How to improve your rotating machinery reliability with online and offline testing

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Service Engineer

Engineering expertise and advanced diagnostics to ensure that all people globally have ***reliable***, ***safe*** & ***secure*** energy in a sustainable world

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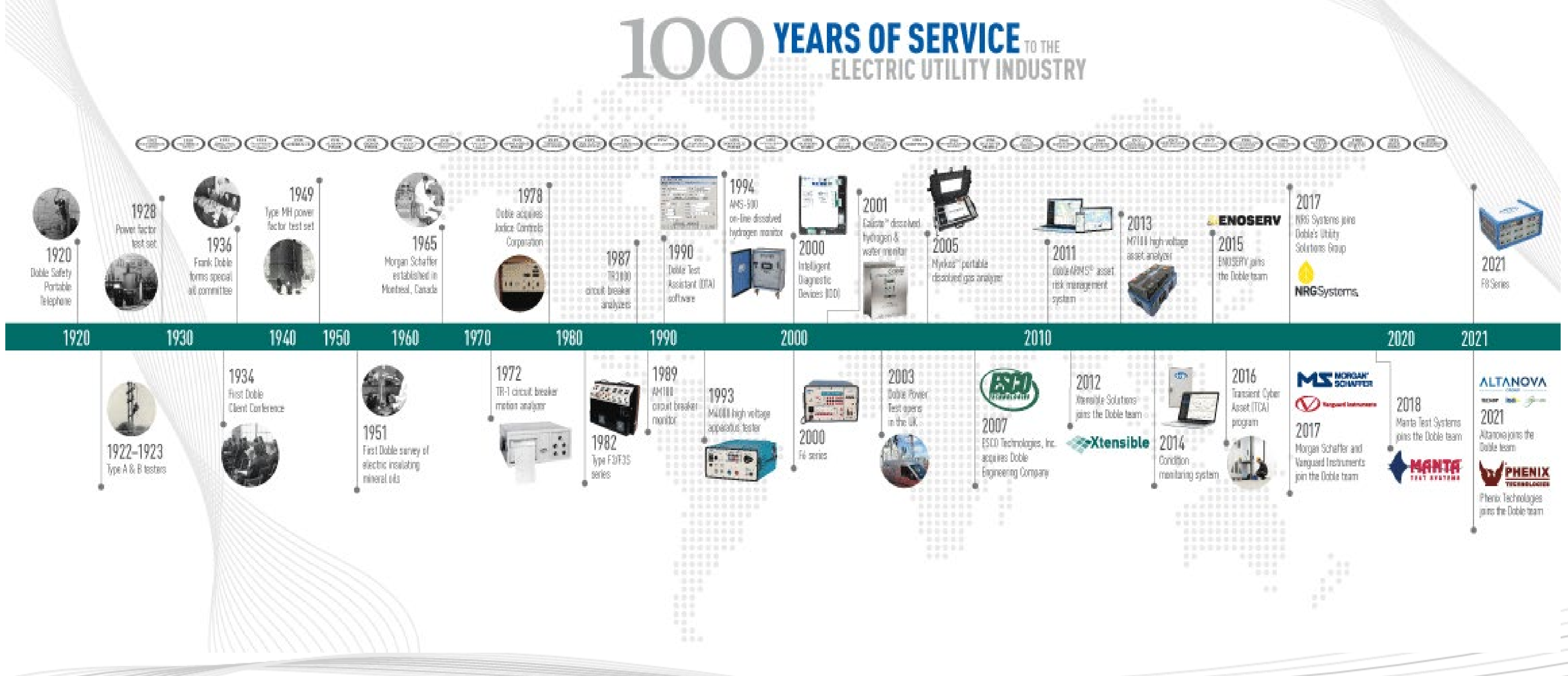
BUILT ON OVER A CENTURY OF INNOVATION AND EXPERTISE.

FOR THE NEXT CENTURY.


100 YEARS OF SERVICE TO THE ELECTRIC UTILITY INDUSTRY
1920 Doble Safety Portable Telephone
1928 Power factor test set
1936 Frank Doble forms special oil committee
1949 Type MH power factor test set
1965 Morgan Schaffer established in Montreal, Canada
1978 Doble acquires Justice Controls Corporation
1987 TR3100 circuit breaker analyzers
1990 Doble Test Assistant (DTA) software
1994 AMS-500 on-line dissolved hydrogen monitor
2000 Intelligent Diagnostic Devices (IDD)
2001 Calisto™ dissolved hydrogen & water monitor
2005 Myrkos™ portable dissolved gas analyzer
2011 doble ARMS™ asset risk management system
2013 M7100 high voltage asset analyzer
ENOSERV
2015 ENOSERV joins the Doble team
2017 NRG Systems joins Doble's Utility Solutions Group
NRG Systems
2021 F8 Series
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2021
1922-1923 Type A & B testers
1934 First Doble Client Conference
1951 First Doble survey of electric insulating mineral oils
1972 TR-1 circuit breaker motion analyzer
1982 Type F3/F35 series
1989 AM100 circuit breaker monitor
1993 M4000 high voltage apparatus tester
2000 F6 series
2003 Doble Power Test opens in the UK
ESCO
2007 ESCO Technologies, Inc. acquires Doble Engineering Company
2012 Xtensible Solutions joins the Doble team
Xtensible
2014 Condition monitoring system
2016 Transient Cyber Asset (TCA) program
MS MORGAN SCHAFFER
Vanguard Instruments
2017 Morgan Schaffer and Vanguard Instruments join the Doble team
2018 Manta Test Systems joins the Doble team
MANTA TEST SYSTEMS
ALTANOVA
2021 Altanova joins the Doble team
PHENIX TECHNOLOGIES
Phenix Technologies joins the Doble team

DOBLE TODAY

110
COUNTRIES

12
GLOBAL OFFICE LOCATIONS

800+
EMPLOYEES

5,550+
CUSTOMERS GLOBALLY

ESCO TECHNOLOGIES

Part of ESCO Technologies' Utility Solutions Group

OUR BRANDS

isa
MORGAN® SCHAFFER
PHENIX TECHNOLOGIES
TECHIMP
Vanguard Instruments

Testing And Monitoring Solutions For:



- Power transformers;
- Circuit breakers;
- HV gas insulated switchgears;
- MV/HV/EHV cables;
- MV/LV switchgears;
- Batteries;
- Current & voltage transformers;
- Protective relays;
- Meters and transducers;
- Rotating machines;
- Variables speed drives;
- Overhead lines.



OUR SOLUTIONS

Electrical Test Equipment

Essential for day-to-day maintenance tests of electrical assets. Useful in specific phases of the asset lifecycle:

- Procure
- Operate
- Maintain
- Decommission.

Professional Services

Diversified offer according to the electrical asset lifecycle:

- Installation and commissioning
- Diagnostic test
- Data analysis
- Consultancy
- Training.

Monitoring Systems

Shift from a time-based maintenance to a condition-based maintenance.

Focus on predictive maintenance and shift in focus from electric asset value cost to network outage costs.

Strong evolution of digitalization trend in the power industry.

RM Diagnostics

Traditional rotating machines electrical tests:

- *Insulating Resistance*
- *Polarization Index*
- *TanDelta*
- *Capacitance*
- *Partial Discharges*
- *EMI*

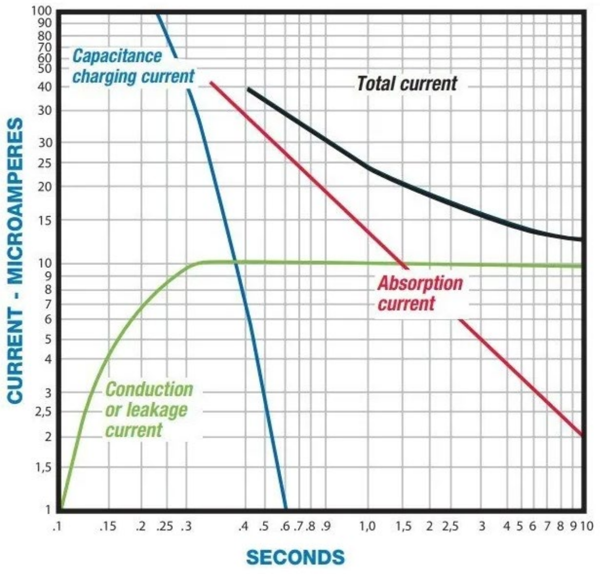
RM diagnostics

Insulation Resistance (IR) & Polarization Index (IP)

Target	*Stator windings*
Sensors	*CA 6547*
Regulations	*IEEE 43*

Routine tests useful for diagnosing possible contamination and shortcircuit, it is carried out before AC test and commissioning.

IR is temperature dependent compared to PI.



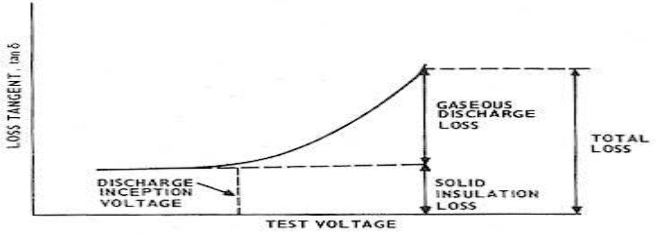
Efficient in detecting problems related to the surface of the insulation systems, less sensible for internal defects or delaminations.

RM diagnostics

TanDelta (TD) & Capacitance

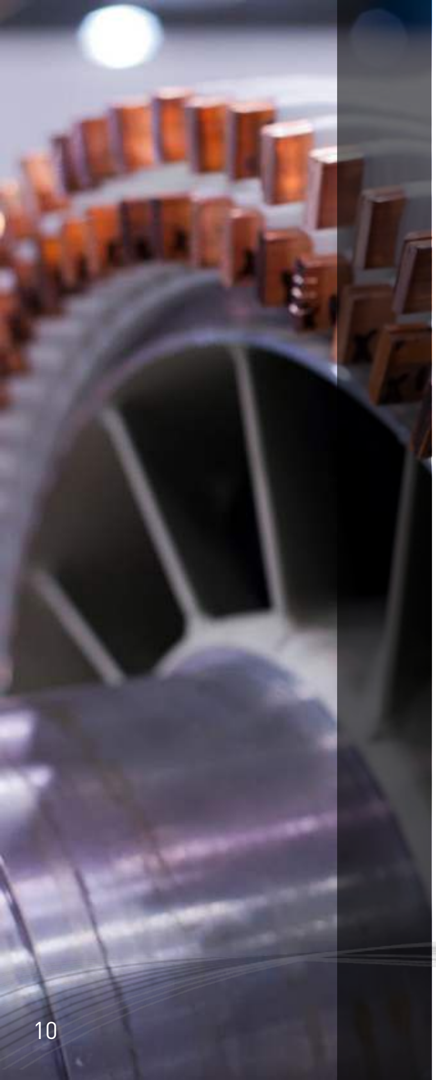
Target	*Stator windings*
Sensors	*Doble M4100*
Regulations	*IEEE 286; IEC 60034-27-3*

The measurement of stray currents (or TanDelta) of the stator windings is a macroscopic index of the behaviour of the insulation stressed with different voltage levels.



Unacceptable TanDelta values can be due to:

- ❑ Moisture;
- ❑ Deterioration of semiconductive layers → presence of PD;
- ❑ Wedges not tightened;
- ❑ Contamination of the insulating system.



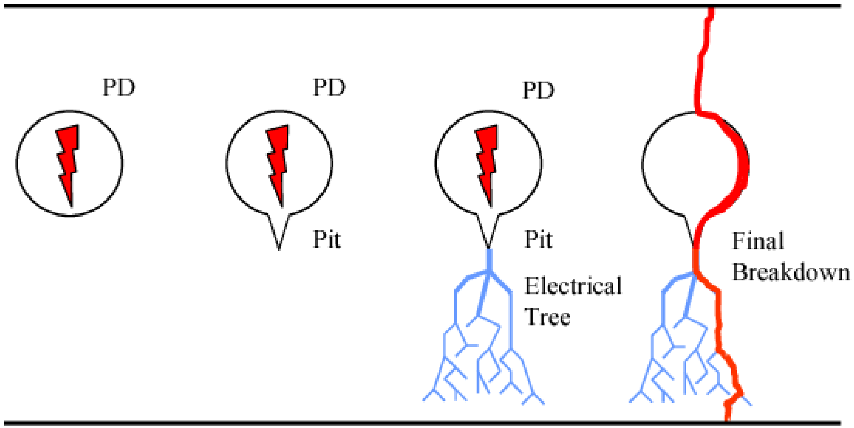
PARTIAL DISCHARGES (PD) TESTING

Partial Discharges & Rotating Machines

Partial Discharge Definition:

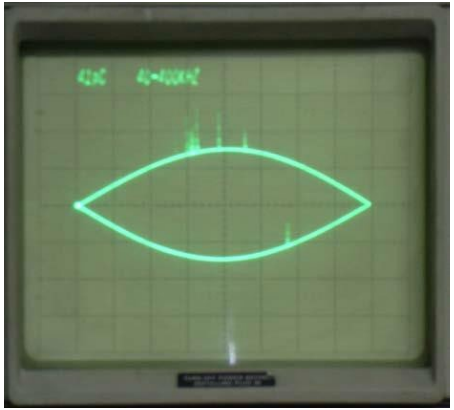
IEC: *"Localized electrical discharge that only partially bridges the insulation between conductors and which can or can not occur adjacent to a conductor"*

IEEE: *"Localized electrical discharge that only partially bridges the insulation between conductors"*

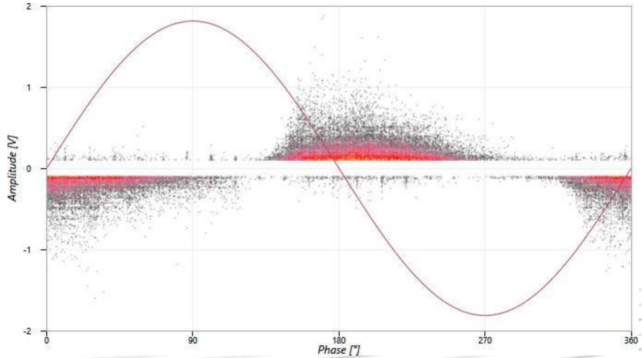


Partial Discharges & Rotating Machines

Phase Resolved Partial Discharge Pattern



Each PD phenomenon generates thousands of PD pulse each second. The common way to visualize them is to plot the pulses' amplitude correlated with the applied voltage.



The correlation is based on the PD physics, the electrical stress due to the applied voltage activates PD.

PRPD pattern recognition is the key for PD diagnostics outside of laboratories.

