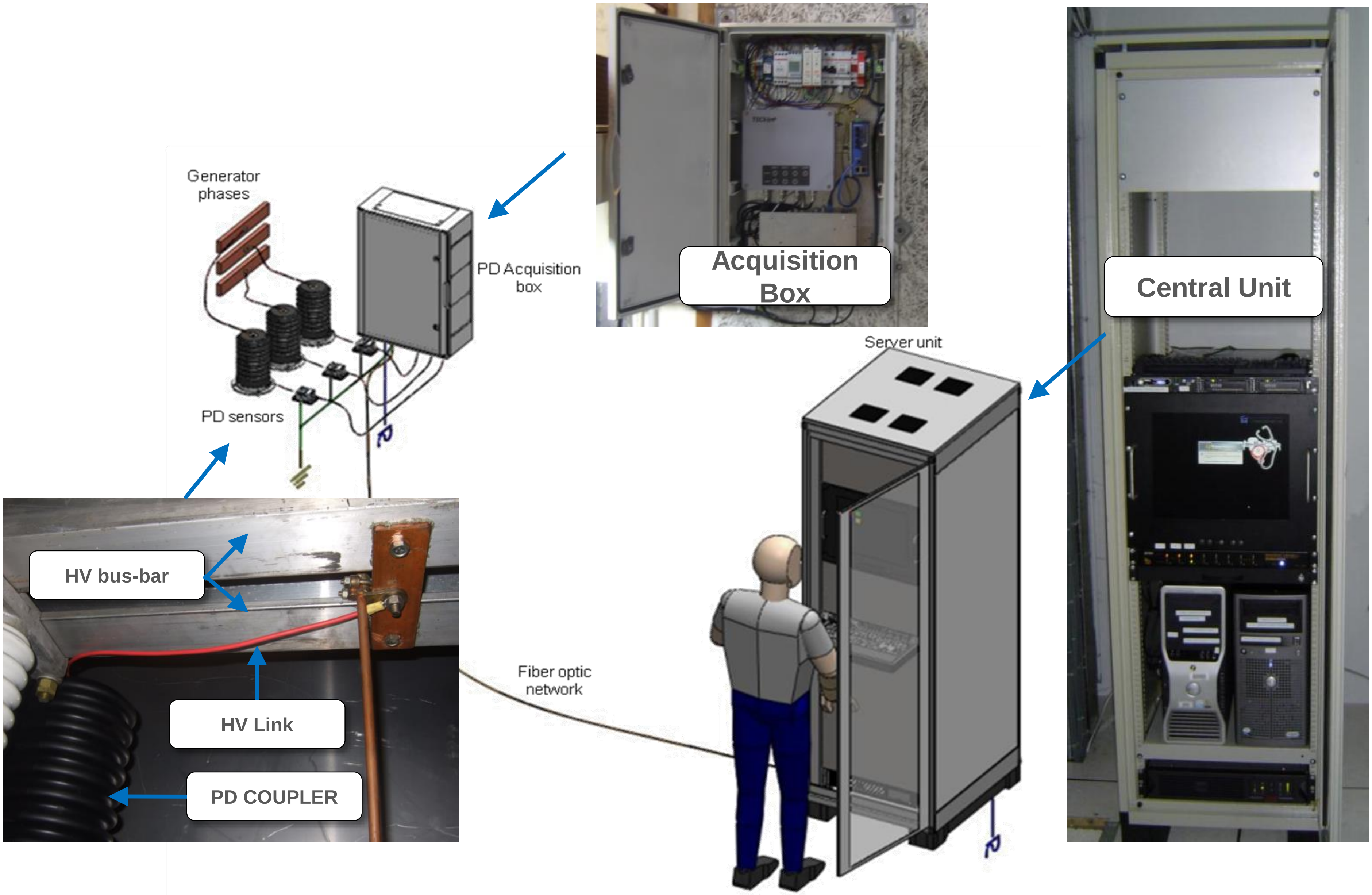
Expert system for Condition Monitoring of power plant generator

- Combined monitoring of PD and Vibrations allows pre-failure indication to be obtained for both mechanical and electrical insulation failure modes;
- Advanced decision rules can be applied, based on cross correlation of:
  - Pressure of cooling gas,
  - Temperature;
  - PD activity.



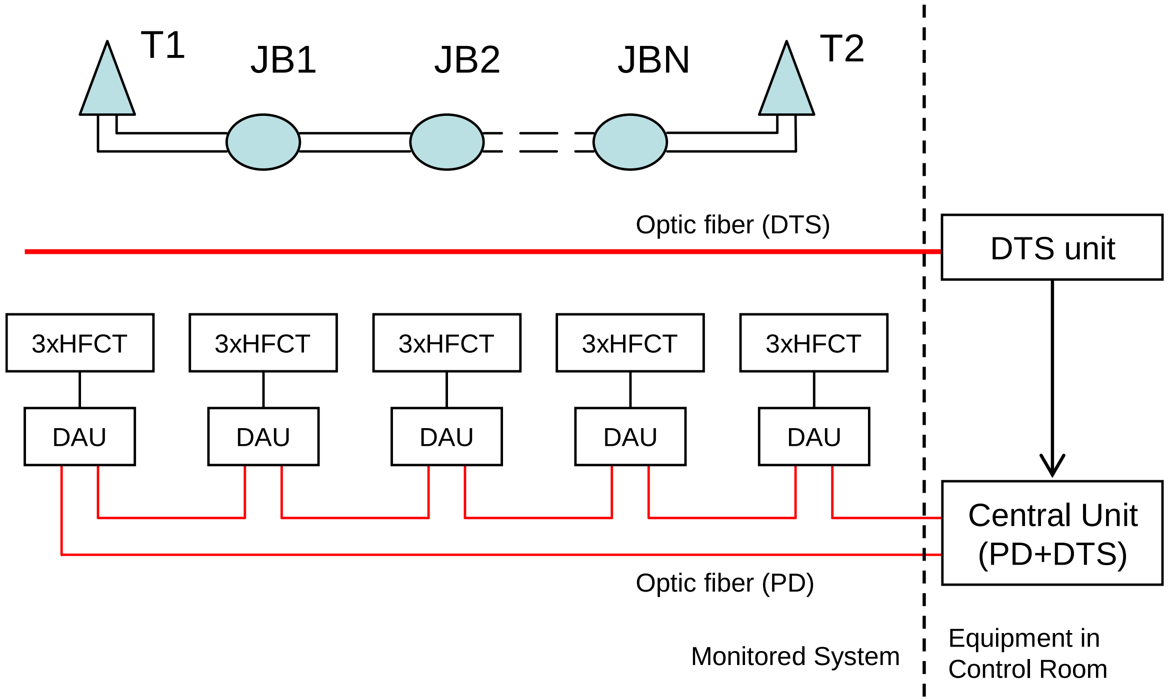
- **C**: PD Coupler
- **VS**: Vibration Sensor
- **TS**: Temperature Sensor
- **PS**: Pressure Sensor

