TECHIMP
Technologies & Services for Diagnostics and Monitoring of High Voltage Assets
TECHIMP is one of the leading providers of

- Condition Assessment Services
- Data Acquisition and Test Equipment
- and Permanent Monitoring Systems

for any kind of electrical Medium and High Voltage Assets.
Who we are

- Started in 1999 as a spin-off of University of Bologna/Italy
  Founded by Prof. Montanari

- Techimp HQ: Located in Zola Predosa, close to Bologna/Italy
  Techimp Germany: Located in Helpsen, close to Hanover/Germany

- More than 50 employees active in R&D, production, project management, sales, service & administration

- Serving customers in more than 100 countries
# Our Customers

<table>
<thead>
<tr>
<th>Transmission Network Operators</th>
<th>Distribution Network Operators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable Energy Sector</td>
<td>Oil &amp; Gas Industry</td>
</tr>
<tr>
<td>Petrochemical &amp; Process Industry</td>
<td>Power Plants</td>
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<tr>
<td>Marine &amp; Traffic</td>
<td>OEMs</td>
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<tr>
<td>Assets</td>
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<tr>
<td>HV Cables</td>
<td></td>
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<tr>
<td>GIS (Gas Insulated Switchgear)</td>
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<tr>
<td>MV Cables</td>
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<tr>
<td>MV Switchgear</td>
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<td>Transformers</td>
<td></td>
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<tr>
<td>Motors &amp; Generators</td>
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<td>Variable Speed Drives</td>
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In the past years the evaluation of PD test results has proven to be an essential tool for reliable condition assessment and monitoring of medium and high voltage cable systems and assets.

- Partial Discharges are the main cause of MV/HV faults
- Spot PD measurements are effective, but cannot provide indication about what could happen after the test. In facts, events like overvoltages, mechanical and thermal stress can incept PD with unforeseen behavior.
- Regular PD measurements or permanent monitoring not only identify hot spots and degradation for condition based maintenance but also prevent electrical assets from unplanned and costly outages.
Why PD as major diagnostic marker?

Phase Resolved PD Pattern: most common representation of Partial Discharges where Amplitude and Phase position of each collected pulse are represented. PRPD pattern shows repetition rate through a color scale.

Diagnosis based on pattern → Experts
Based on PD Pattern, defect identification can be carried out, since different defect typologies forms different PD pattern shapes.
Problem: Difficult to identify PD sources

DAUs usually acquire all signals occurring in the frequency range they are covering.
**Why PD as major diagnostic marker?**

**Solution:** With its S I D approach Techimp is able to provide the most advanced PD diagnosis on the market:

- **Separation**
  - Noise rejection
  - Source separation

- **Identification**
  - Identification of PD Type
  - and Harmfulness (one source at a time)

- **Diagnosis**
  - Risk assessment
  - Maintenance program
  - Life extension (Trend)
Separation

For each pulse the FFT (Fast Fourier Transform) is calculated. On the base of such Fourier Transform two quantities are calculated and plotted on the T-F Map:

- **Equivalent Timelength**
- **Equivalent Frequency**

Having different waveforms, different phenomena either PD or noise will be located in different parts of the T-F map, allowing **Separation**!
Identification & Diagnosis

Entire PD pattern

T-F Map  Techimps patented technology for PD analysis

Waveform A

Sub-pattern A

Sub-pattern B

Waveform B

Identification

Invalid Data

Corona Discharges

Surface Discharges

Internal Discharges

Diagnosis

Internal Discharges

Noise
Key Elements of Permanent Monitoring System

• **Sensors**
  Terminations, Joints, Transformers & Switchgears

• **Acquisition Unit**
  PD Hub / Instruments (TD Guard, PDScope)

• **Low Voltage Power Supply** *

• **Communication System**

• **Server/Virtual Machine**
  Collecting & Analyzing Data

• **Effective Separation of Noise & External Disturbances**
  Effective Diagnostics – T/F-Map – SMART ALARMS
TECHIMP sensors are designed to have the best sensitivity for every application.