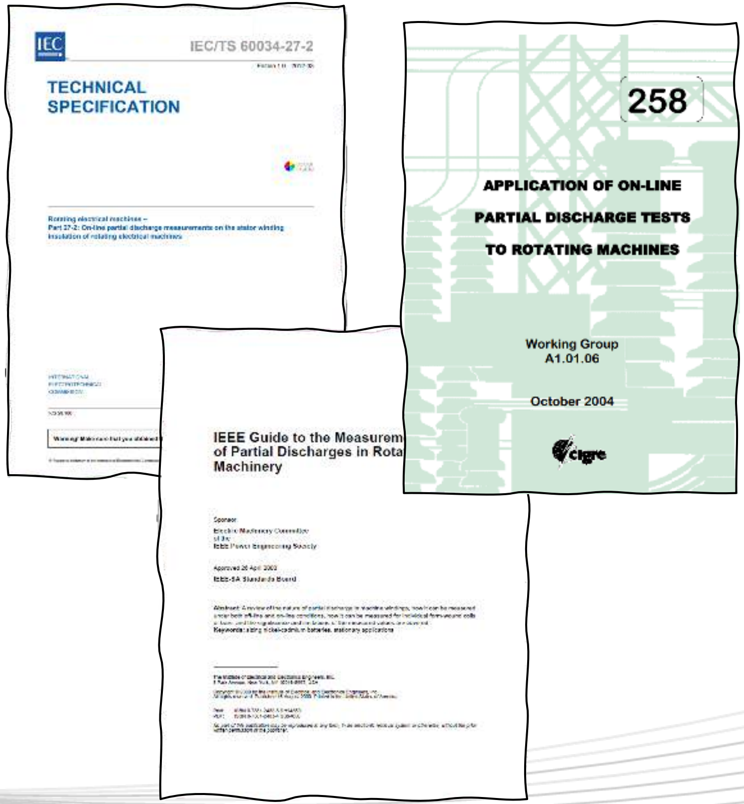
Partial Discharges & Rotating Machines

PD test standards on RM

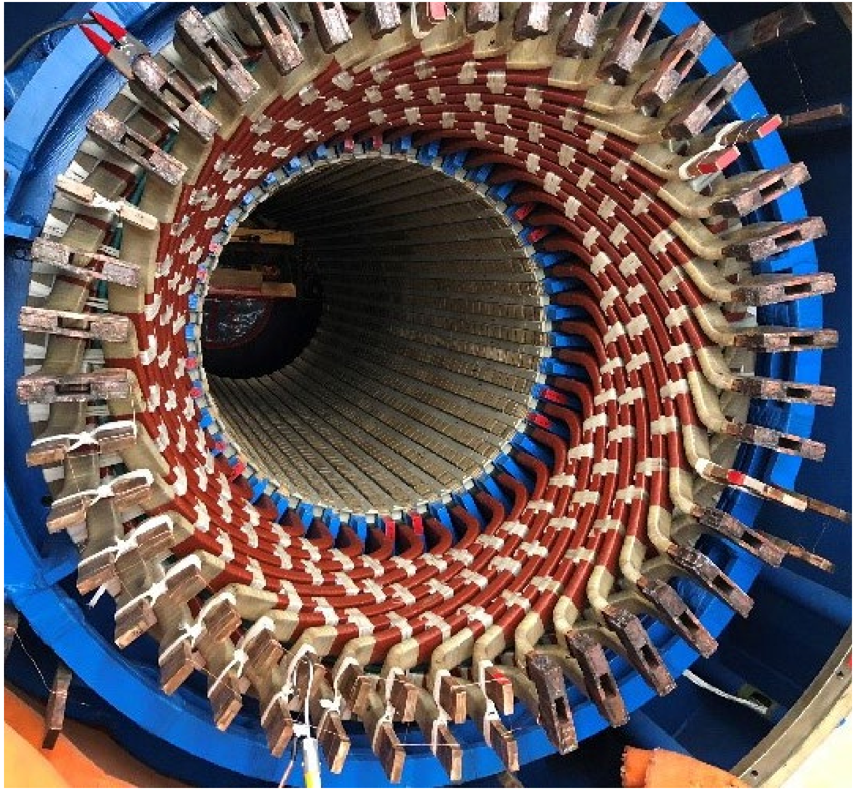
IEC 60034-27-2: *On-line partial discharge measurements on the stator winding insulation of rotating electrical machines*

IEEE 1434: *Guide for the Measurement of Partial Discharges in AC Electric Machinery*

CIGRE 258: *Application of on-line partial discharge tests to rotating machines*



PD Phenomena



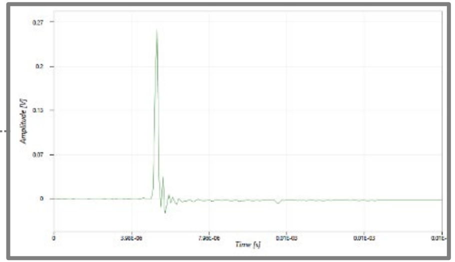
- PRPD pattern & polarity
- Microvoids
- Delamination
- Conductor side delamination
- Slot discharges
- Stress grading discharges
- Bar to Bar/Bar to Ground

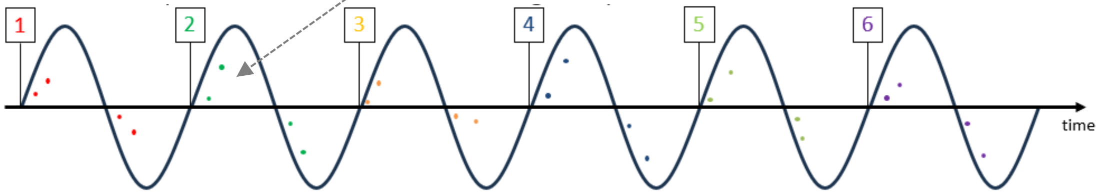
PD Phenomena

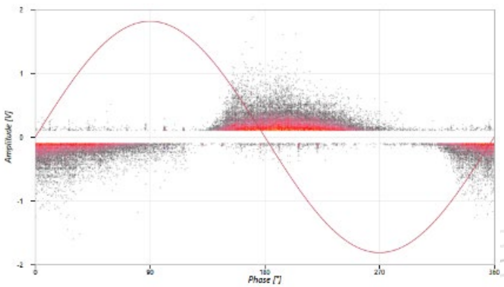
PRPD pattern and polarity

The PRPD pattern study is the key of advanced PD test diagnostics, knowledge is required to make a proper interpretation, as well as acquire good PD data.

- Pulse Amplitude;
- Pulse Polarity;
- Phase Angle.







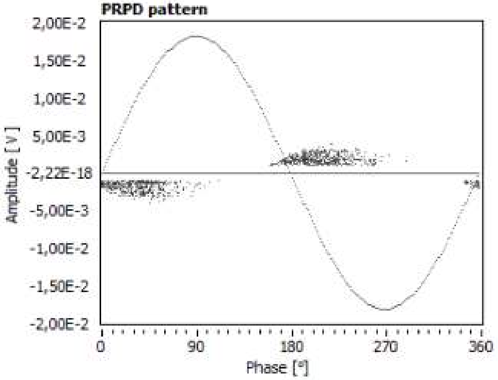
Microvoids

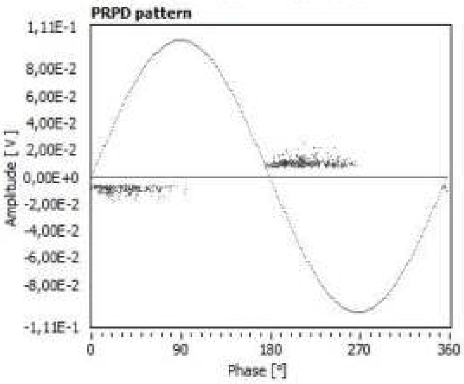
Defects internal to the groundwall (mica foils) insulation, consisting of small voids. It is expected that this kind of defect is present in any machine due to unavoidable imperfections in the impregnation process, from the first day of operation until the end of life without reducing the expected life of the machine.

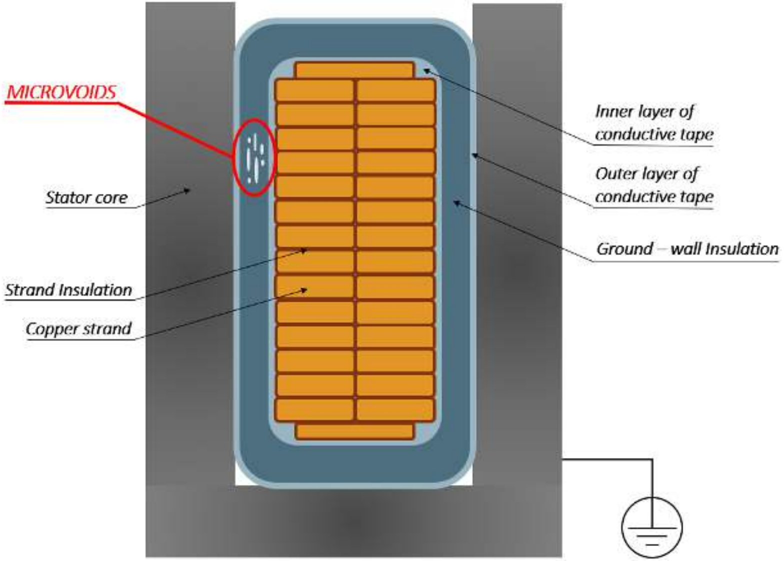
Typical Characteristics:

- ❑ *Simmetry PD + & PD -;*
- ❑ *Phase angle intervals regular;*
- ❑ *Magnitude low;*
- ❑ *Triangular shape.*

**+/- is referred to pulse amplitude not to applied voltage*







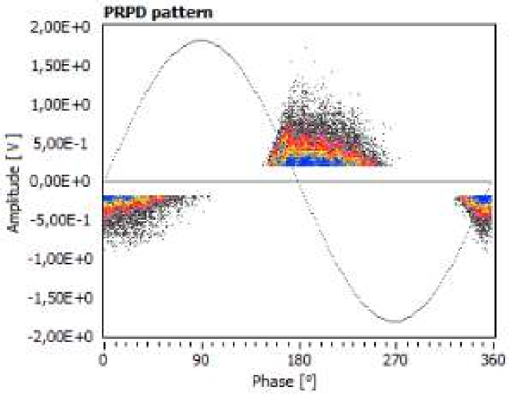
Embedded Delaminations

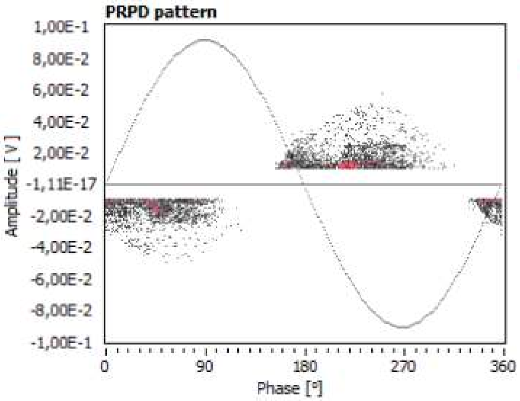
Detachments between mica foils within the insulation. They are flat voids caused by imperfect curing of the insulation system during manufacturing or by mechanical or thermal over-stressing during operation. These delaminations will reduce the thermal conductivity of the insulation, which might lead to accelerated ageing or thermal runaway.

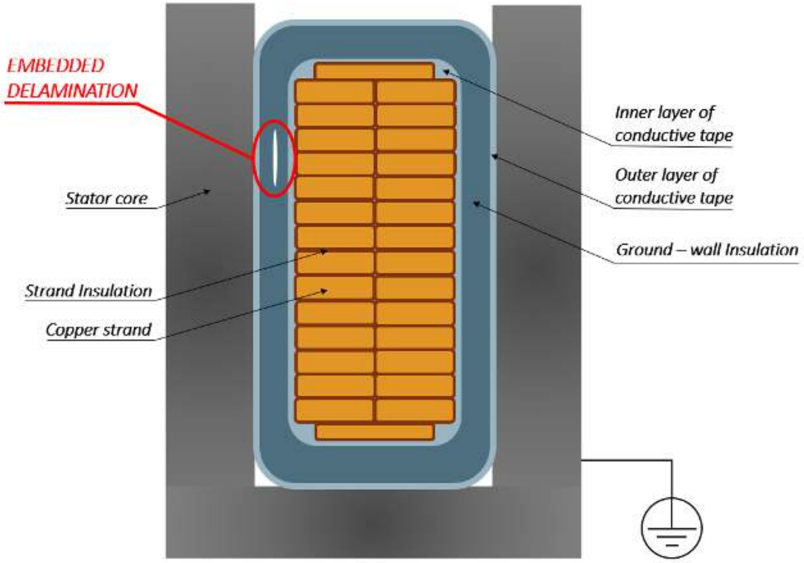
Typical Characteristics:

- *Simmetry PD + & PD -;*
- *Large phase angle intervals;*
- *Triangular shape;*
- *Starting before zero-crossing;*

**+/- is referred to pulse amplitude not to applied voltage*







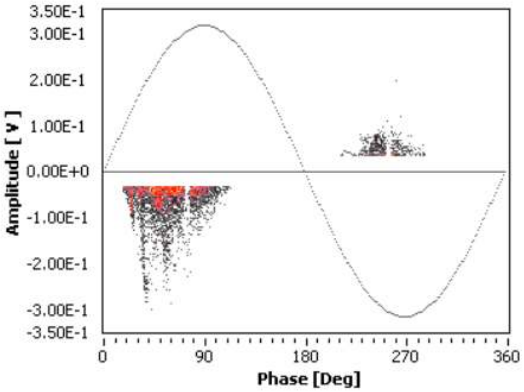
Conductor-Side Delamination

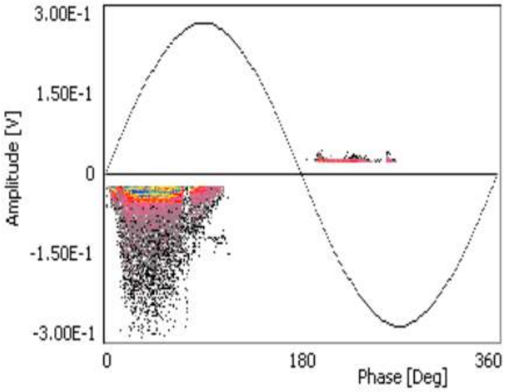
Detachments of the insulation from HV electrode (copper part of the bar). These defects consist of flat voids placed between HV electrode and insulation. As for embedded, they might lead to overheating (hotspot).

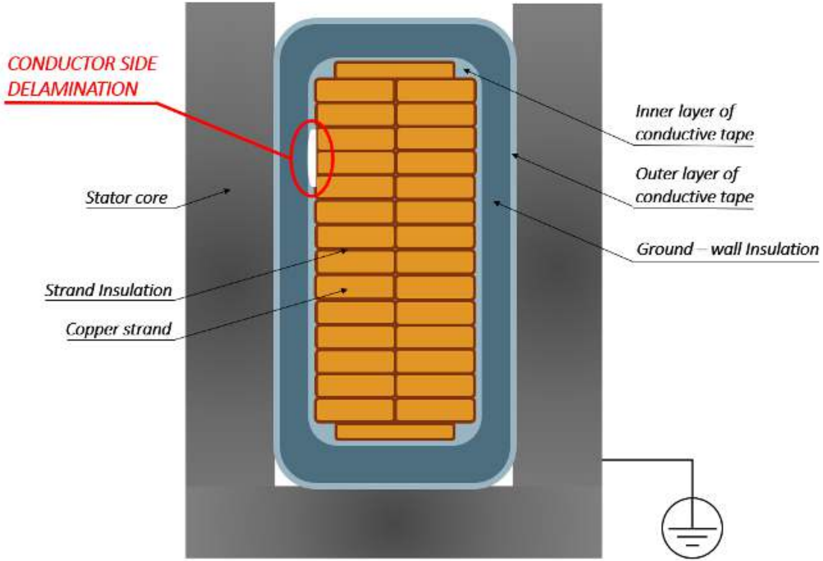
Typical Characteristics:

- *PD - >> PD +;*
- *Phase angle intervals regular;*
- *Starting before zero-crossing;*

**+/- is referred to pulse amplitude not to applied voltage*







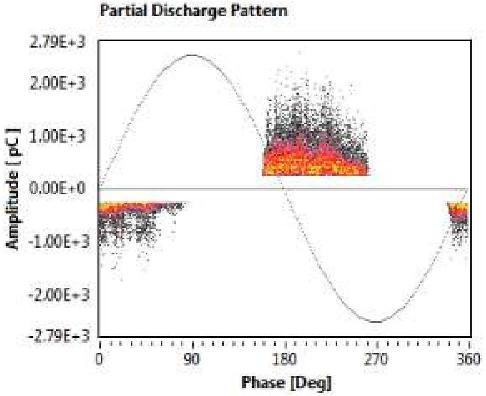
Slot Discharges

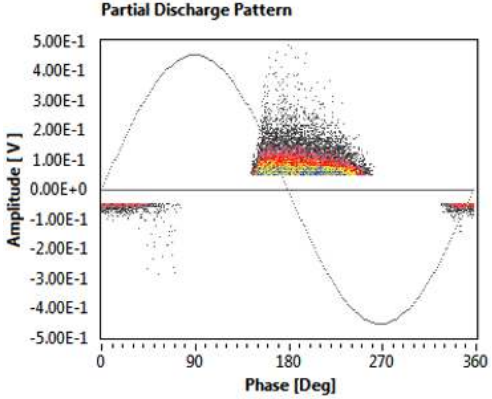
Discharges between the semi-conductive slot coating and the stator iron core. They occur when the coating is damaged due to bar/coil movement in the slot, for example by erosion, discontinuities or chemical contamination of the coating. They firstly erode the semi-conductive coating, then the insulation

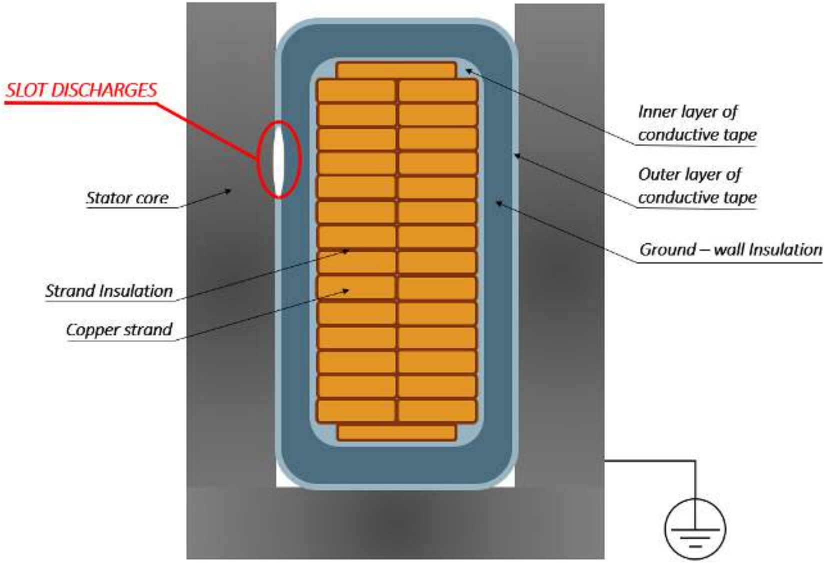
Typical Characteristics:

- ❑ *PD + >> PD -;*
- ❑ *Phase angle intervals regular;*
- ❑ *Starting before zero-crossing;*
- ❑ *PD + max values ≈ zero-crossing*

**+/- is referred to pulse amplitude not to applied voltage*







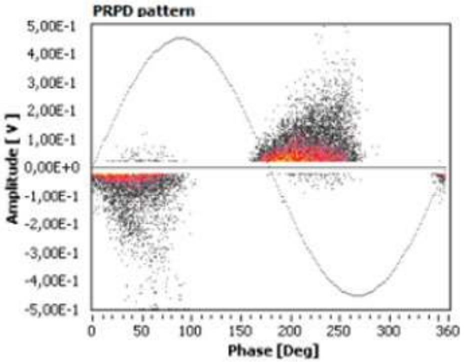
Stress Grading

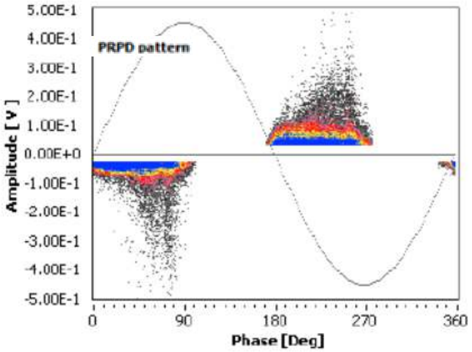
Discharges occurring at the interface between the semi-conductive slot coating and stress control coating at the slot exit in presence of pollution, contamination or degradation. This is normally a slow failure mechanism even if PD behaviour might change rapidly due to surface effects.