PD monitoring setup - Generator



PD monitoring setup – EHV Cable

PD and DTS permanent monitoring of extra-high voltage cable system

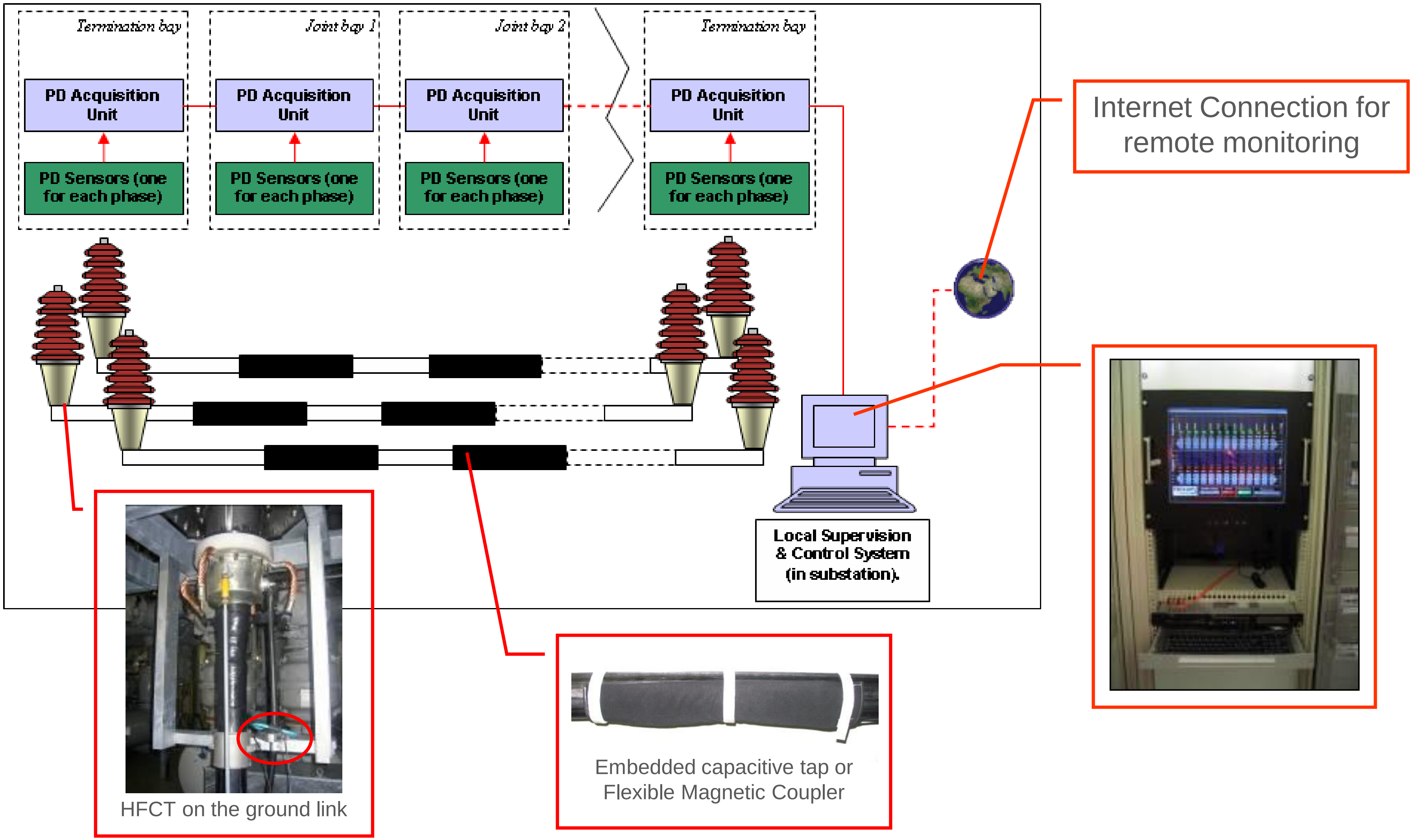


- Integrated monitoring of Partial Discharge and Distributed Temperature Sensing and their correlation allows optimal exploitation of the asset, as reliability and best working conditions:
  - PD trending
  - Real conductor temperature
  - Real Time Thermal Rating (to calculate ampacity under given conditions for the steady state and dynamic conditions

- **T**: Termination
- **JB**: Joint Bay
- **HFCT**: High Frequency Current Transformer

PD monitoring setup – EHV Cable

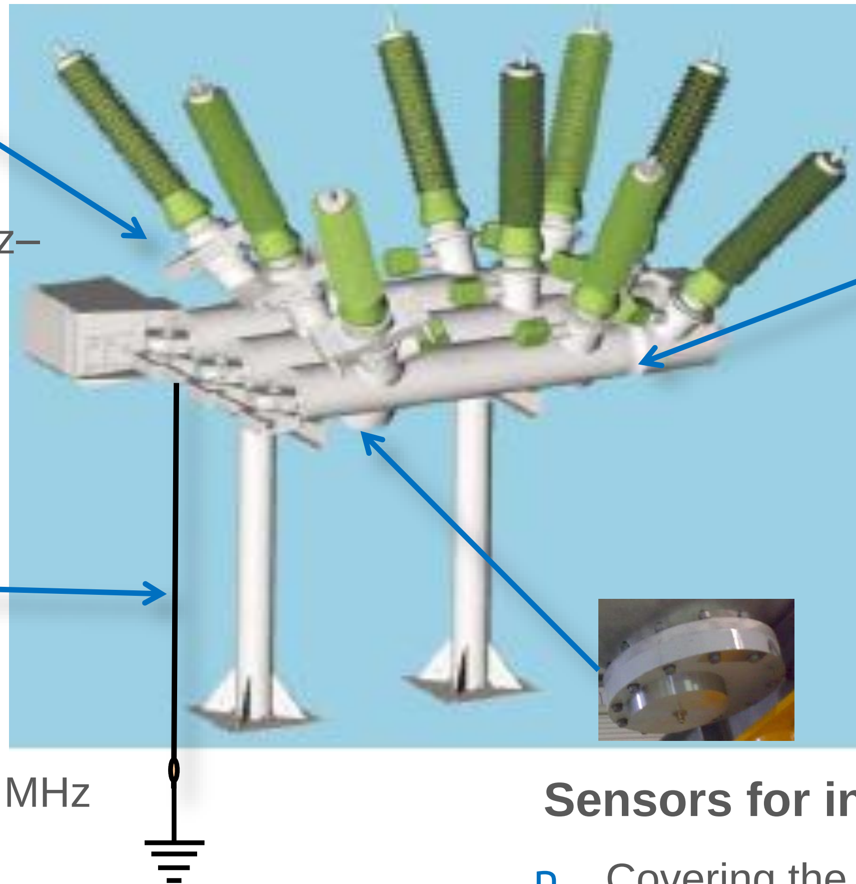
Global Monitoring of PD and DTS in a EHV cable system