- Generators, Motors
  - Capacitive couplers
  - HFCT on ground leads
  - Antennas

- Transformers
  - Bushing taps
  - Antennas
  - Acoustic sensors
  - HFCT

- Cables
  - HFCT
  - Coupling capacitor
  - Antennas

- Switchgear, GIS, GIL
  - Antennas
  - Acoustic sensors
  - HFCT
Each Standard Acquisition Box
PD Hub includes 1 PDScope

Each PDScope will be connected to 3 (or 6) PD sensors (through coaxial cables) and will acquire the HF signals coming from the PD sensors.

TD Guard (when present) uses the same sensors as the PDScope, hence no additional cables or sensors are needed.

PDHub with different number of channels are available 3, 6, 9, 12 (and customize design)
PD Hub Installation Example
PD Monitoring of HV Cables

HV Cables
Typical Setup of a HV Cable Monitoring System

- TiSCADA
- Synoptik
- Data Acquisition Unit

PD Hub N -> PD Hub 4 -> PD Hub 3 -> PD Hub 2 -> PD Hub 1

PD Hub 0

Termination T1

Joint #1

Joint #2

Joint #3

Joint #4

PD Hub N

Sensors
Typical Setup of a HV Cable Monitoring System

- All the stress factors relevant to real working conditions are available during ON-LINE measurements
- Trending of the PD phenomena
- Possible correlation PD vs quantities (e.g. temperature, current, etc.)
PD Monitoring of HV Cables

Three-phase GIS termination

Coaxial cable RS232 with adapta flex pipeline (from HFCT sensors to Acquisition box)
Installation of HFCT Sensors

Regular Joints

Cross-bonding Joints
Installation Examples
PPS2 - innovative power source for PD systems

- PPS2 provides power supply to the PD detectors installed on HV cable where low voltage AC power is not available.
- The PPS2 takes the required power directly from the HV cable under monitoring by means of units clamped on the HV cable(s).
- PPS2 is designed to withstand High Voltage line failure events such as temporary overload and short circuit conditions.
- An internal detection and self limiting circuit guarantees the PPS2 and the connected equipment survives in case of such events.
Gas Insulated Switchgear (GIS)
Identifying PD resulting from poor workmanship or installation can avoid costly outages and production losses.

Sensors

- UHF antennas for internal or external application
- HFCTs on earth leads of cable connections
- FMC Sensors possible where no internal sensors and no access from outside is available
Typical Defects

- Moving particles;
- Electrode protrusions/scratches;
- Fixed particles on insulating surfaces;
- Floating electrodes (stress shields);
- Loose, non-floating electrodes;
- Voids in solid insulation, delaminations.
PD Testing & Monitoring of GIS

Typical GIS Monitoring Layout

Detection Point #N

LV switchboard

Acquisition unit

Multiplexer

Frequency shifter+splitter

x6 external UHF Antenna Horn sensor

Detection Point #N-1

LV switchboard

Acquisition unit

Multiplexer

Frequency shifter+splitter

x6 external UHF Antenna Horn sensor

Detection Point #2

LV switchboard

Acquisition unit

Multiplexer

Frequency shifter+splitter

x6 external UHF Antenna Horn sensor

Detection Point #1

LV switchboard

Acquisition unit

Multiplexer

Frequency shifter+splitter

x6 external UHF Antenna Horn sensor

Central Unit

Legend:

- Fiber Optic for Ethernet communication network
- Coaxial Cable RG-223 between synchro transformer and PDScope
- Coaxial Cable RG-214 between PD sensors and Frequency Shifter
- Coaxial Cable RG-223 between Frequency Shifter and PDScope
- 5 Vdc, 2 A power supply
- 220 Vac or 110 Vdc power supply bipolar shielded cable
- 13 Vdc
Extra High Voltage (EHV) Cable online monitoring

Apparatus: Cable System
Voltage level: 400 kV
Location: Europe

Monitoring can provide fundamental information but effective tools are needed to get rid of noise.
Case Study

**Cable system:**
- 400 kV XLPE
- One indoor termination
- One outdoor termination
- Two joints.

**PD signal detection:**
- HFCT clamped on grounding leads of terminations.
- Joints equipped with capacitive taps
Two phenomena were detected in the cable system by measuring at a joint capacitive tap.