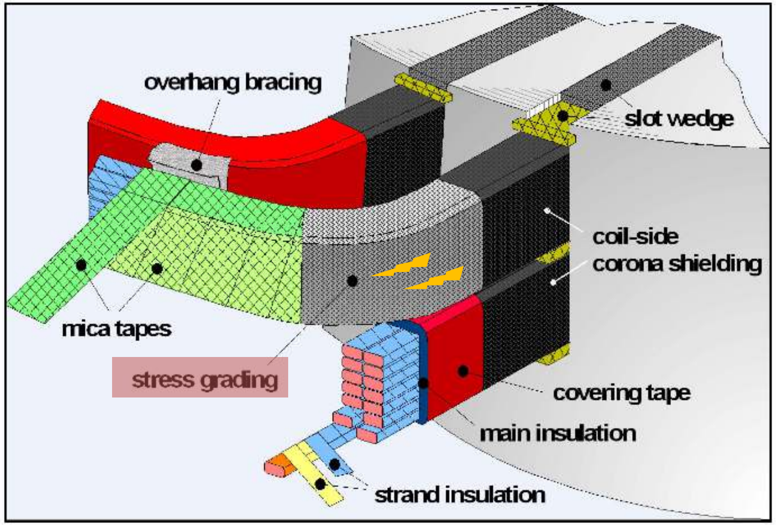
Typical Characteristics:

- ❑ *PD + > PD -;*
- ❑ *Phase angle intervals regular;*
- ❑ *Rounded shape.*

**+/- is referred to pulse amplitude not to applied voltage*







Bar-to-Bar / Bar-to Ground

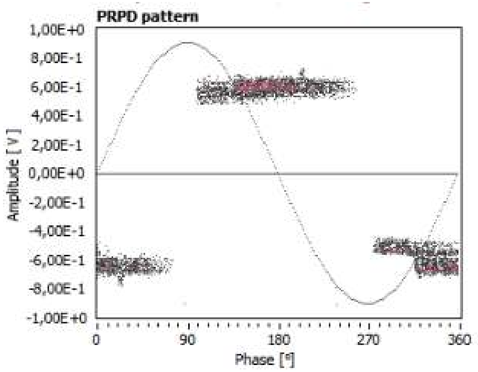
These discharges occur in the air gap between bars of different phases, or between bar and the ground in overhang due to inadequate clearance.

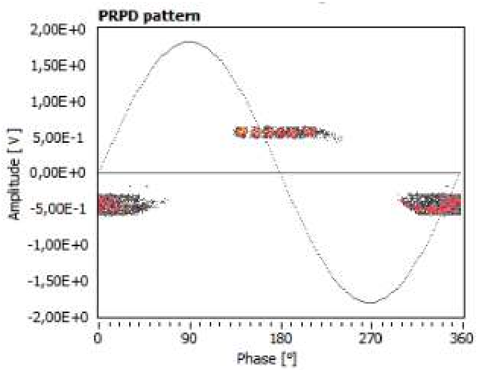
They may deteriorate the insulation system faster than corona discharges resulting in phase-to-phase/ground breakdown.

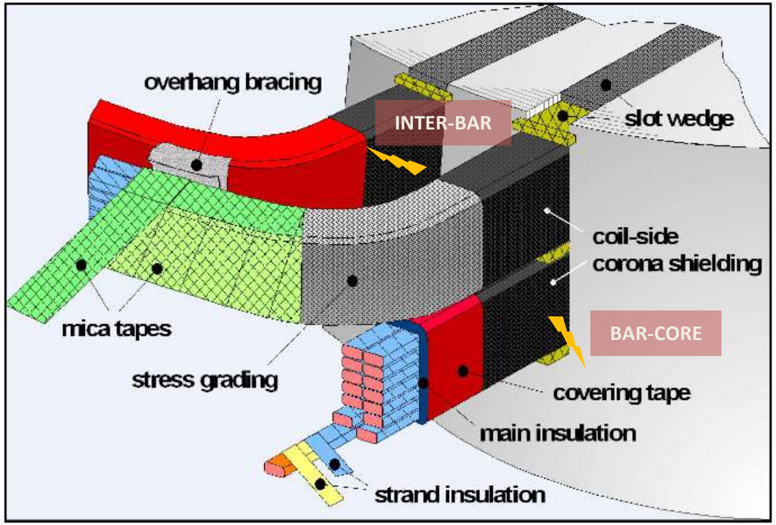
Typical Characteristics:

- ❑ *PD + ≈ PD -;*
- ❑ *High repetition rate;*
- ❑ *«Squared» shapes;*
- ❑ *Detached from trigger level.*

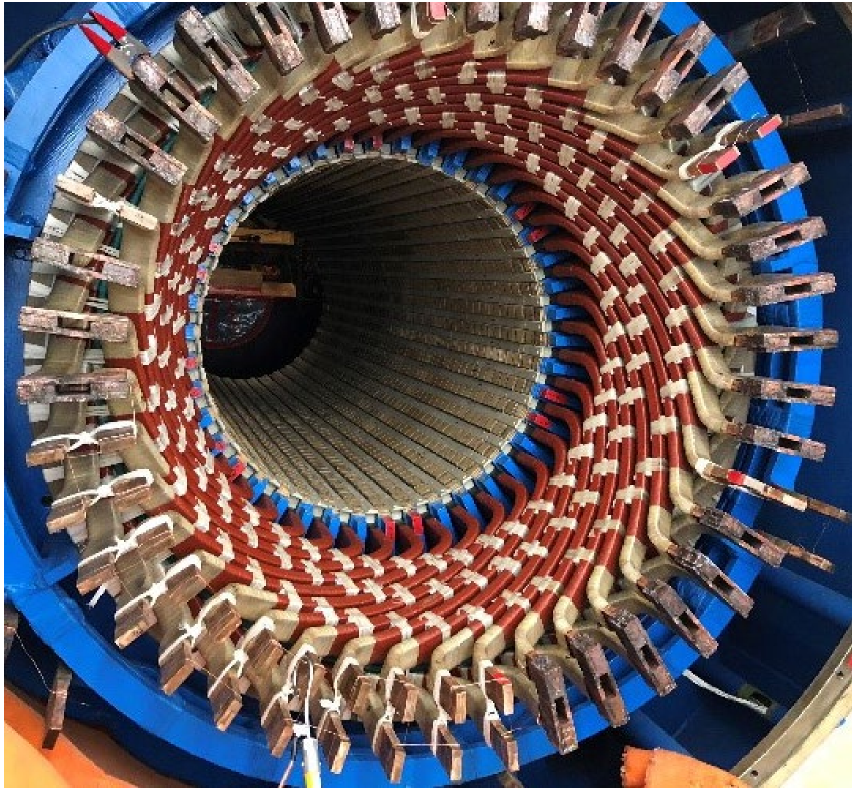
**+/- is referred to pulse amplitude not to applied voltage*







Noise and Disturbances



- ❑ RM noise and disturbances
- ❑ Exciter & Electronics
- ❑ Cross-Talks
- ❑ HW filtering
- ❑ Time-Frequency Map filtering

Noise and Disturbances

RM PD noise & disturbances

When testing a generator, it is possible to experience many different noise signals affecting the insulation due to the complex electrical system involved, some of the noise disturbances can be considered “classic” and recognized easily: exciter noise, external disturbances and crosstalk.

- Unsynchronized disturbances (crane excitation, power tool operations, etc.);
- Synchronized disturbances (PD sourced in external assets, poor electrical connections, etc).

<u>PRPD pattern allows to:</u>

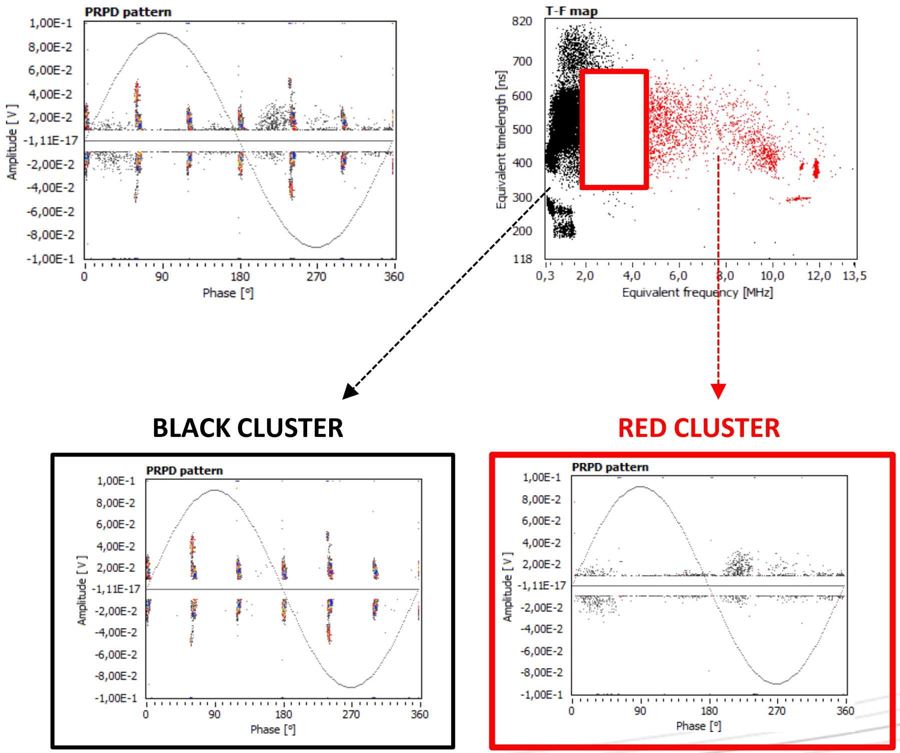
- ❑ *Recognize voltage correlated signals;*
- ❑ *Identify the PD correlation with the proper phases;*
- ❑ *Identify crosstalk.*

Noise and Disturbances

Exciter & Electronics

Exciter noise may be very annoying affecting the readings of amplitude and repetition rate of the pulses.

The signal is normally characterized by low frequency component and can be filtered out by the mean of hardware filters or by TF filter tool.

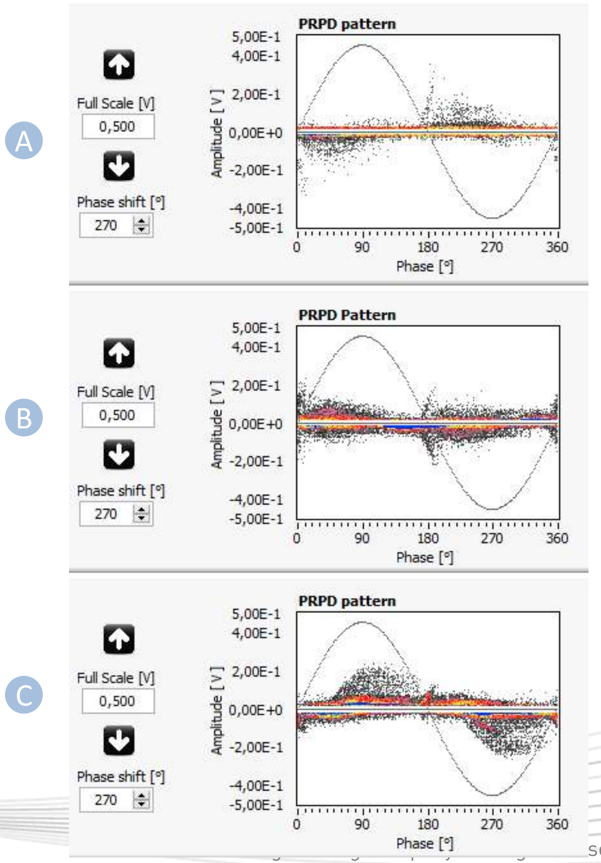


Noise and Disturbances

Crosstalk is a very frequent phenomenon in RM as the windings of the three phases are extremely close to each other.

In order to determine which phase the PD phenomenon belongs to, it is necessary to:

- ❑ Set the same phase shift for all the three phases;
- ❑ Look at amplitude;
- ❑ Check the polarity.

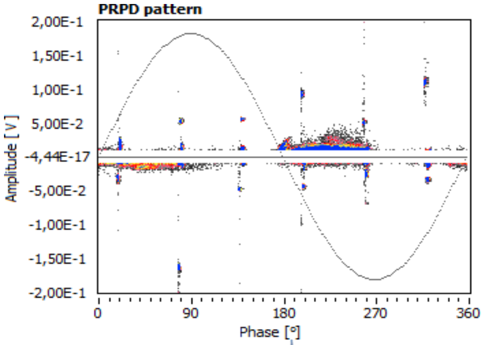


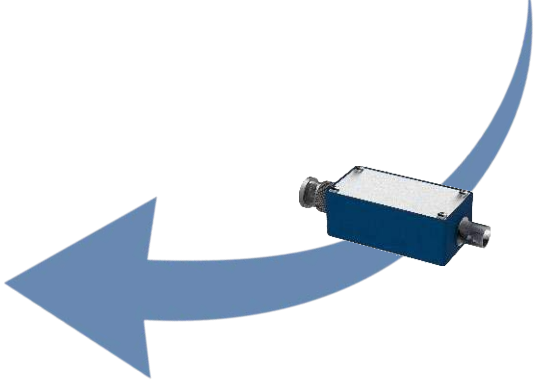
Noise and Disturbances

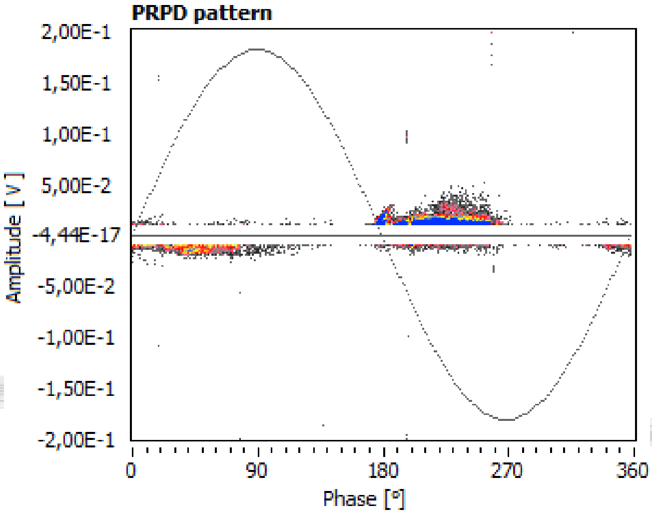
HW filtering

It is possible to install signal conditioning devices at the sensor output in order to:

- Remove low frequency disturbances;
- Remove high frequency disturbances;
- Create a band pass filter or attenuate the existing signal.