PD monitoring setup - GIS

UHF Sensor

Horn Antenna:
- **Bandwidth:** 500MHz–3GHz
- **Gain**: 2.7 - 7.1 dB



HFCT:
- **Bandwidth:** 1 – 40 MHz

Spacer sensors

Spacer Antenna:
- UHF sensor
- **Bandwidth:** 700MHz–3GHz

TEV Sensor:
- Capacitive Coupling
- **Bandwidth:** 0.1 MHz–300MHz

Sensors for insulating windows

- Covering the dielectric inspection window
- **Bandwidth:** UHF band, Typically > 700MHz-2 GHz)

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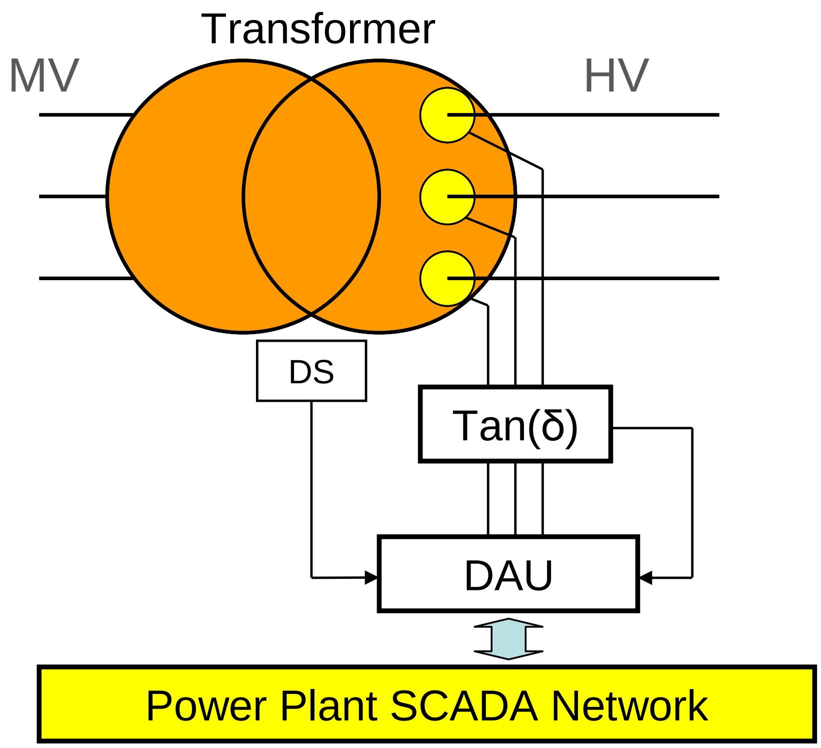
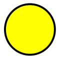
CASE STUDY

On-line PD Monitoring System in a Power Transformer

LOCATION	**SOUTH AMERICA**
EUT	**POWER TRANSFORMER**
RATED VOLTAGE	
INSULATION	
LENGTH	
VINTAGE	
TYPE OF TEST	**ON-LINE**

PD, Tan(δ) and DGA permanent monitoring of power plant step-up transformer



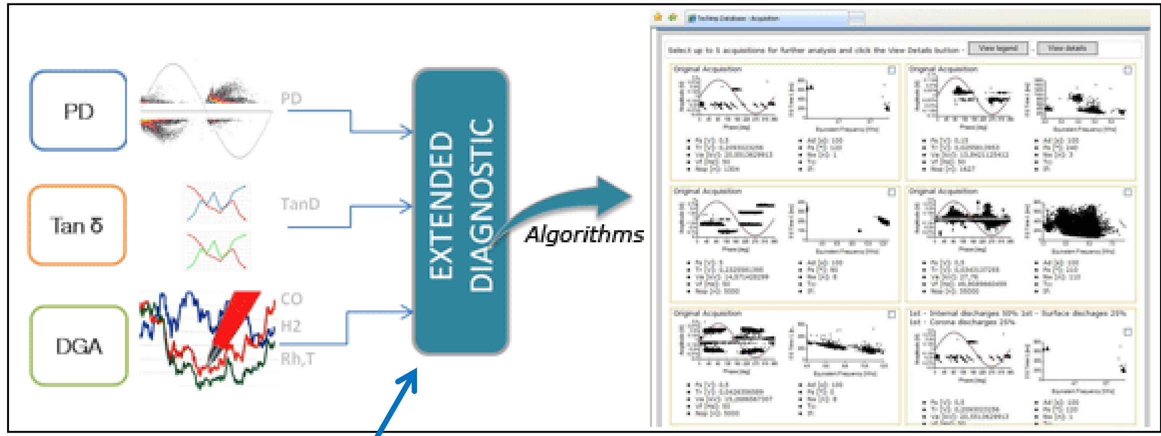
- DS: DGA Sensor
- Tan(δ): Tan(δ) front-end
-  : Bushing with Capacitive Tap

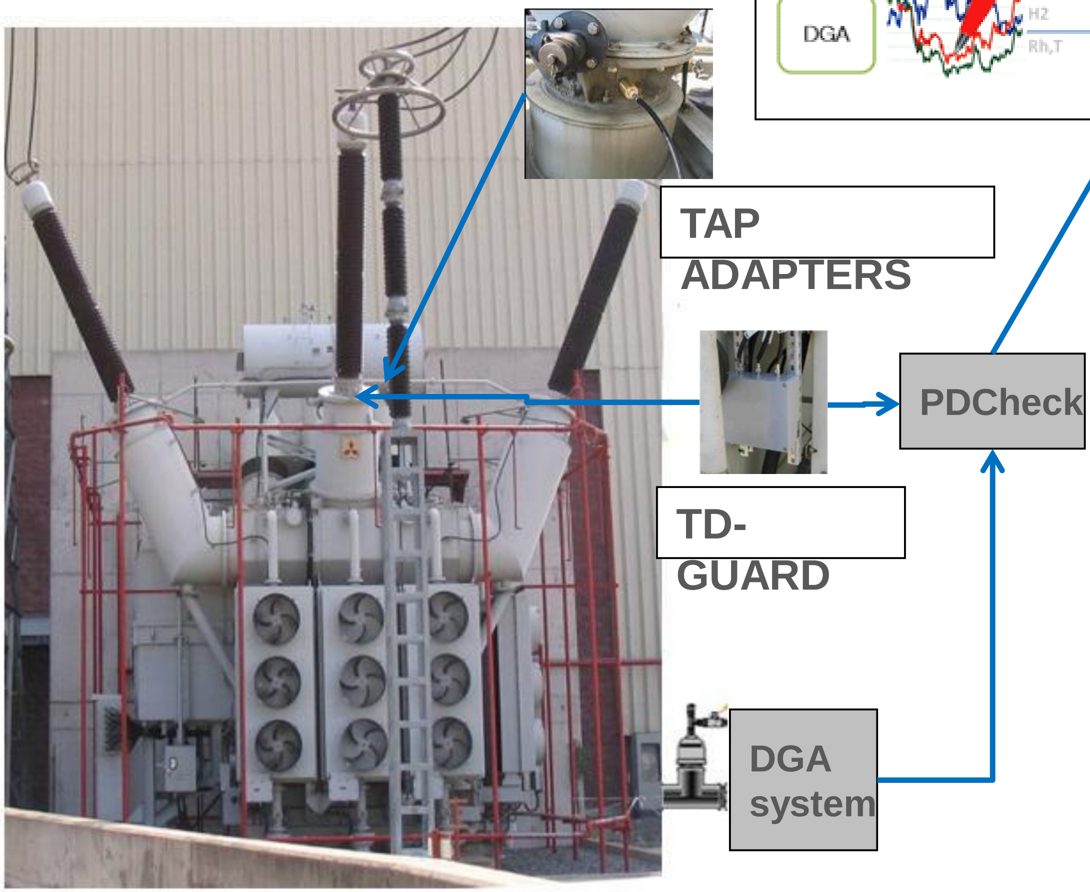
- Capacitive taps of transformer bushings are PD sensors with good SNR
- DGA sensor checks transformer oil on-line for gases and moisture;
- Loss factor (i.e. tan(δ)) of transformer bushing provide further and complementary diagnostic indication about the state of the insulation system
- PD, DGA, tan(δ) can be integrated in extended diagnostic levels: most of the failure modes can be diagnosed