A. Discharges on the external surface of outdoor termination
B. Discharges internal to the joint

Monitoring diagnostic strategy:
- Define two windows, $W_A$ and $W_B$, on the TF map
- Track pulses in $W_A$ and $W_B$ separately.
Case Study

- **Phenomenon A**
  - Large magnitude
  - Does not evidence a trend

- **Phenomenon B**
  - Lower magnitude
  - Evidences a trend till breakdown

- The only way to accurately monitor PD harmfulness is track A and B separately.
Power Transformers
PD: Testing & Monitoring of insulation degradation inside the transformer

- Sensors using measuring taps of the bushings
- Alternative Sensors: UHF, HFCT, acoustic
- Same DAU as for cables
- Same server can be used
- Can be added at later stage
Condition Assessment & Monitoring of Transformers

TDG-IS is an on-line CONTINUOUS Capacitance and tan-δ monitoring system for transformer bushings.

- Tan-delta is a physical quantity describing the dielectric properties of an insulating material
- Providing tan-δ
- Acquisition Unit, digital front end able to process the extracted signals and rise alarm
DGA: DGA-XL is an on-line monitoring system for Dissolved Gas Analysis (DGA).

- CO and H₂ gasses indicator for thermal faults, PD or electrical discharges.
- CO: Thermal decomposition
- H₂: Arcing in oil and Corona
- Monitoring of oil temperature and moisture in oil
Global Monitoring System Layout

POWER TRANSFORMER

TD Splitter

"TECHIMP ACQUISITION BOX" (DGA+TD+PD)

Coaxial RG-223 cables between Tap Adapter/TD-Box and TD-Box/TD-Guard
220 Vac power supply tripolar shielded cable
CAT6 LAN cable between the Ethernet Switch and the TD-Guard
12 Vdc, 1 A power supply
5 Vdc, 2 A for PDCheck / 100mA max for TD Splitter
Fiber optic connection cable

T-H sensor

Low Voltage power supply

Low Voltage switchboard

TD-Standard+PD

Ethernet Switch

LFA

PD+Tanδ signals

PD Check

5 Vdc, 2 A for PDCheck / 100mA max for TD Splitter

Fiber optic connection cable

DGA

DGA& Temperature

Coaxial RG-223 cables between Tap Adapter/TD-Box and TD-Box/TD-Guard
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Fiber optic connection cable
# CASE STUDY

**Global Monitoring of HV Transformer**

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUT</td>
<td>HV transformer</td>
</tr>
<tr>
<td>RATED VOLTAGE</td>
<td>220/132 kV</td>
</tr>
<tr>
<td>INSULATION</td>
<td>Oil-filled</td>
</tr>
<tr>
<td>TYPE OF TEST</td>
<td>Global Monitoring</td>
</tr>
<tr>
<td>PD SENSOR</td>
<td>Tap adapter / DGA-IS</td>
</tr>
</tbody>
</table>
• Location: Europe

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

• TECHIMP global monitoring system also confirmed that Interface PDs (PD activities between two different insulation materials) were happening in every phases

• Utility is looking for the TECHIMP suggestion corresponding the situation
Partial Discharges (PD)
- Tap Adapters installed in the bushings capacitive taps
- Both Tank PD and Bushing PD can be detected
- Trend over time can be evaluated