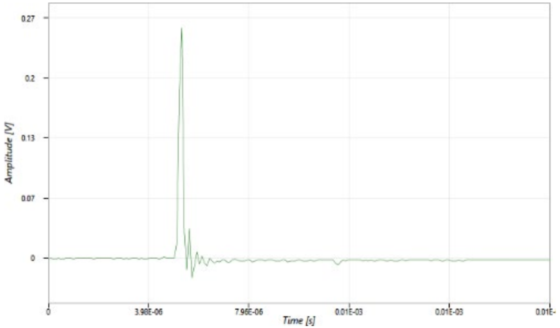




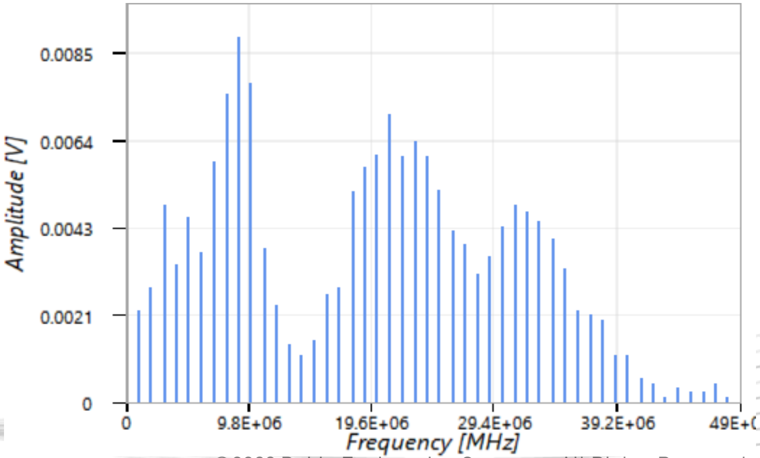
Noise and Disturbances

Time-Frequency Map

Every second the PD instrument acquires thousands of pulses; it is impossible high frequency PD pulse, the only two information saved are <u>amplitude </u>and <u>phase angle.</u>

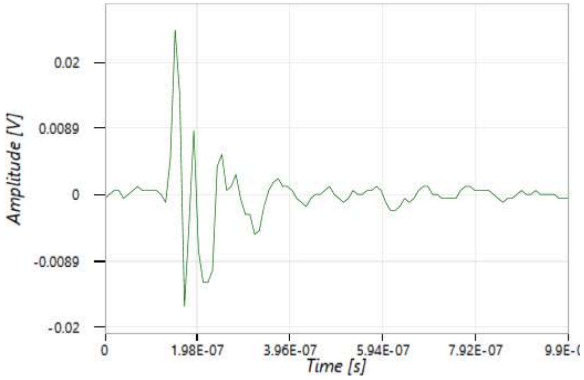


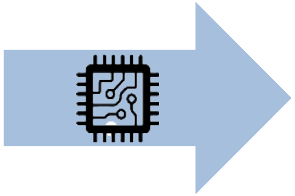
It is well known that high frequency signals can be studied from the frequency content, each signal can be visualized with its pulse spectrum and such information can be considered as a signal fingerprint.

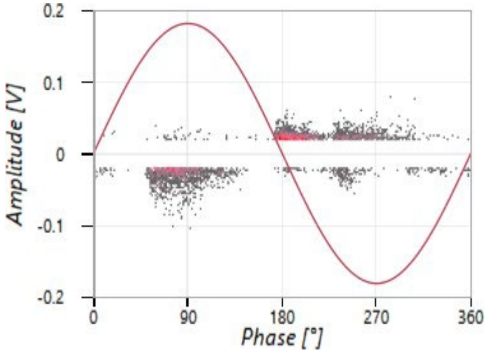


Noise and Disturbances

Time-Frequency Map

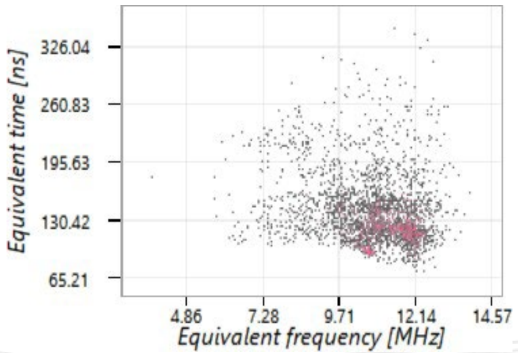






Pulse Amplitude & Phase Angle

Phase Resolved PD Pattern



Equivalent Timelength & Equivalent Frequency

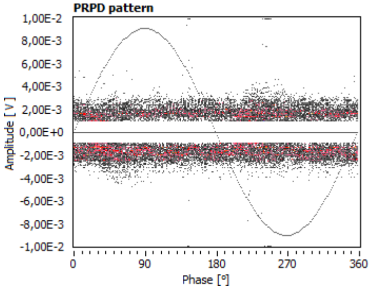
T- F Map

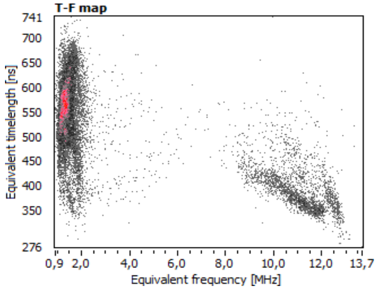
Noise and Disturbances

Time-Frequency Map

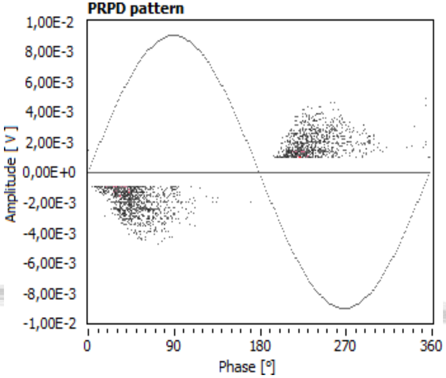
By the mean of the Time Frequency signal footprint we can set areas of the TF map to be filtered out

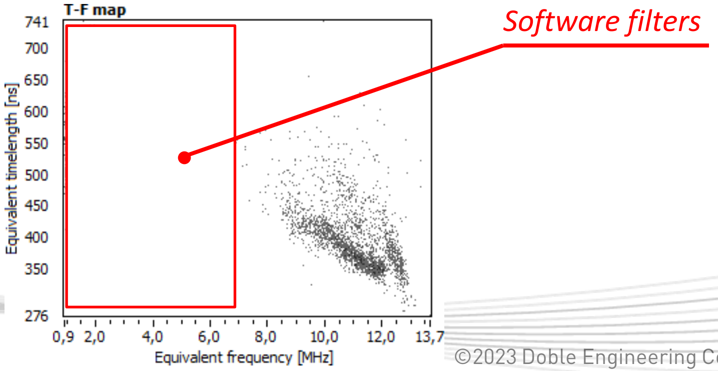
BEFORE



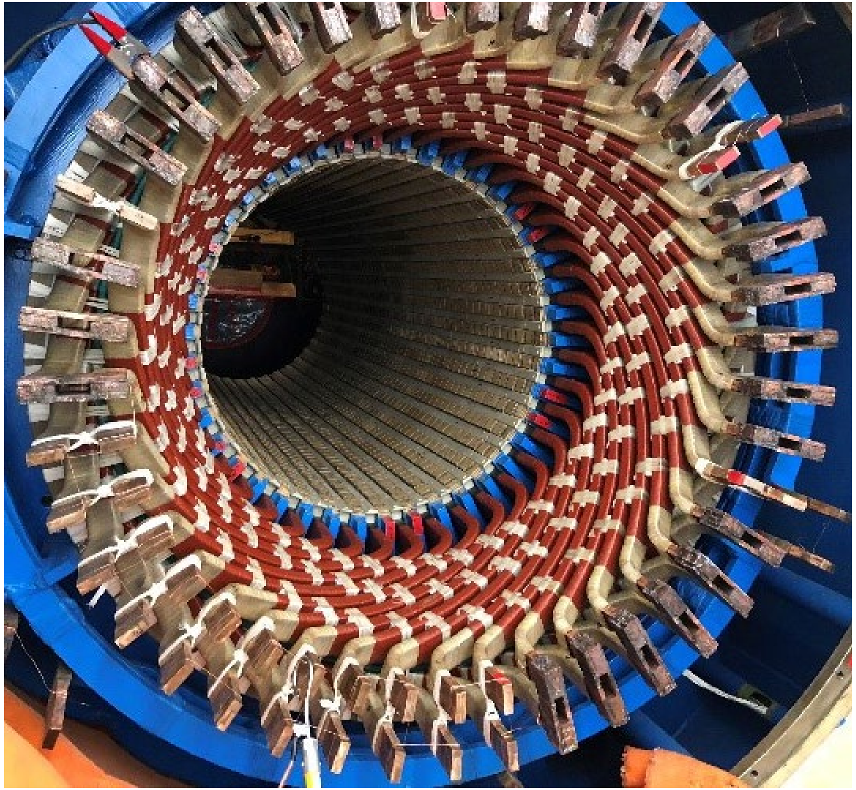


AFTER





PD Analysis



- ❑ Acquisition Process
- ❑ Data sets
- ❑ Time-Frequency Map separation
- ❑ Single phenomenon identification
- ❑ Trending

PD Analysis

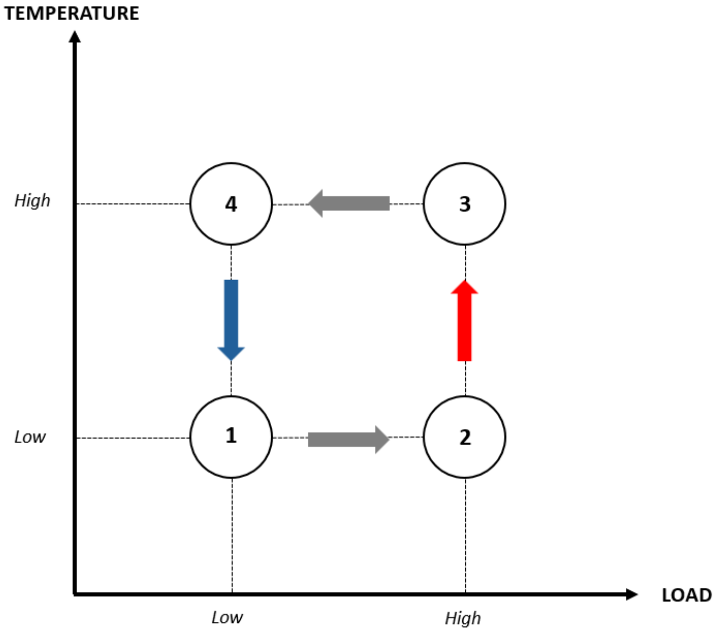
Acquisition Process

PD analysis starts during the acquisition process, a proper acquisition session shall provide the following data & info to be used during analysis:

- ❑ High amplitude PD signals data;
- ❑ Low amplitude PD signals data;
- ❑ Machine working parameters (Load & T).

During a PD session it is also suggested to use:

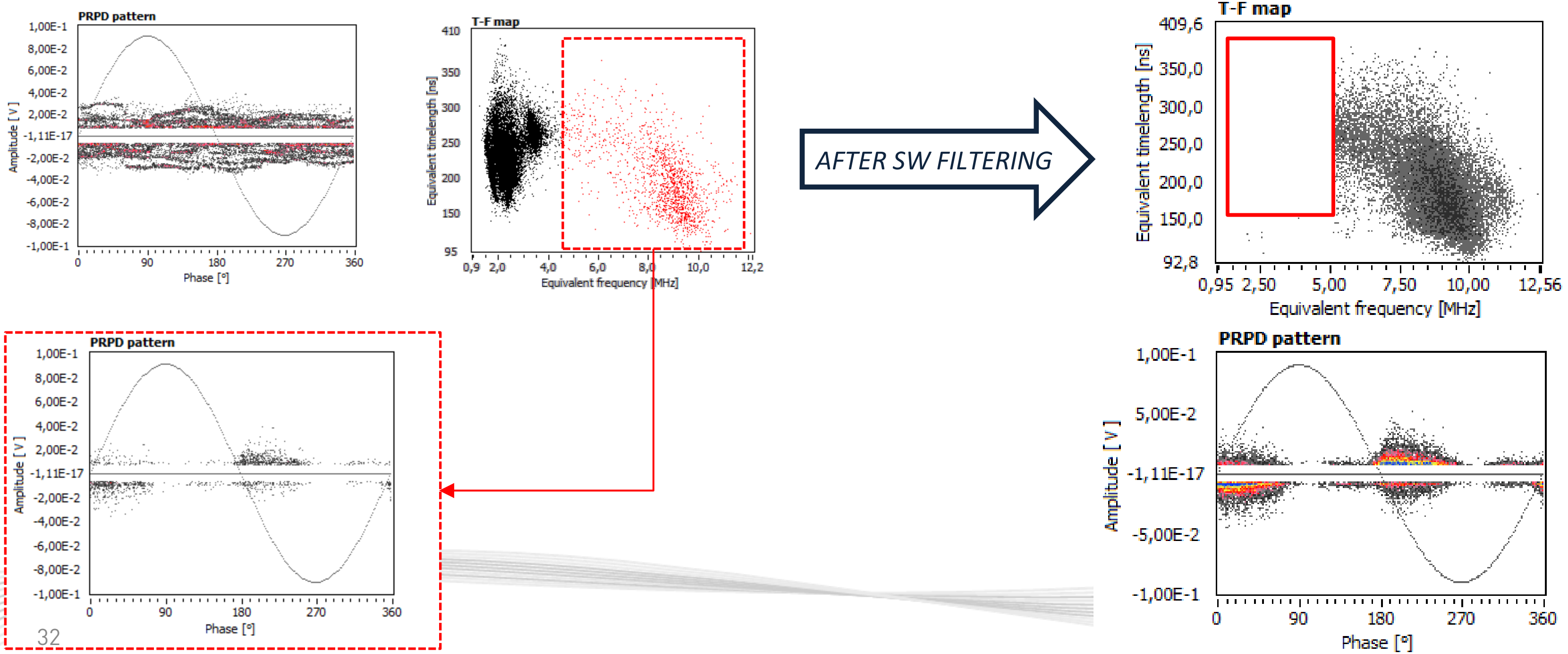
- ❑ Different timelenghts;
- ❑ Different pre-triggers;
- ❑ HW filtering.



PD Analysis

Acquisition Process

PD signals are classically displayed on an amplitude basis, if no further filtering tools are used the PD measurement output will be focused the highest amplitude signals only.