PD monitoring setup

PD, DGA, Tan-δ are integrated in Extended diagnostic levels.

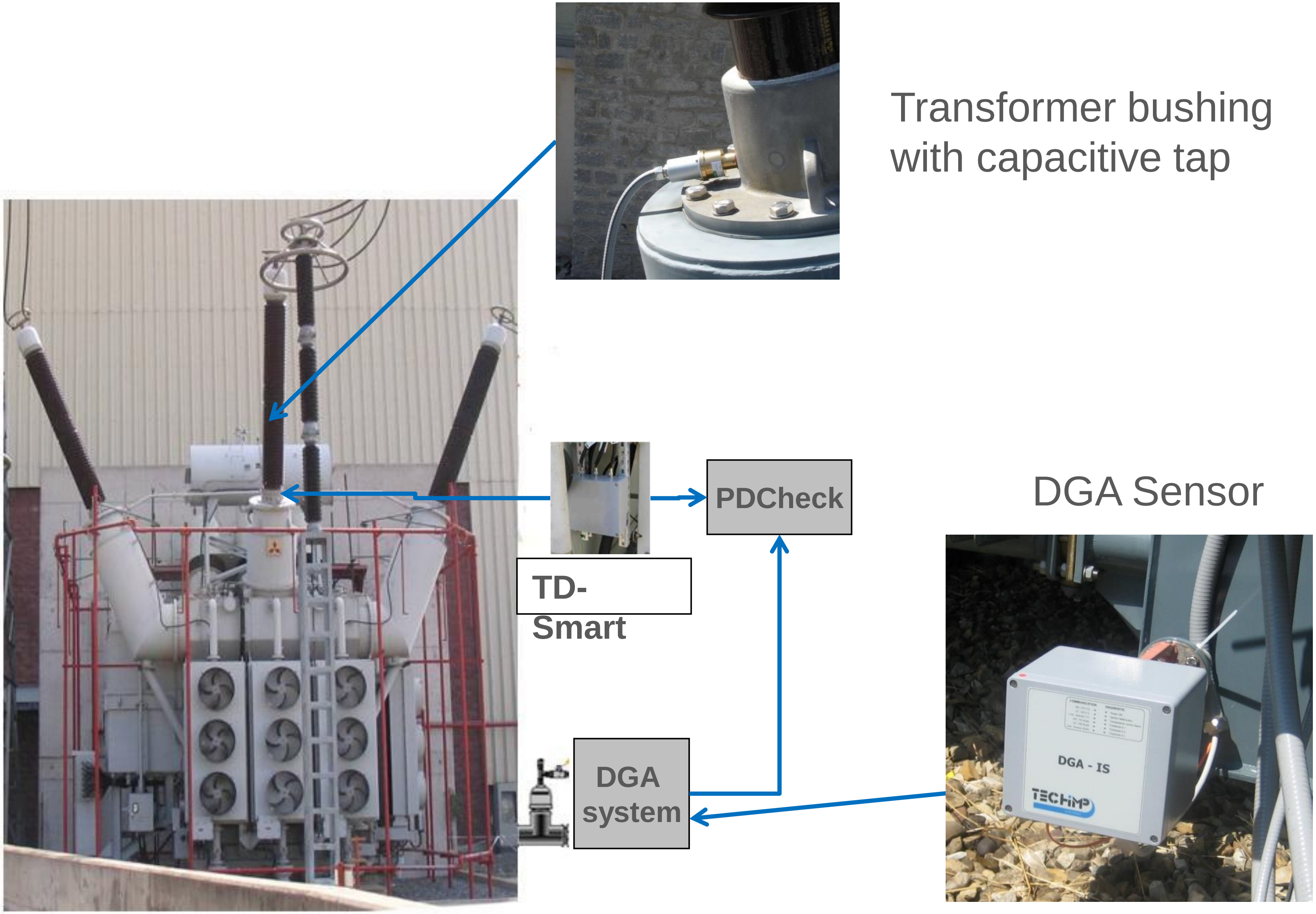
Cross-correlations and multiple diagnostics are provided





- **Partial Discharges:**
  - Through Bushing sensors on the bushing capacitive taps
- **DGA**
  - Integrated DGA unit monitoring dissolved H2 +CO and Moisture
- **Tan-δ:**
  - Integrated TD-Guard unit monitoring tan-δ, Capacity and Bushing Insulation Resistance
- **And even more:**
  - Temperature;
  - Environmental parameters