Dissolved Gas Analysis (DGA)
- Monitoring dissolved $H_2 + CO$ and Moisture

Leakage current in the bushing (Tan-$\delta$) & Capacitance
- Tap Adapters installed in the bushings capacitive taps
- Measures tan-$\delta$ and Capacity of Bushings
Case Study: 6 Months Monitoring Results 1/4

- No PD present in the bushings
- Three PD present in the main tank, one each phase (Max > 500 mV)
- Identified as an Interface (Internal/Surface) defects at the interface between different materials
Case Study: 6 Months Monitoring Results 2/4

- Thanks to separation, a precise PD Trend plotting is possible.
- No amplitude increase over time.

\[ q_{\text{MAX}95\%} = \text{PD amplitude} \]
\[ N_w = \text{PD repetition rate} \]

A phase -220 kV side

B phase -220 kV side

C phase -220 kV side
• DGA H₂ increased constantly by a rate of 60 – 70 ppm/month
• DGA H₂ reached a value of 1250 ppm
• DGA CO value (not plotted) was always below 350 ppm

Hydrogen increase confirmed due to the three interface PD activities inside the Transformer!
Case Study: 6 Months Monitoring Results 4/4

- No significant change in Tan-δ value of the Bushings
- No significant change in Capacitance value of the Bushings
Case Study: On-line Results

- Three PD activities inside the Transformer, one for each phase
- Such PD activities are the cause of H₂ increase
- High Frequency content → PD in the upper part of the Transformer
- PD identified as an Interface phenomenon between different dielectric materials
- Stable Trend over time would suggest that no solid insulation systems are concerned

**Conclusion:** PD possibly generated at three interfaces air/oil in the three domes just below the bushings due to not perfect oil filling of the Transformer
# Case Study: Offline Results

<table>
<thead>
<tr>
<th>MEASURED PARAMETER</th>
<th>ON-LINE RESULT</th>
<th>OFF-LINE RESULT</th>
<th>COMPARISON</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD in the Tank</td>
<td>&gt; 500 mV</td>
<td>&gt; 500 pC PDIV = 0.6 U_n</td>
<td><strong>Confirmed</strong></td>
</tr>
<tr>
<td>PD in the Bushing</td>
<td>Not Present</td>
<td>Not Present</td>
<td><strong>Confirmed</strong></td>
</tr>
<tr>
<td>DGA of Transformer oil</td>
<td>High H₂</td>
<td>High H₂</td>
<td><strong>Confirmed</strong></td>
</tr>
<tr>
<td>DGA of Bushings</td>
<td>Not possible</td>
<td>Clean</td>
<td><strong>Confirmed</strong> no PD in Bushings</td>
</tr>
<tr>
<td>tanδ of Bushings</td>
<td>&lt; 0.007</td>
<td>&lt; 0.007</td>
<td><strong>Confirmed</strong></td>
</tr>
<tr>
<td>Capacitance of Bushings</td>
<td>&lt; 300 pF</td>
<td>&lt; 300 pF</td>
<td><strong>Confirmed</strong></td>
</tr>
</tbody>
</table>

PD pattern detected off-line
Utility actions:

• Transformer oil was drained and degassed
• Transformer was filled up again slowly with hot oil in order to avoid any kind of empty regions.
• Transformer was put on-service again with the monitoring installed

Result:

• Transformer PD Free!
• No further H₂ increase
• Elimination of interfaces air/oil
TiSCADA – Complete Network Monitoring

One! platform for all Assets and all CM data.

- TiSCADA is able to retrieve, manage and combine data from any source of CM for MV/HV assets like PD, Tan-D, DGA, Temp, Current, Voltage, Vibration, oil level, ...

- Multi standard protocols (OPC/DNP3/MODBUS/IEC61850/...) are implemented in order to guarantee high reliability data exchange needs.
TiSCADA provides a Real Time Condition (RTC) control of the assets, with a powerful Human Machine Interface (HMI)

- Web based
- Fully configurable multi standard protocols (OPC/DNP3/MODBUS/IEC61850/...) are implemented
Thank you for your attention!