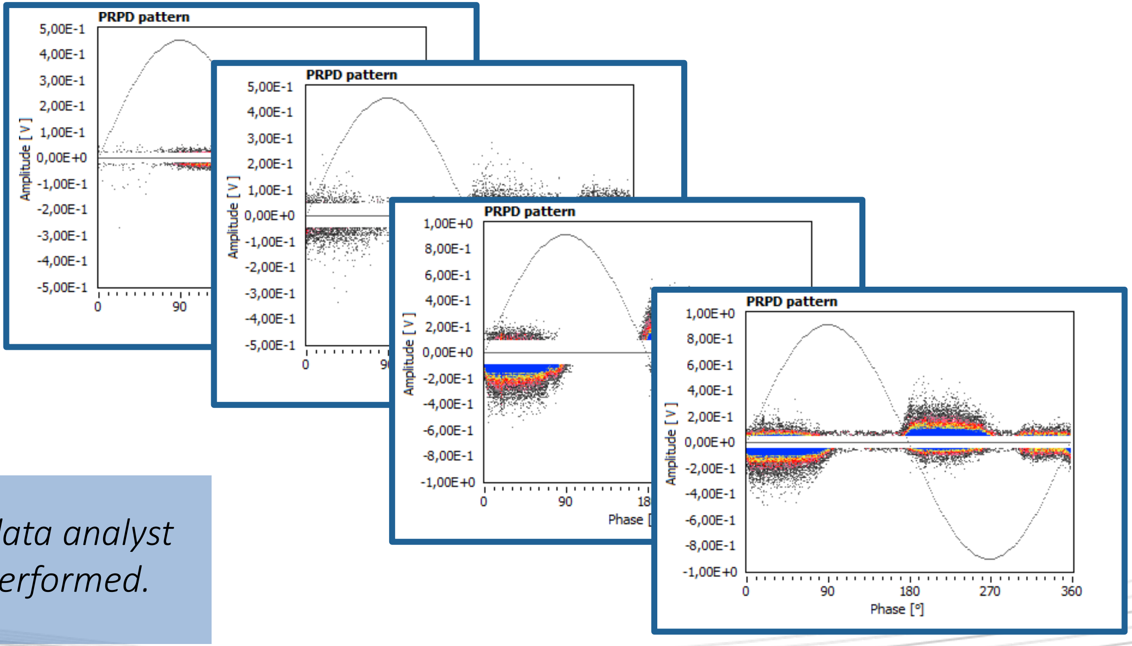


PD Analysis

Data Sets

For each detection point it is strongly suggested to acquire not just 1 PRPD pattern but a full set of data including:

- ❑ Different Full scale
- ❑ Different Trigger level
- ❑ Waveform acquisitions
- ❑ With and without HW filters
- ❑ With and without SW filters



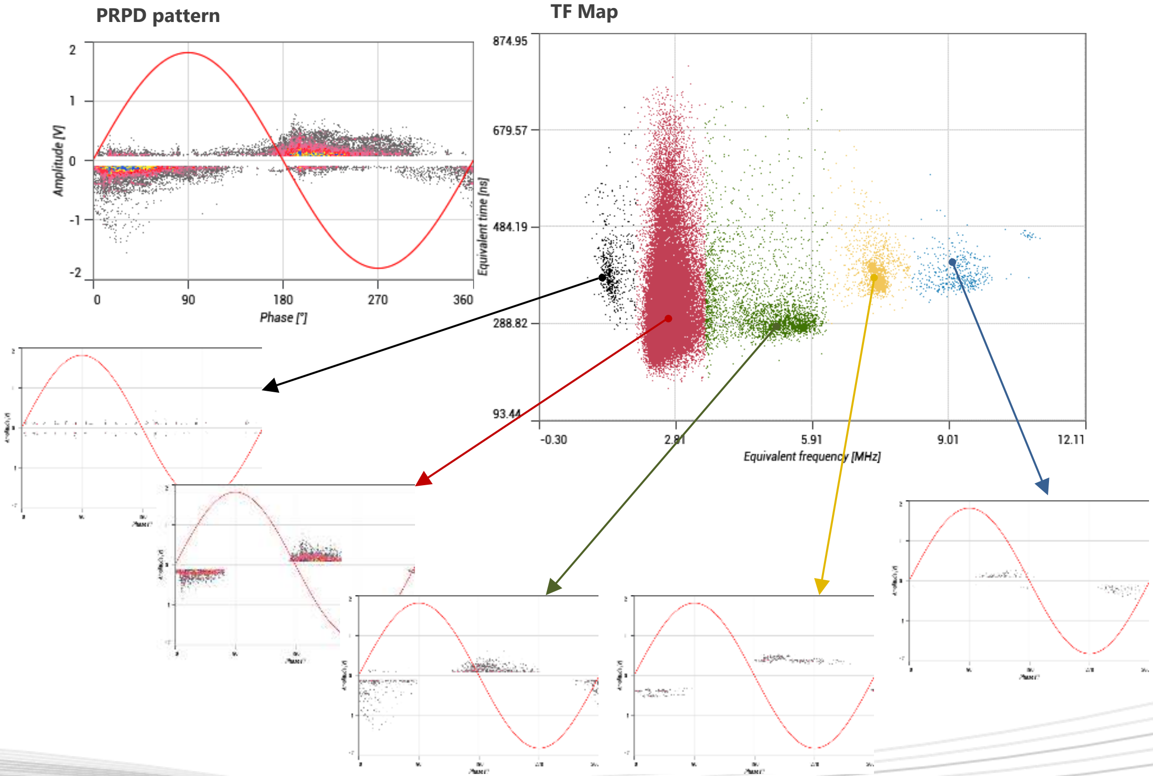
Ideally when studying the data, the data analyst shall be able to recognize each step performed.

PD Analysis

TF map separation

TF map signals is used during acquisition to remove undesired signals & can be used during the

analysis to separate the various PD sources present in the acquisition

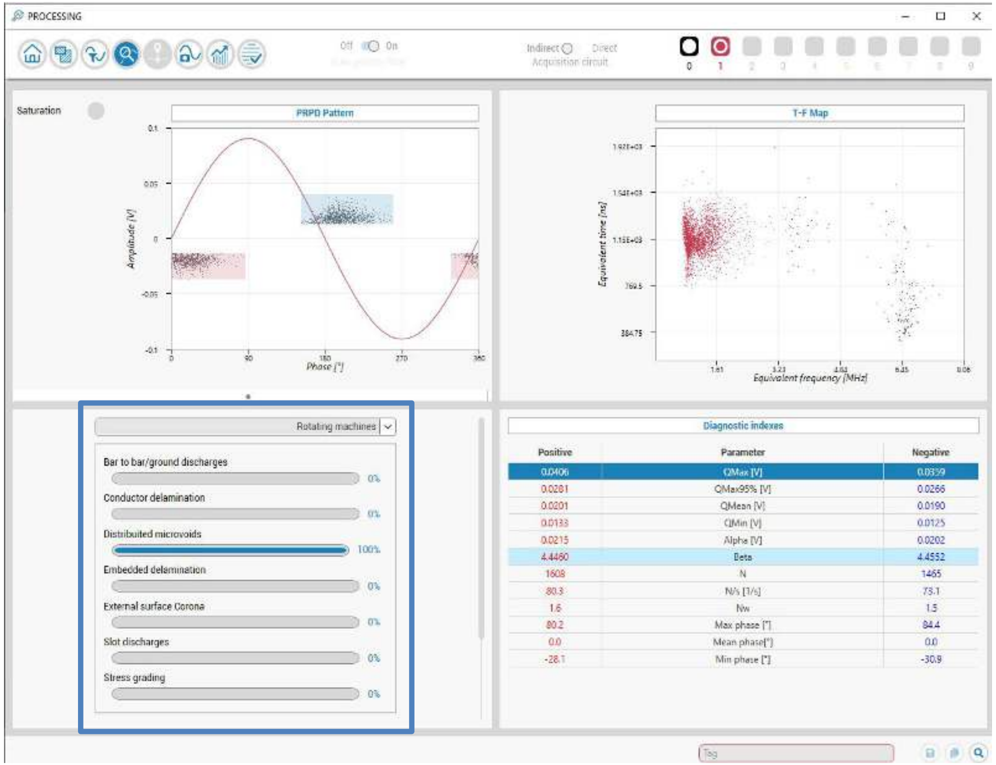


PD Analysis

Phenomena identification

- The data acquired properly
- Noise removed
- PD phenomena are separated

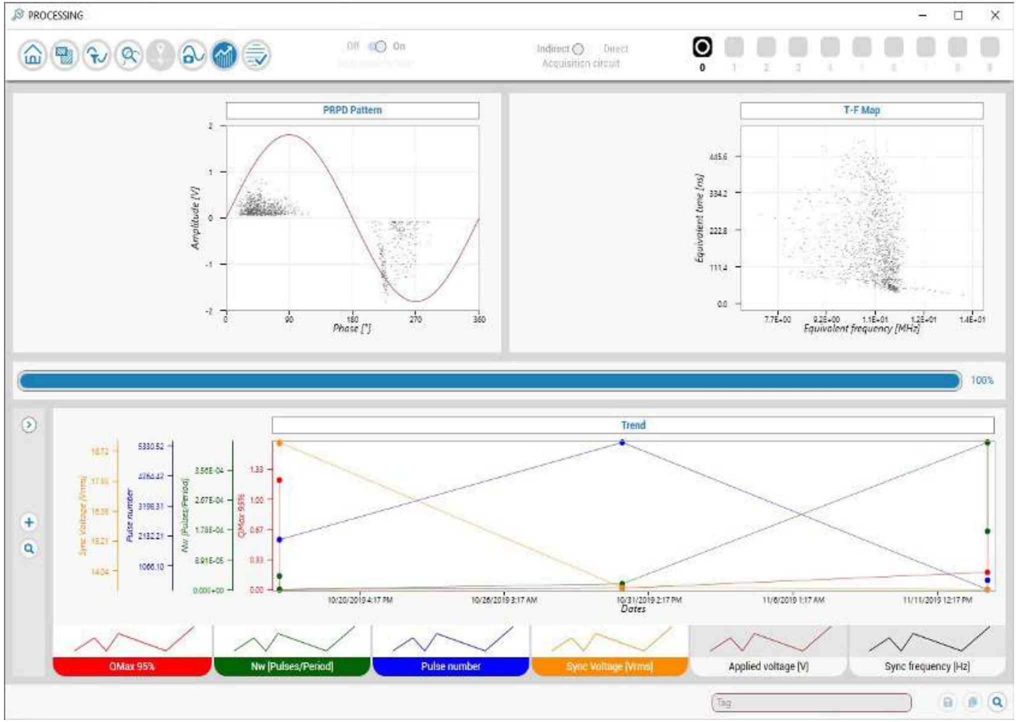
The identification of the PD can take place: manual PRPD pattern analysis and PD Pro identification tool.



PD Analysis

Trending

Amplitude and repetition rate are markers of the PD evolution: we can have PD lasting for years at the same levels or quickly evolving in amplitude and rep rate



PD Sensors for Rotating Machines

- ❑ How to detect the signal
- ❑ Sensors typologies
- ❑ Sensors requirements
- ❑ Sensors positioning
- ❑ Signals & Safety

PD Sensors for Rotating Machines

How to detect the signal

Localized insulation defects generate PD signals when subjected to electrical stress: the phenomena is a source of high frequency electromagnetic signals & irradiated signals.

The conducted signal path can be force into a sensor and measured while the irradiated signal is subjected to generator design those can attenuate & affect the sensitivity.

Different sensors:

- *Different PD output*
- *Sensitivity*
- *Sync signal*

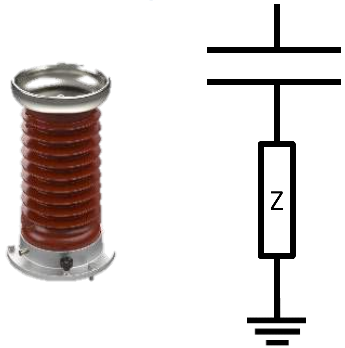
PD Sensors for Rotating Machines

Sensors Typology

The most popular sensors are capacitive couplers, connected to the machine windings, the PD signal is then measured:

1. As voltage drop cross and impedance;
2. By current transformers;
3. Slot sensors are used as well: installed close to windings to capture irradiated PD signal.

1



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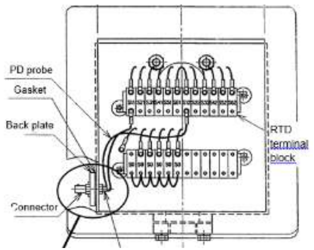


PD Sensors for Rotating Machines

Sensors Typology

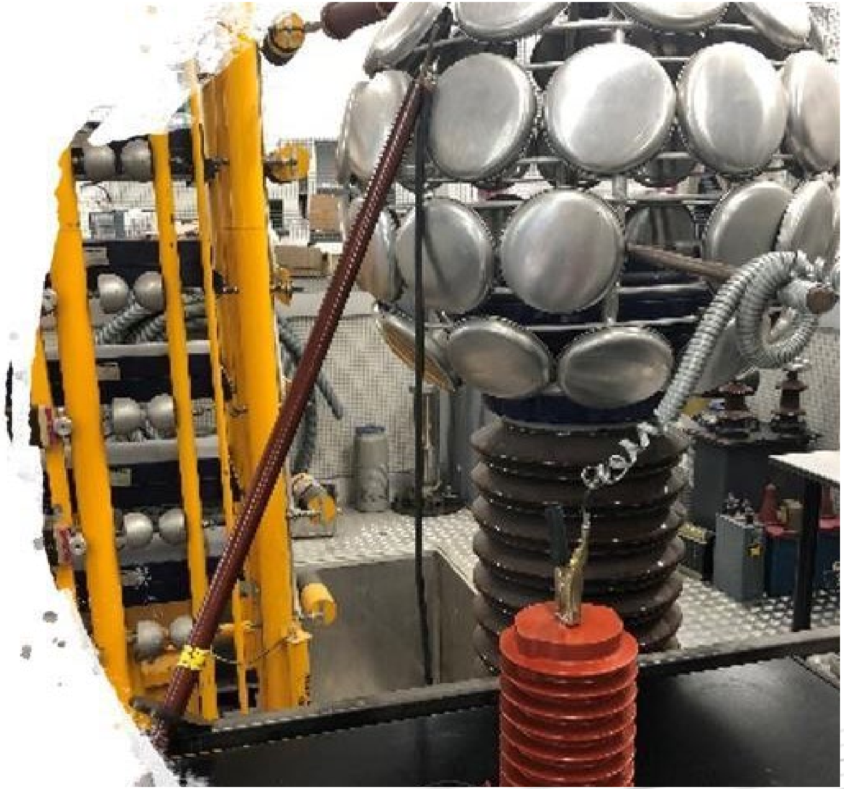
	Capacitive	Capacitive + HFCT	Antennas
Sensitivity	High	Poor	Very high locally
Installation	Medium Effort	Medium Effort	High effort
Safety	Medium	Very high	High
Synch signal	YES	NO	NO
Coupling principle	Conducted signal	Inducted signal	Radiated signal

PD Sensors for Rotating Machines

Sensors Requirements

Permanent PD sensor will be installed to HV rotating machine, the first requirement is to avoid any failure risk for the equipment under monitoring:

- ❑ Stressful type testing (impulsive test, thermal, long run HVAC);
- ❑ Each sensor subjected to 3x rated voltage withstand test;
- ❑ Each sensor PD free @rated voltage after pres-stress session;
- ❑ Capacitance and voltage ratio tested with small tolerance values.



PD Sensors for Rotating Machines

PD COUPLERS 7KV 1000pF THREE-PHASE KIT

Ideal solution for 6.6 kV motors, limited room required for the installation, light sensor, the permanent installation kit comes with the derivation box (ip 68 selectable), signal cables and HV connection kit.

PD COUPLERS 12/17/24KV 1000pF THREE-PHASE KIT

3 different voltage classes 12kV, 17,5 and 24kV. The voltage classes are influenced by the creepage distances required for the different classes, sensors dimensions depend on such distance

PD Sensors for Rotating Machines

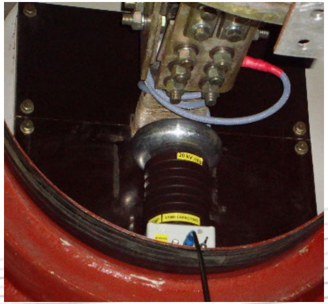
Sensors Positioning

PD sensors are installed in hazard zones and the risk of failures shall be minimal.

- Metallic parts shall be nonmagnetic;
- The PD sensor system shall not reduce the insulation capabilities of the stator;
- Temperature and vibration stress to be considered;
- Avoid Corona & surface PD.







PD Sensors for Rotating Machines

Signal & Safety

Coaxial cables are used to bring the signal to the derivation box.

Derivation box is required not just to get PD & sync signal from sensors but enhances the safety of the whole system by adding a passive safety on the derivation box side.