PD monitoring setup



History

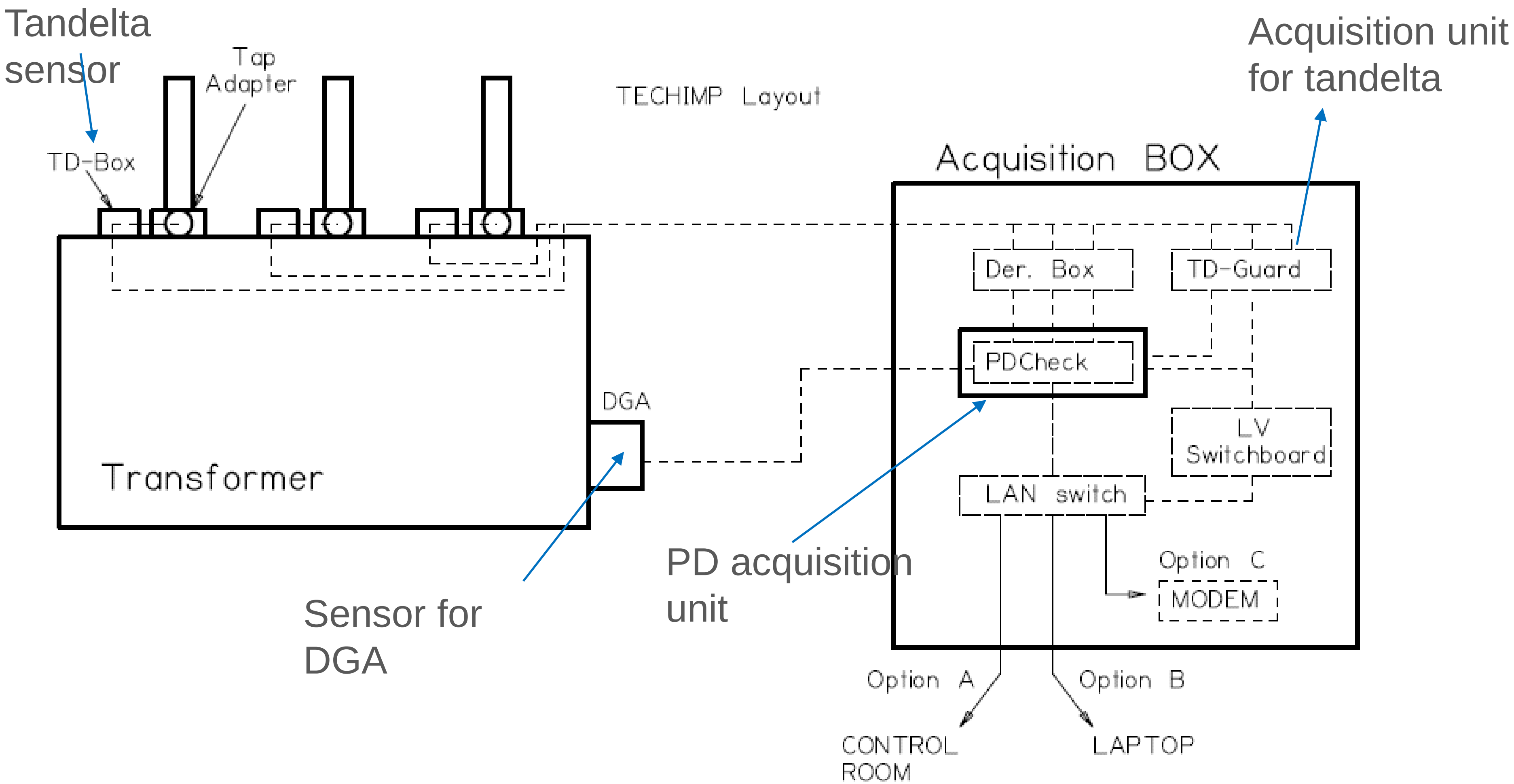
After the installation of a big autotransformer, the utility started immediately to see a critical level of equivalent gas (using a 2 gas DGA unit)

According to the IEC and IEEE specs, the level and the trend of H2 were critical after only one month: *(Exercise caution- Analyze for individual gases Determine load dependence)*

BUT:

- is it now necessary to take out of service the transformer…or it can stay on service for a longer period in order to properly plan the maintenance and avoid to increase the indirect costs associated to the outage?
- Why the H2 is so high? Electrical or thermal problem? PD?

PD monitoring setup



Techimp was asked to install a global monitoring (PD+DGA+Tandelta) in

order to get into deep analysis and to improve the diagnosis

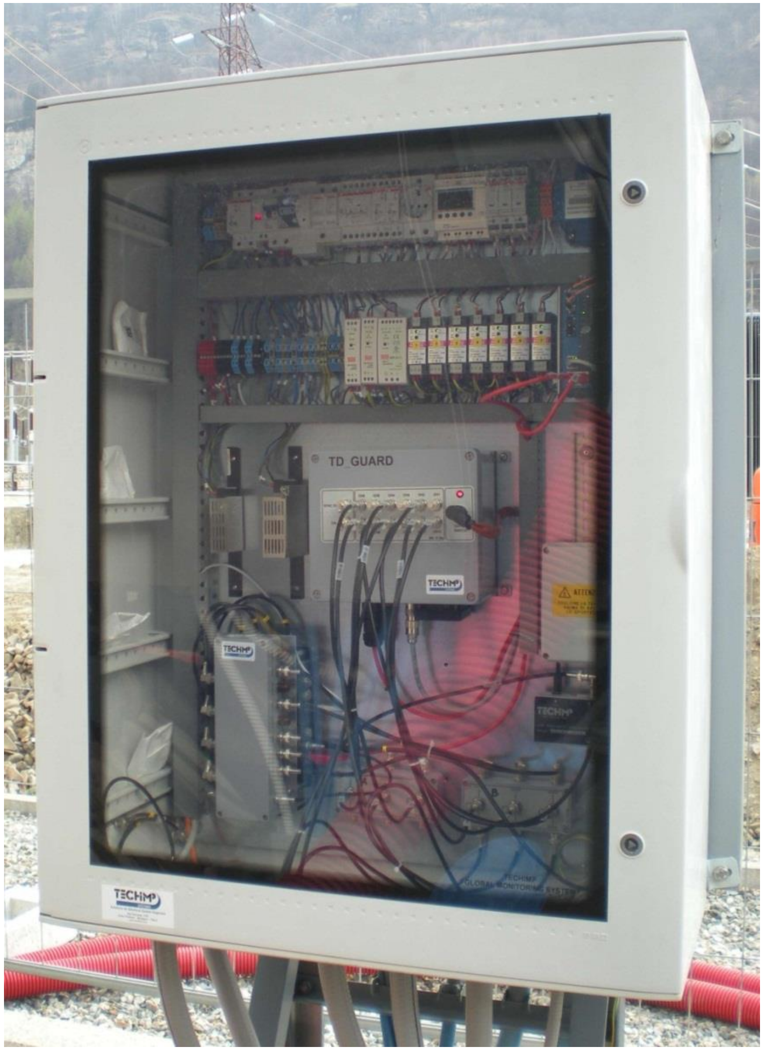
PD monitoring setup

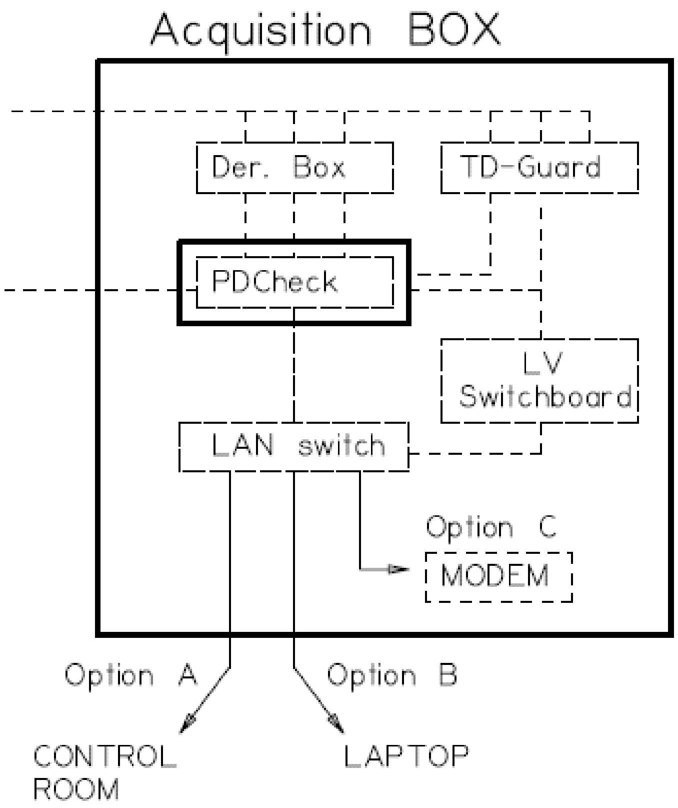
TAP ADAPTERS were installed in the 6 bushing capacitive taps