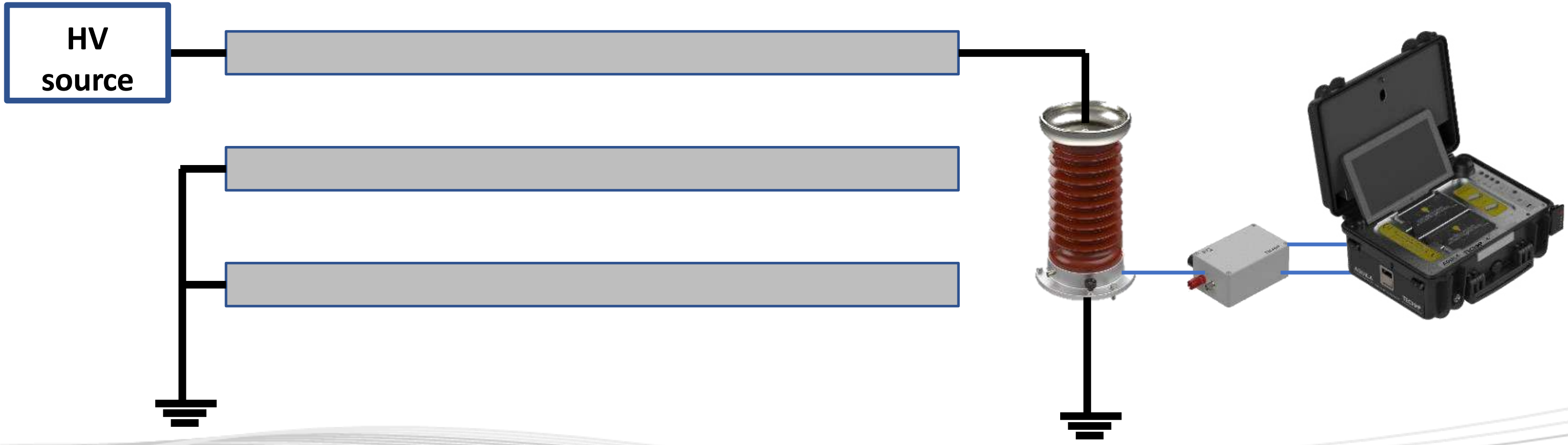
On-line vs Off-line

- PD offline test
- PD online test
- Technical comparison
- Practical comparison

On-line vs Off-line

Off-line PD test

Off-line PD test refers to a PD measurement performed during machine outages with external voltage source, the PD sensor can be temporary installed and removed after the test.



On-line vs Off-line

Off-line PD test

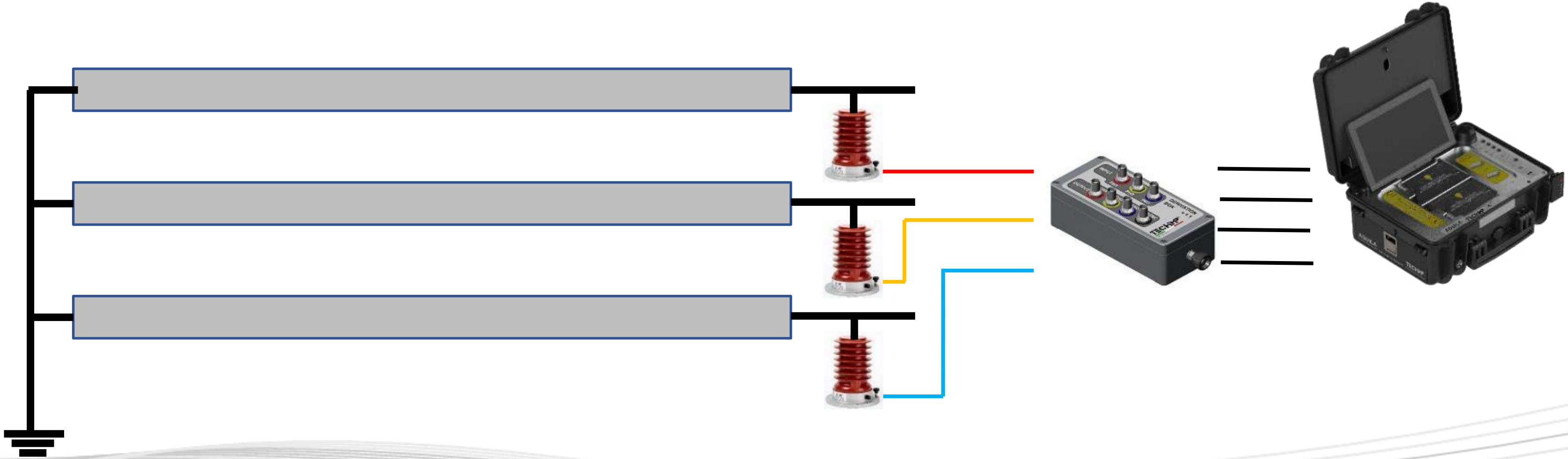
In the offline PD test we have to take into account few technical aspects:

- Phase to ground only, constant along the winding;
- Motionless, no temperature change occurs during the test;
- Steady, the test is not taking into account mechanical behavior;
- Phase by phase test;
- The voltage source shall be free of PD signals;
- PDIV & PDEV evaluation;
- Insulation overstress.

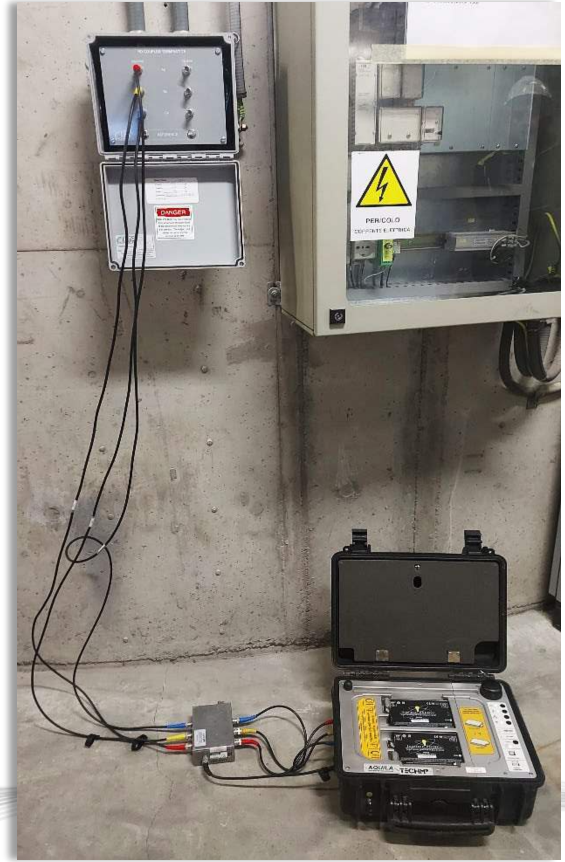
On-line vs Off-line

Online PD test

Online PD test is performed with running machine in load conditions, permanent sensor are required, it is also possible to temporary install the PD sensors by taking strict precautions and planning an outage.



On-line vs Off-line



Online PD test

In the online PD test we have to take into account few technical aspects:

- Routine stress;
- Different load and different temperature;
- Crosstalk effects;
- External disturbances;
- 3 phase simultaneous phase;
- Permanent sensors;
- Safe test.

On-line vs Off-line

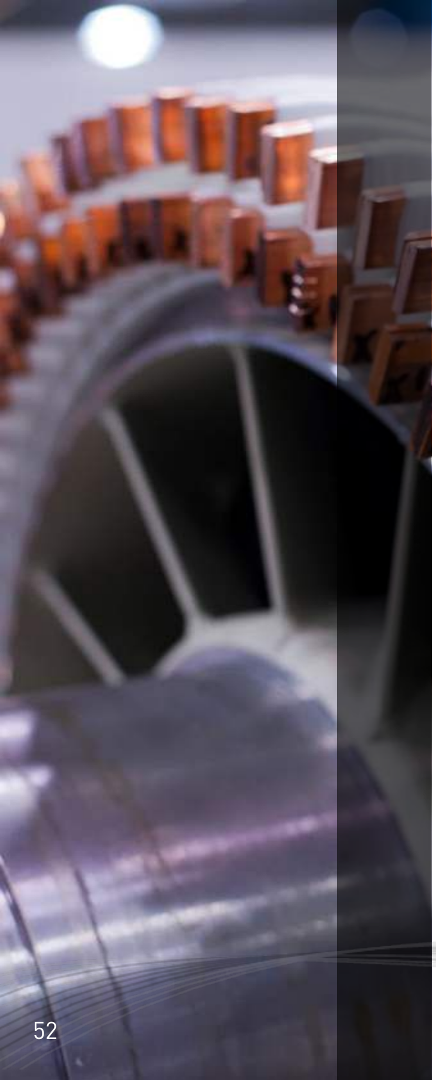
Technical Comparison

	Offline	Online
Permanent sensor required	NO	YES
Crosstalk effect	NO	YES
Real electrical stress	NO	YES
Correlation of historic data	Depending on sensor and acquisition unit	Same sensors Depending on acquisition unit
TEAM stress	NO	YES

On-line vs Off-line

Practical Comparison

	Offline	On line
Price	High	Low
Customer effort	High	Low
Outage required	YES	NO
PD Sensor	Brought by service company	Sensors compatibility
Safety	Potential hazards	Safe test
Stress	Different voltage levels applied	Electrical Temperature – Load changes
Material Required	HV source, sensor PD acq unit	PD acq unit

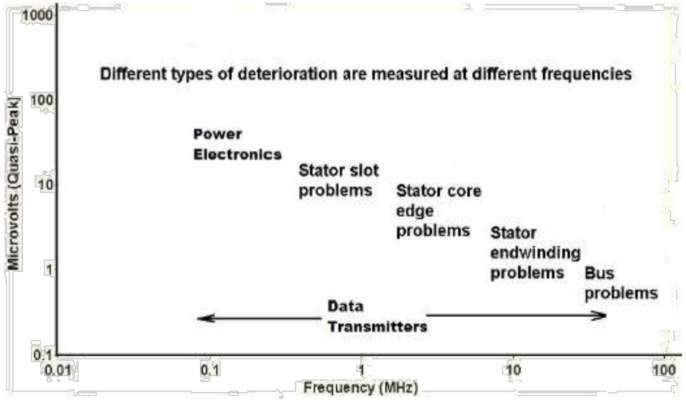


ELECTRO-MAGNETIC INTERFERENCE (EMI) TESTING

EMI Testing

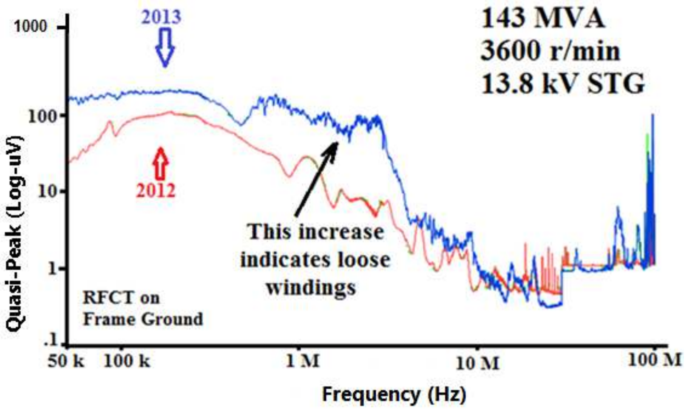
EMI is a frequency domain analysis from 50kHz up to 100 MHz able to collect electromagnetic signals produced by the EUT and the external environment.

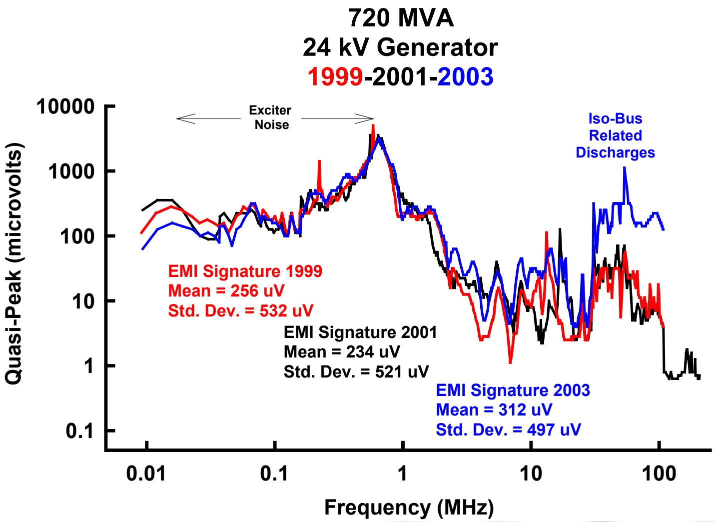
Target	*Stator windings* *Exciter system* *Wedges*
Sensors	*Doble Spark; Doble PDS200*
Regulations	*CISPR-16*



EMI Testing

Each type of defects, including PD impulses or arcing, produces an EMI signature and pattern that is unique and depends also on its location in the EUT.





EMI Testing

Over 65 different electrical and mechanical conditions have been identified and verified.

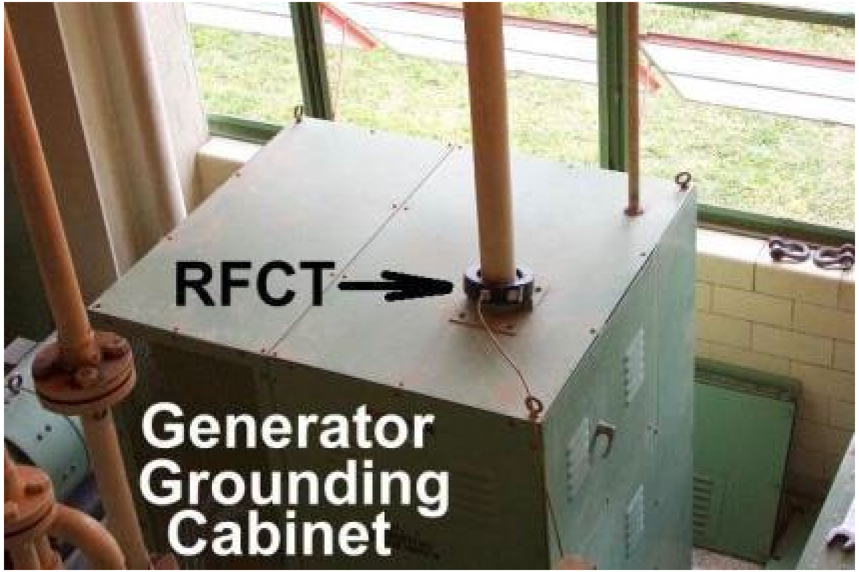
Generators	Motors	Iso-Phase Bus
Stator bar slot discharges	Stator coil partial discharges	Loose or broken support insulators
Stator slot side-packing erosion	Deterioration in slots & ends	Loose or corroded hardware
Stator bar stress grading system deterioration	Defective bolted or crimped stator lead connections	Defective insulation
Loose stator wedging	Shaft oil seal rub	Stray circulating currents
Loose end winding ties	Broken induction motor rotor bars	Foreign material or objects inside bus
Blocking and circuit rings	Bearing problems	Defective bus PT connections
Loose or broken stator sub-conductors	Misalignment	Open PT high-voltage fuses
Winding contamination	Winding contamination	Contaminated insulators
Exciter issues		

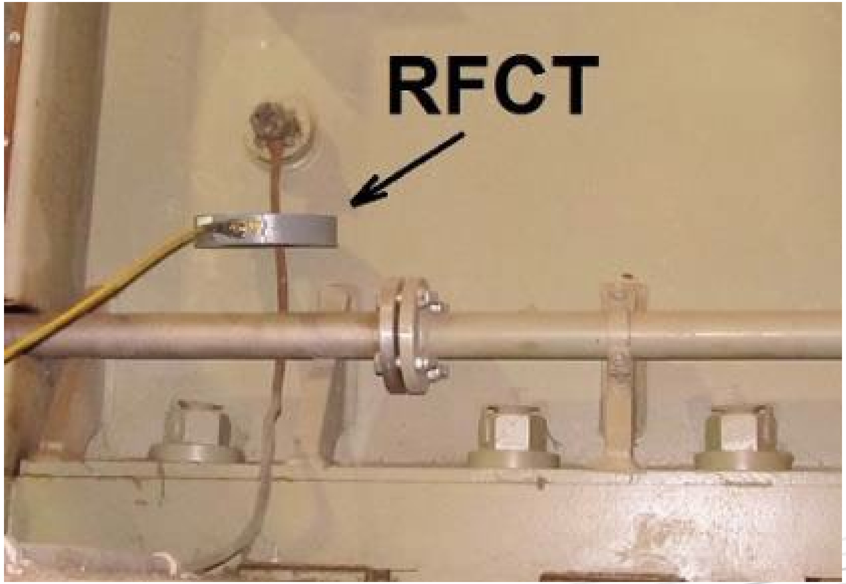
EMI Testing

- Where the HFCT is placed depends on the electrical apparatus under investigation.
- A safe low voltage or earthed location is selected for data collection.
- There is never a connection to a “HOT” circuit.
- Never an arc flash concern.
- No interference with normal operations to collect data.
- No signal of any kind is injected into the system.