TD sensor was connected between the tap adapter and the TD Guard

PD monitoring setup

The acquisition Box was installed 2 meters far from the transformer

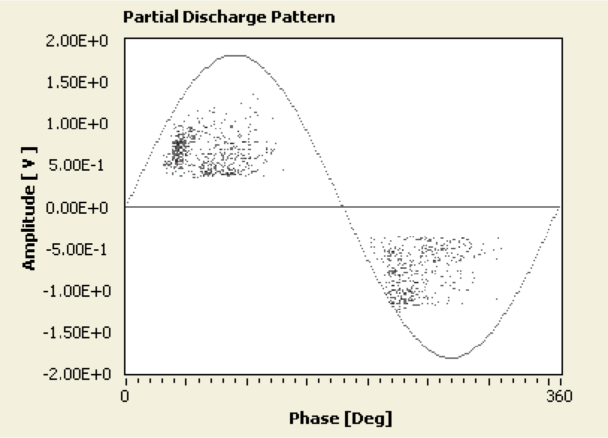


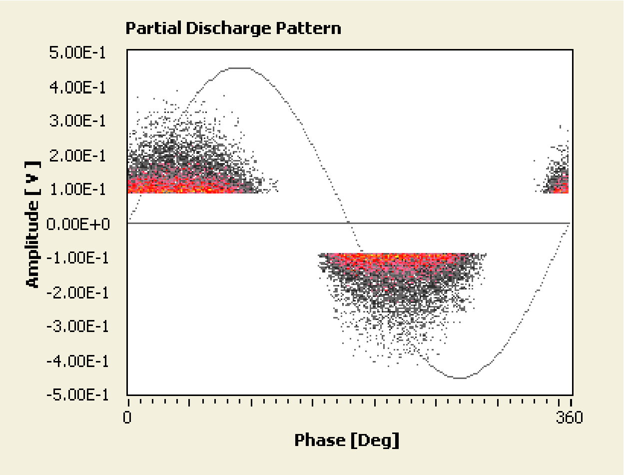


TWO PD phenomena were detected on-line:

- A sporadic activity due to small gas bubbles in the oil. This activity was intermittent and detected few times in a month. The probability of triggering such activities increases significantly installing **PERMANENT Monitoring Systems**.

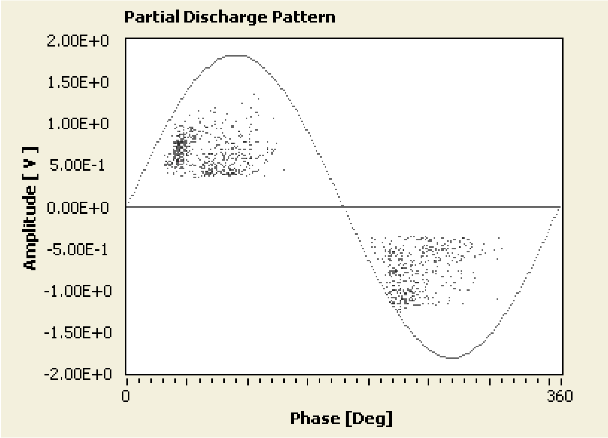
- A strong activity was detected in all the HV phases. This activity was identified as **INTERFACE PD**. PD amplitude and repetition rate were high in all phases.

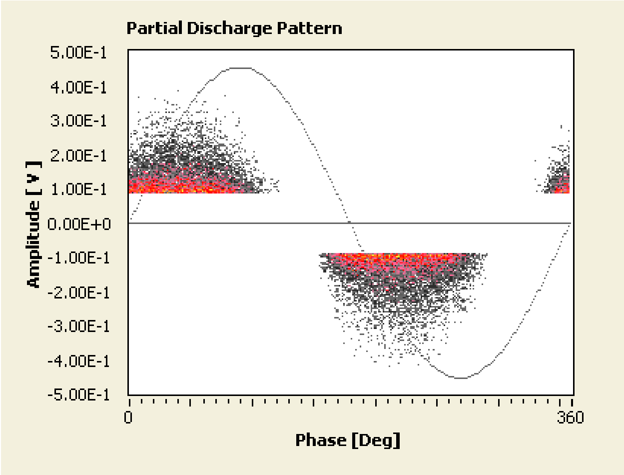




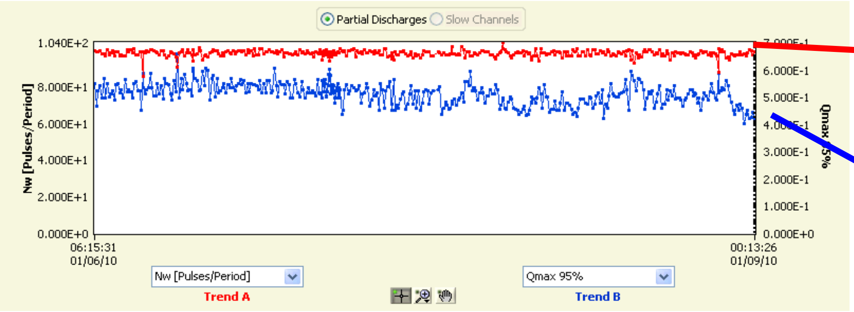
Oil treatment was carried out by the utility after 2 weeks from PDM system installation:

- The first activity, due to the bubbles, disappeared after the oil treatment.
- After the oil treatment, the second activity appeared again, immediately. The oil treatment did not cause any kind of change on such a phenomenon.
- Thus, the permanent PD monitoring was run in the transformer for a period of 6 months.





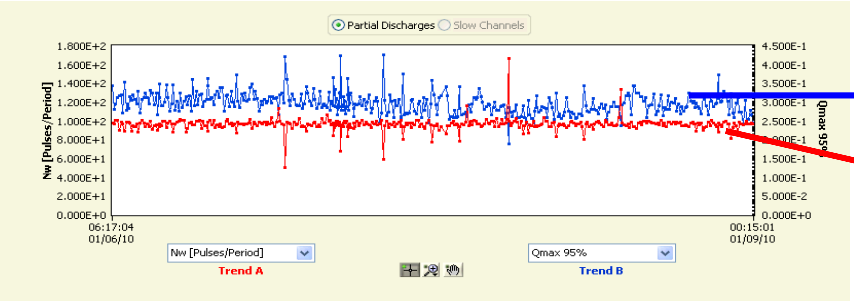
PD monitoring results



Nw > 80

Qmax>500 mV

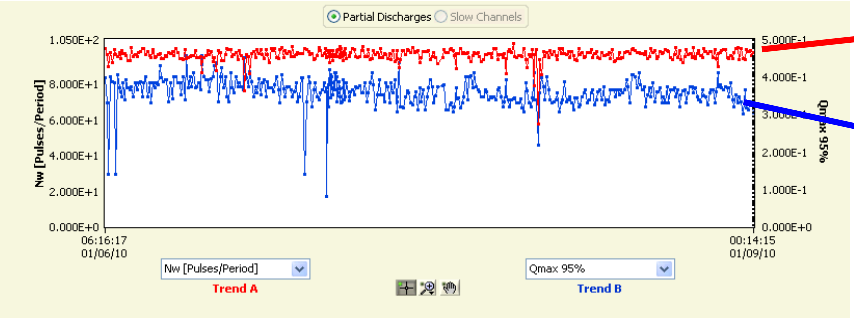
Phase 4



Qmax>250 mV

Nw > 100

Phase 8



Nw > 80

Qmax>300 mV

Phase12

PD monitoring results

After 6 months of global monitoring the following considerations were done:

- No significant changes in bushing tan delta values were noted over the monitoring period (6 months) **highlighting that there are no problems inside the bushings.**

- The H2 gas levels increased during the monitoring period with rates around 30 ppm/day **highlighting that there is a problem inside the transformer.**

- PD activities were detected in correspondence of all the three HV phases, **demonstrating that such phenomena (interface PD) were directly connected to the H2 gas increase.**

- The PD pattern polarity and characteristics indicated clearly **that the PD was located into the transformer.**

- Additional considerations obtained correlating DGA and tan delta results led to the suspect **that PD activity was generated by a constructional defect within the connection between the bushing and the winding leads.**

PD monitoring results

After Techimp report, the utility decided to stop the transformer and perform the following **off-line** measurements:

- **BUSHING DDF**
- **DGA of bushing oil**
- **PD TEST in both UWB and IEC bandwidth**

The first two measurements were carried out in order to be 100% sure that the bushings were problem-free.

The results of such measurements confirmed Techimp diagnosis, i.e. that the bushing insulation was ok and that the increase of the GAS was due to problems internal to the transformer.

The third measurement was carried out because the utility wanted to be 100% sure that the PD detected by Techimp was not relevant to an external interference.

The PD test off-line confirmed that the PD detected by Techimp during the on-line monitoring were relevant to internal phenomena inside the transformer.

PD monitoring results

The transformer was energized from the MV side phase by phase using an external source

Proper corona shield were installed in each HV bushing in order to minimize the interference of external corona/surface outside the bushing insulator.

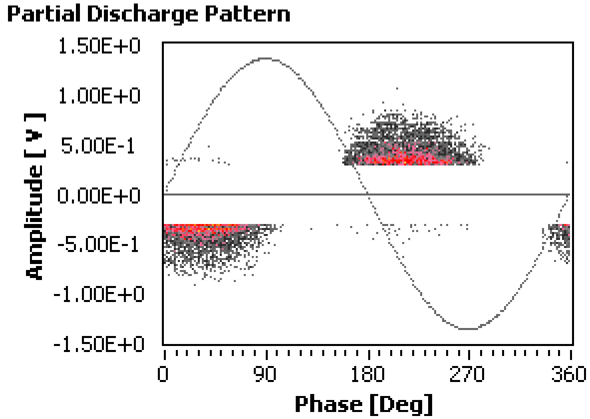
The same Techimp instrument used for on-line monitoring was used also for off-line test.

During the off-line test, a PD activity was recorded in correspondence of each phase and it was **the same activity recorded during the on-line PD monitoring.**

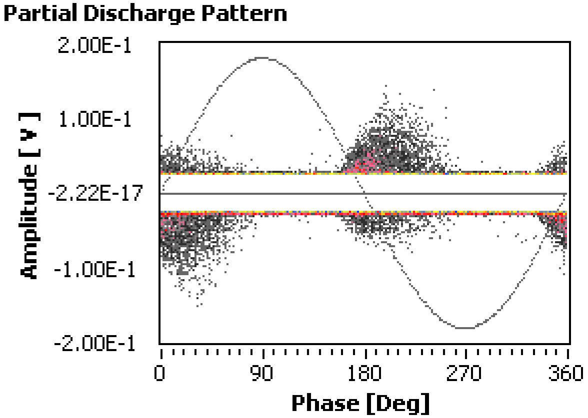
During the off-line test it was possible to realize that the PD Inception Voltage was pretty low, being @ only **60% of the rated voltage.**

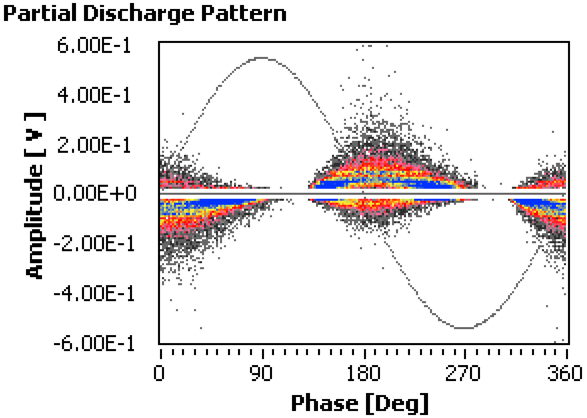
PD monitoring results

- ON-LINE PATTERNS



- OFF-LINE PATTERNS

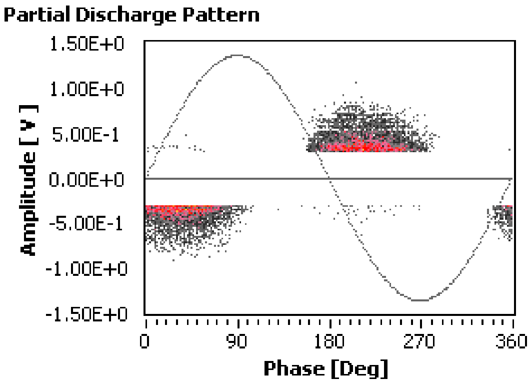


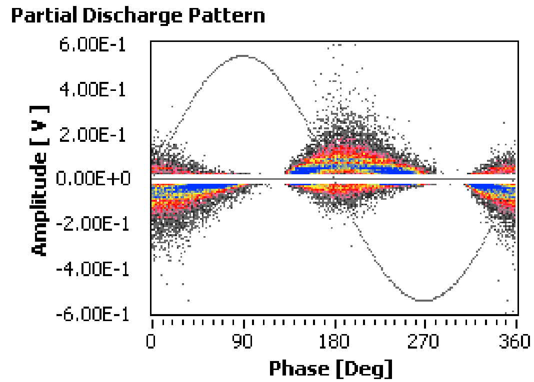


PD monitoring results

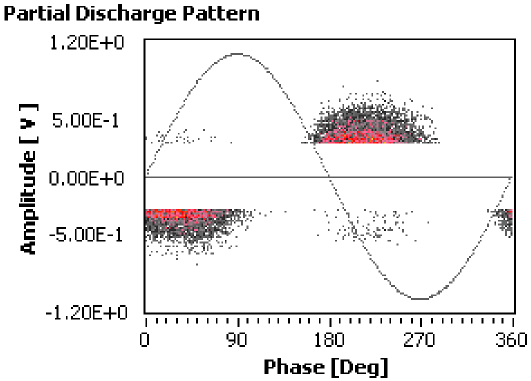
- ON-LINE PATTERNS
- OFF-LINE PATTERNS

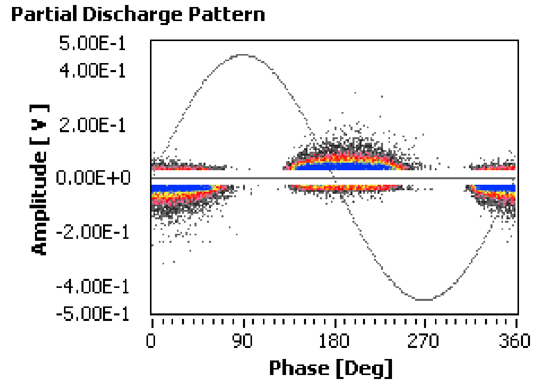
Phase 4



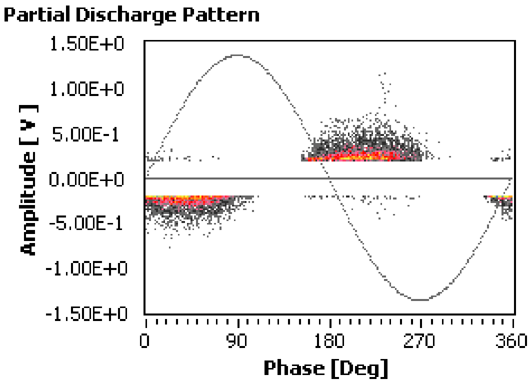


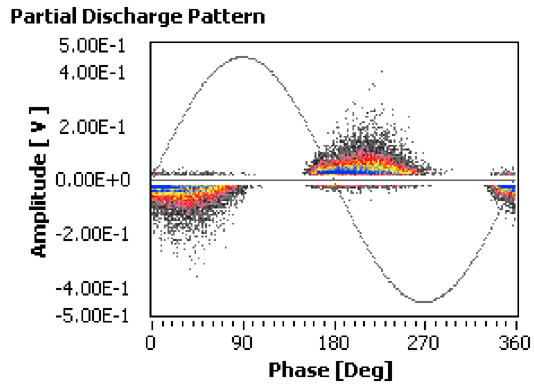
Phase 8



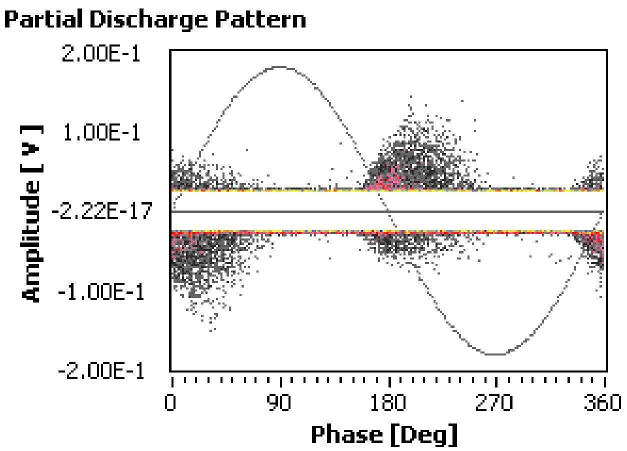


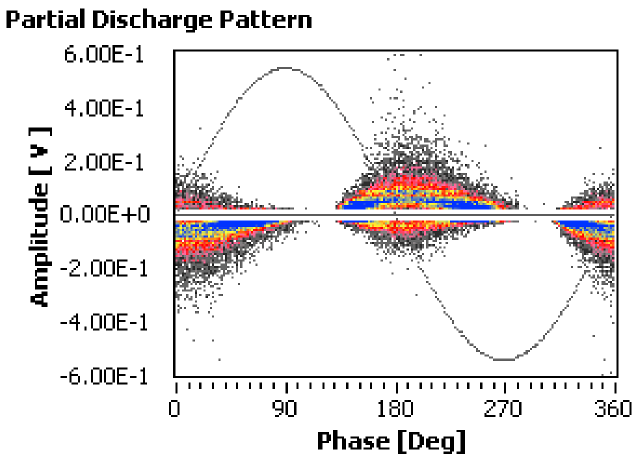
Phase 12





- PDPATTERN @ INCEPTION VOLTAGE (60%)
- PDPATTERN @ RATED VOLTAGE (100%)





Typical behavior of an internal PD between layers of papers.

PD monitoring conclusion

The analysis carried out by Techimp ON-LINE was confirmed by the off-line measurements.

Techimp on-line system is able to achieve sensitivity comparable to that of off-line tests, without the necessity of any:

- External power supply
- Shutdown of the transformer

Techimp DGA and Tandelta subsystem together to the PD monitoring system contributed in providing the diagnosis to the customer.

Techimp diagnosis helped the customer to TAKE PROPER ACTIONS WITHIN THE TRANSFOMER WARRANTY TIME!!

PD monitoring comments

Limits of PD Test according to IEC 60270

Both repetition rate and amplitude of the PD activities can be considered as critical.

H2 level increase also shows criticalities, because a 30ppm/day can not be allowed in a NEW transformer.

All the considerations after the monitoring period led to suppose that the problem was due to constructional arrangement (after an inspection, it was found that the bushing cone was not properly connected to the winding lead).

WHY and HOW this transformer passed the FAT??

Conventional IEC 670270 PD test was carried out by Techimp and the level of PD activity was found to be ONLY 300 pC, which means below the alarm level (500pC).

The PD test in pC is NOT able to really ASSESS the transformer condition, especially when internal PD occur, which can be really critical even at low amplitude!

PD monitoring comments

Property	Techimp TD-Guard	Techimp DGA-IS
Applications	On-line monitoring of Power transformers And measurement transformer	On line monitoring of Power transformers
Monitoring capacity	Max 12 Bushings	Moisture H_2 CO
Working Principles	- Leakage Current Analysis - Dissipation factor direct measurement - Insulation Resistance - No need of three phase set, measures can rely on a single phase	- Gas: Gas-permeable membrane and combustible gas detector - Moisture: Thin film Capacitive sensor
Ouptuts	Capacity Tan-δ Insulation resistance	- Dissolved Gas concentration - Moisture concentration
Accuracy	Tan-$\delta \sim 0.0005$ Capacity < 1% Resistance < 1%	Moisture: +/- 2% RH Gas: ± 10% of reading ± 25 ppm (H2 equivalent)
Transformer Connection	Ad-hoc tap adapters	On transformer valve by ad-hoc adapters
On board Protection	3 levels: Overvoltage protection Surge arresters (max 4kV 1 min.) Gas Dischargers	Opto-isolation Surge arresters
Alarms	Clean Contacts MODBUS	Clean Contacts MODBUS Visual led activity
Communication Port	Ethernet	Ethernet Fibre optics
Protection degree	IP 66	IP 65
Range		Moisture: 0 – 100 %RH Gas: 0-2000 ppm (volume/volume, H2 equivalent