EMI Testing

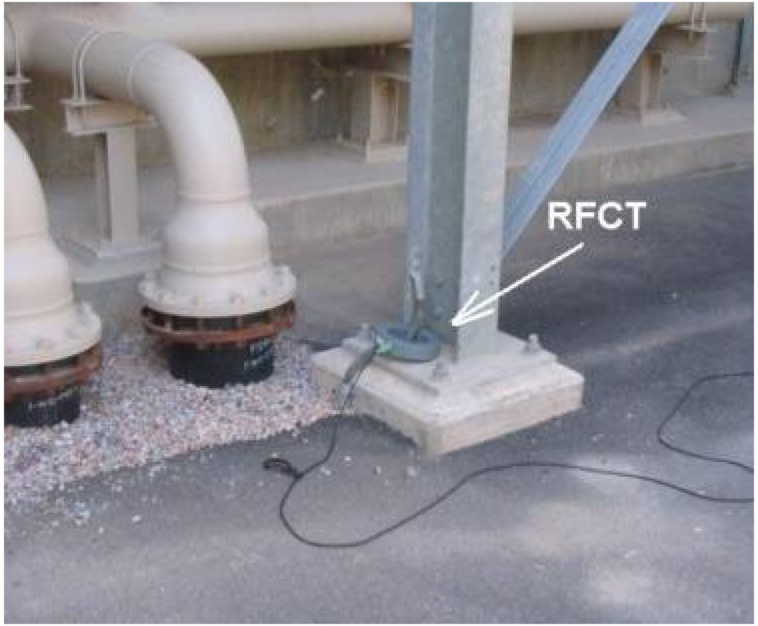
A generator neutral is the preferred HFCT location to collect EMI data. A safety ground can also be used.





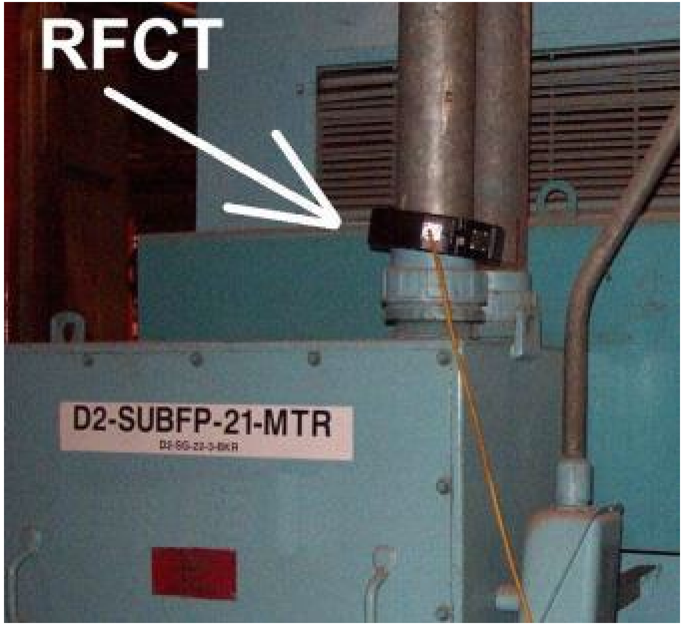
EMI Testing

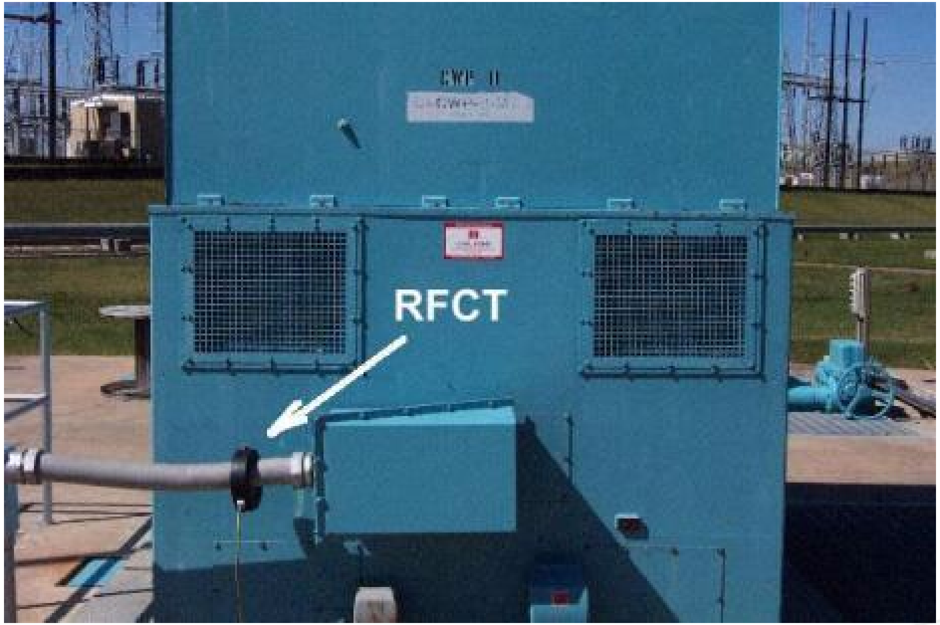
HFCT on a Bus ground near the generator



EMI Testing

The preferred data collection for motors is on the power conduit.

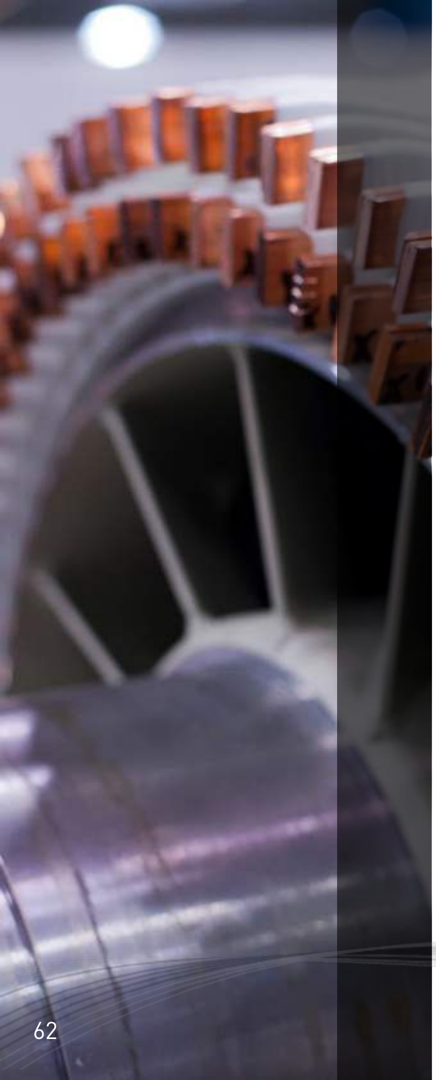




Case Studies

PD TESTING

Case Study #1



PD - Case Study #1

30 MVA (14,7 kV) Synchronous Generator

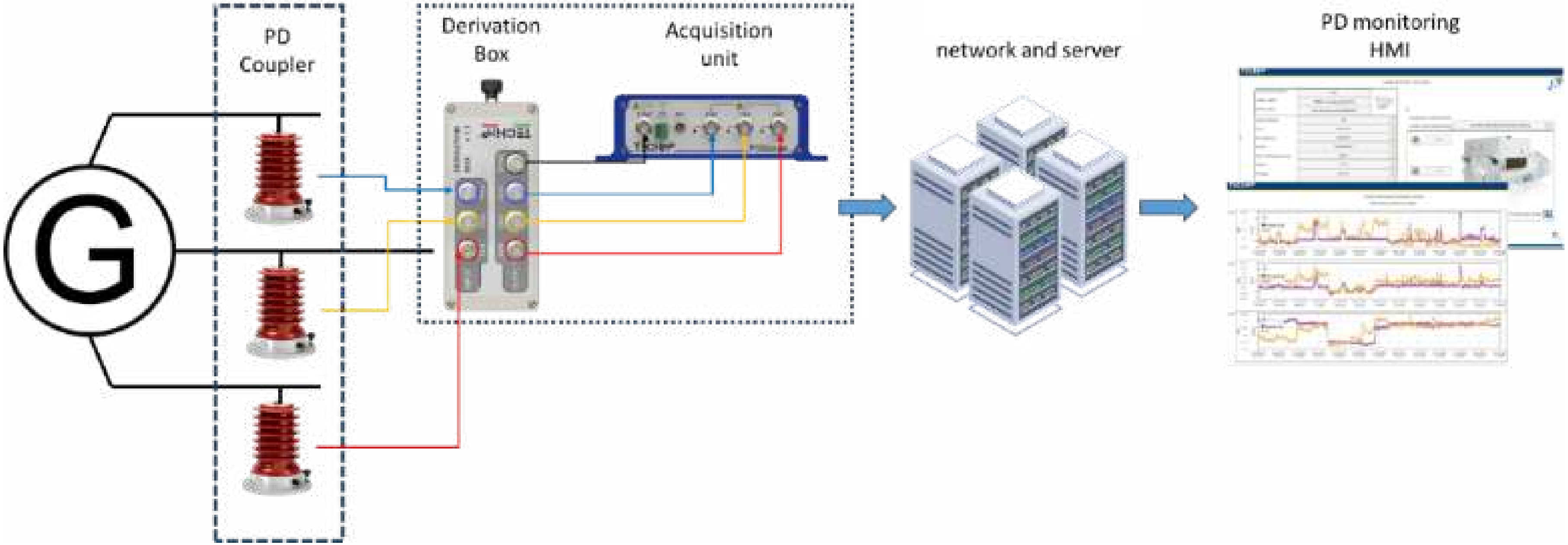
Installed in a co-generation plant and fed by a turbine.

The generator was manufactured in 2009 and has been running on daily cycles since then.

A spot PD measurement in 2017 highlighted some bar-to-ground and some stress-grading PD activities in all three phases.

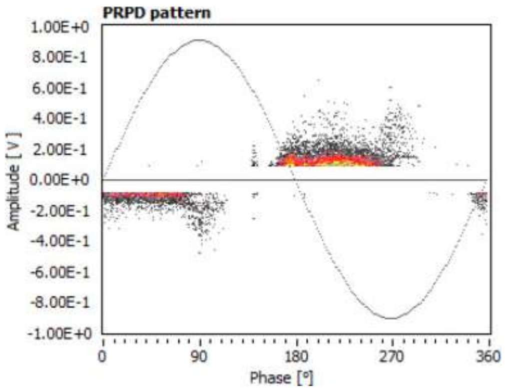
A maintenance action was carried out to remove the bar-to-ground activity and in parallel, an on-line PD monitoring system was installed to keep track of the stress grading.

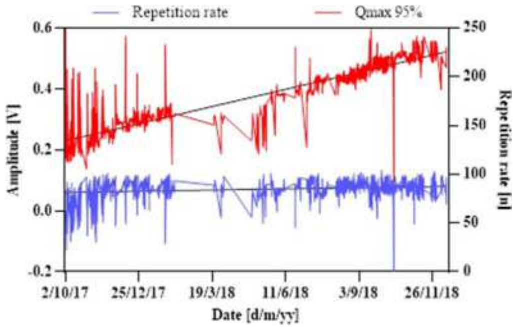
PD - Case Study #2



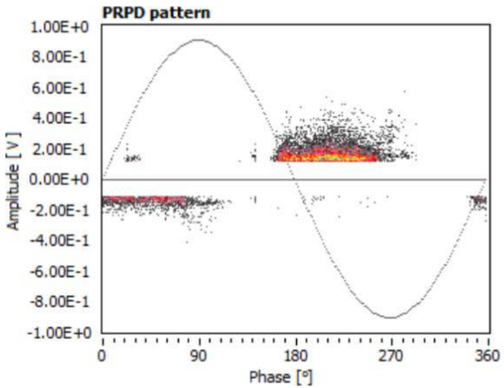
PD - Case Study #1

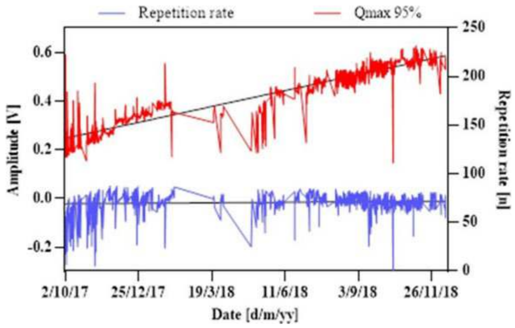
Phase R



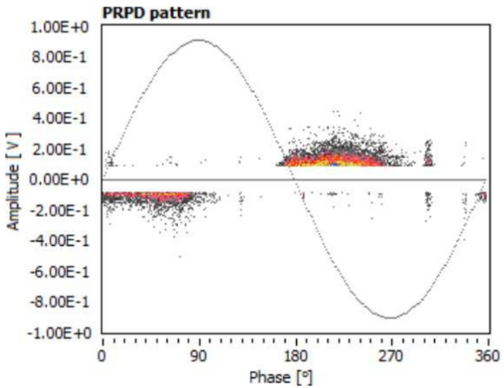


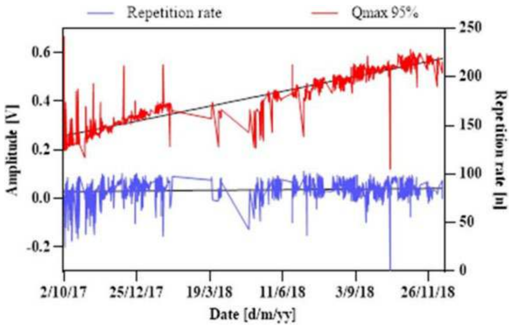
Phase S





Phase T





PD - Case Study #1

From the initial PD measurement, a maintenance session has been performed, swapping the terminations (neutrals to HV) to re-distribute the voltage stresses along the windings.

This action reduced the amplitude of the Stress-Grading PD by a significant level (from 600 mV to 250 mV) which proved to be the correct move, since the following monitoring year showed an increase in amplitude of about 80-100%.

PD - Case Study #1

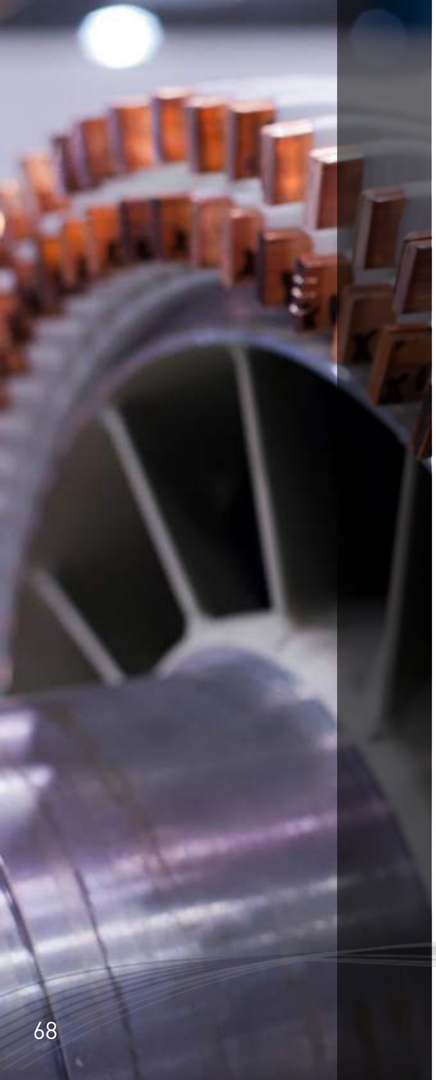
Without the measurement taken by the PDMS and the subsequent analysis, the pre-maintenance stress grading would have doubled its amplitude, most probably resulting in the failure of the machine.

The presence of the PDMS effectively prolonged the working life of the asset of about one-year, postponing by such time any invasive component replacement on the asset.

PD TESTING

Case Study #2

PD - Case Study #2



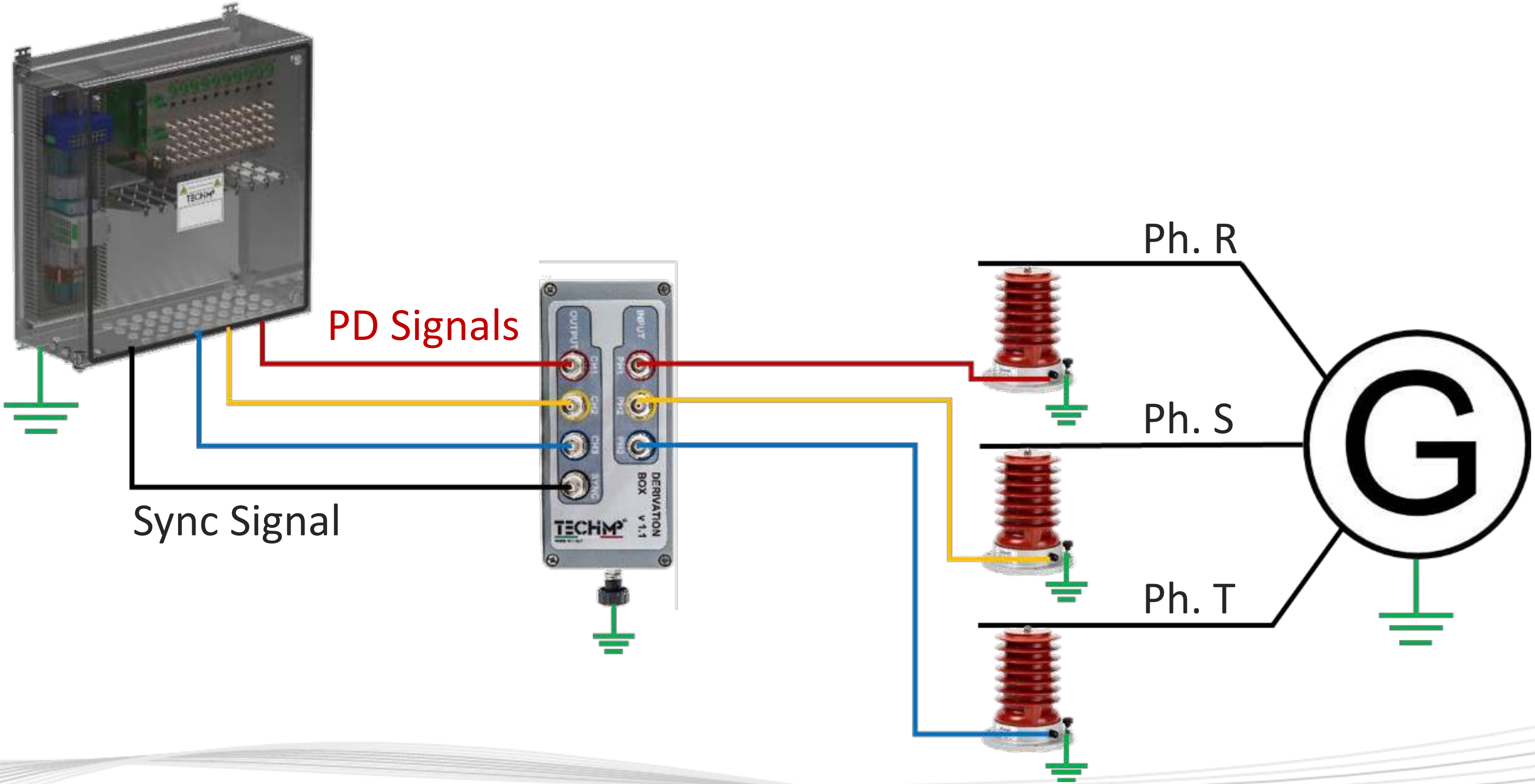
Fleet of Synchronous and Asynchronous MV Motors

Installed in an air-separation facility.

The already present PDMS with 80 pF Capacitive Couplers was unable to detect dangerous PD Phenomena due to the presence of numerous disturbances and cross-talk.

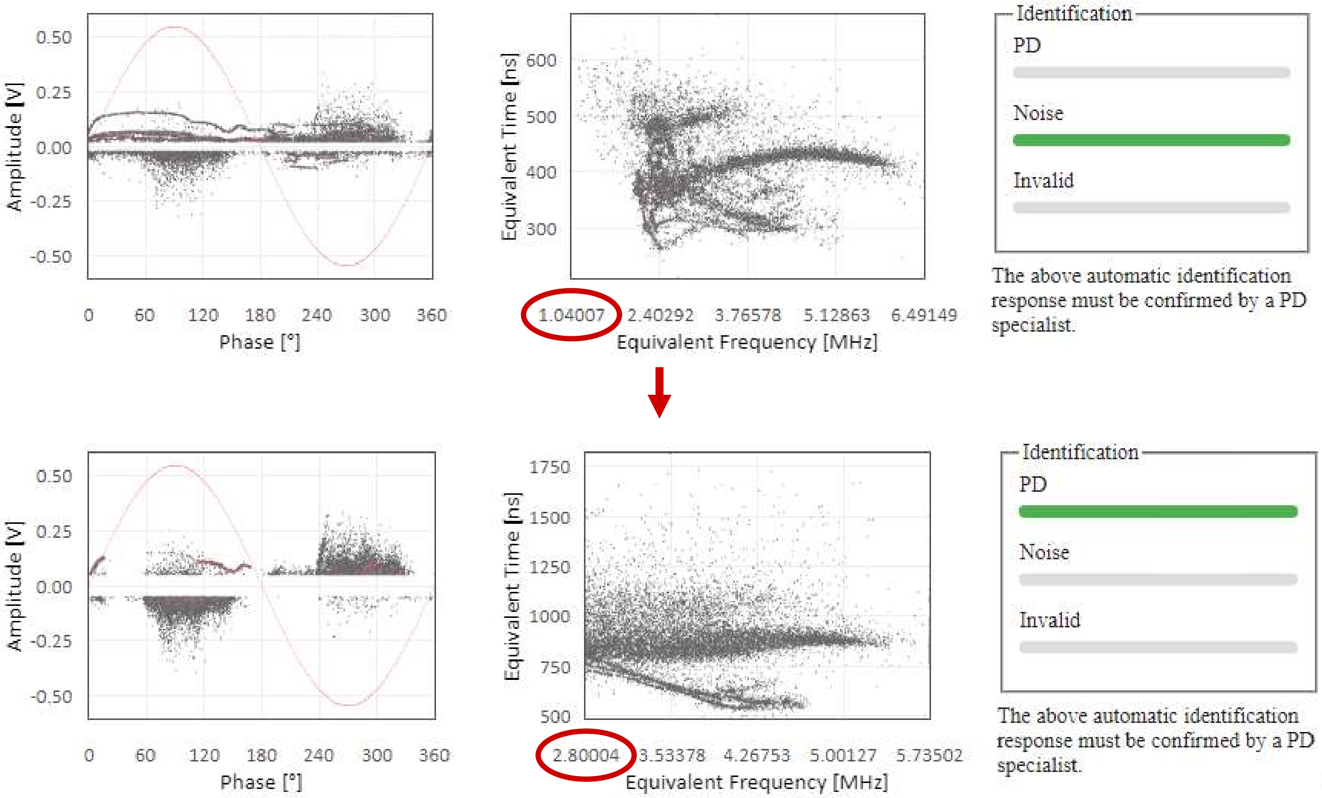
Techimp UWB (16 kHz – 30 MHz) PDMS has been installed in its place, employing 1,2 nF Capacitive Couplers with a lower cutoff frequency (≈ 3 MHz).

PD - Case Study #1



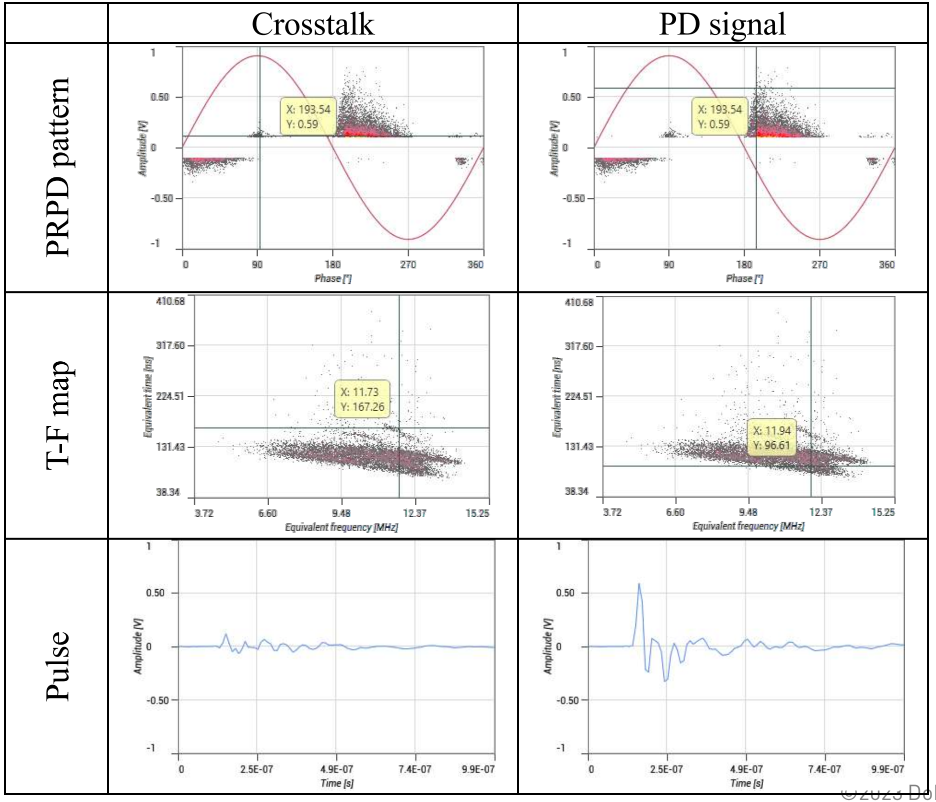
PD - Case Study #2

Through the use of Techimp T-F Map, it was possible to implement **Noise Rejection**...



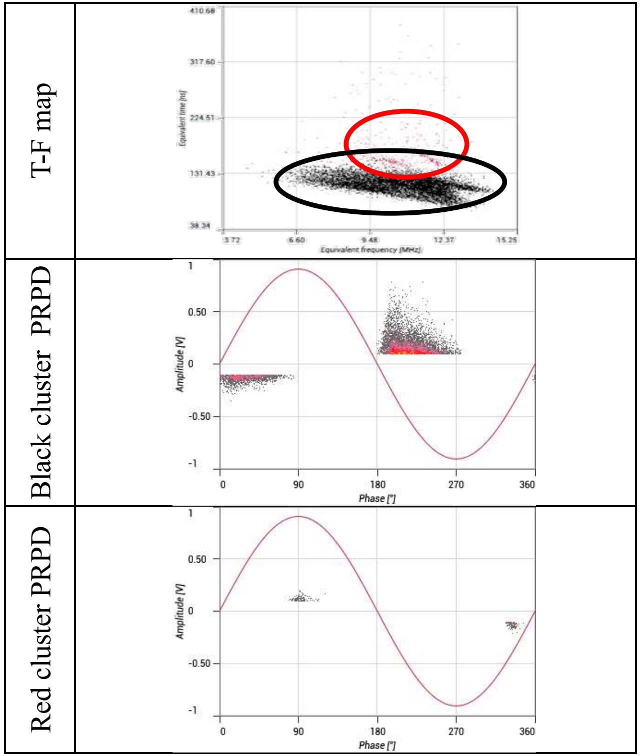
PD - Case Study #2

and **Phenomena Separation**.



PD - Case Study #2

and **Phenomena Separation**.



PD - Case Study #2

During a visual inspection of the stator windings in the workshop, the phenomena of PD activity in the motor could be observed by the presence of the typical white powder as a result of the erosion due to PD activity.

PD - Case Study #2

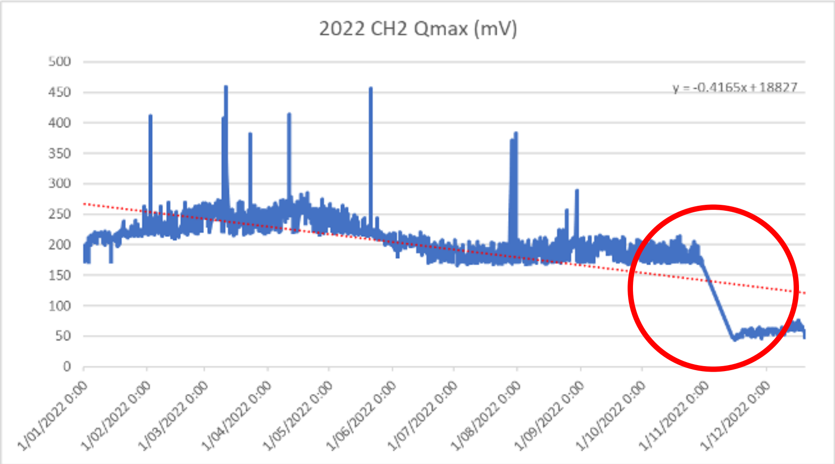
When the test voltage was applied for the electrical tests, sparks could be observed in the area of the end windings.

PD - Case Study #2

The motor was cleaned and the PD damage was repaired.

As an additional measure, the neutral connection of the motor was reversed so the stressed winding part is now subject to lower voltage gradients.

The effect of this action, which had a significant effect on the lifetime of the motor, can be noticed in the amplitude of the phenomena trended by the PDMS:



EMI TESTING

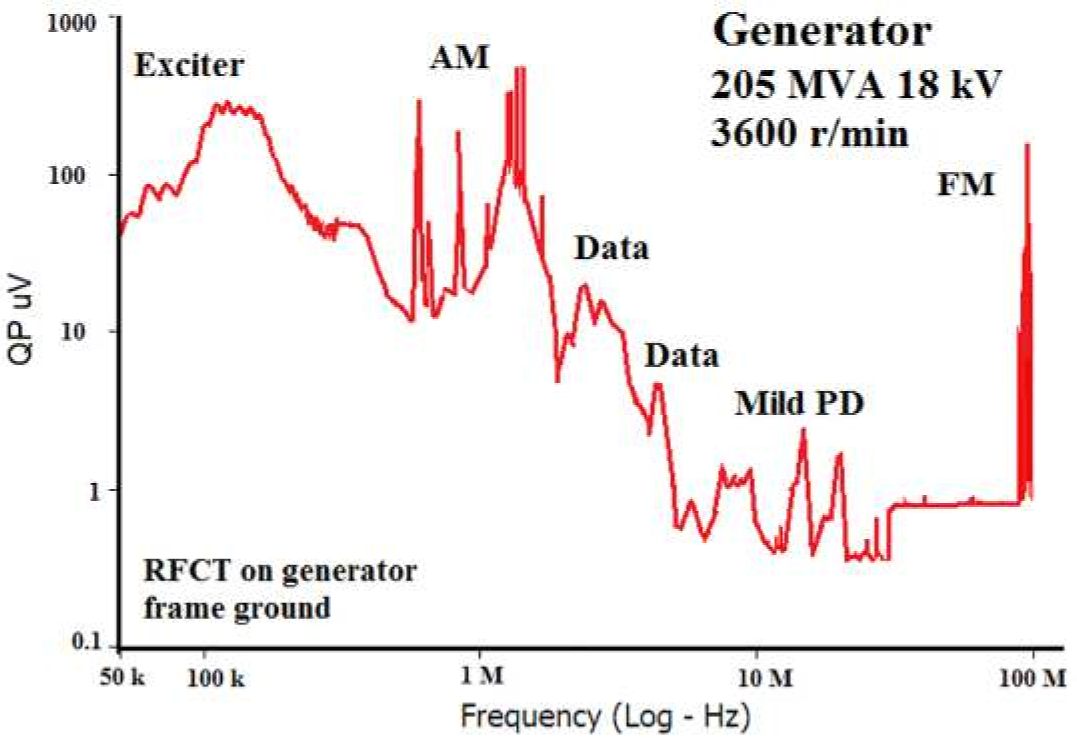
Case Study #1

EMI - Case Study #1

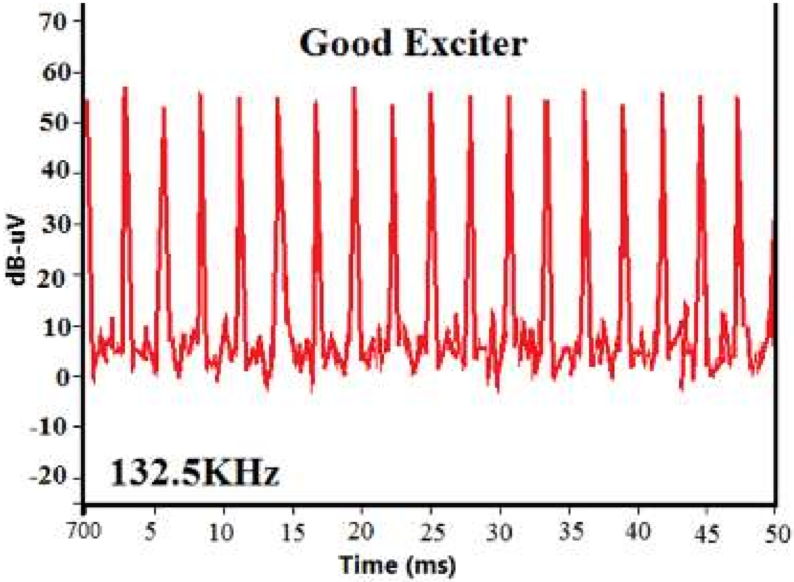
EMI also identifies problems in exciters

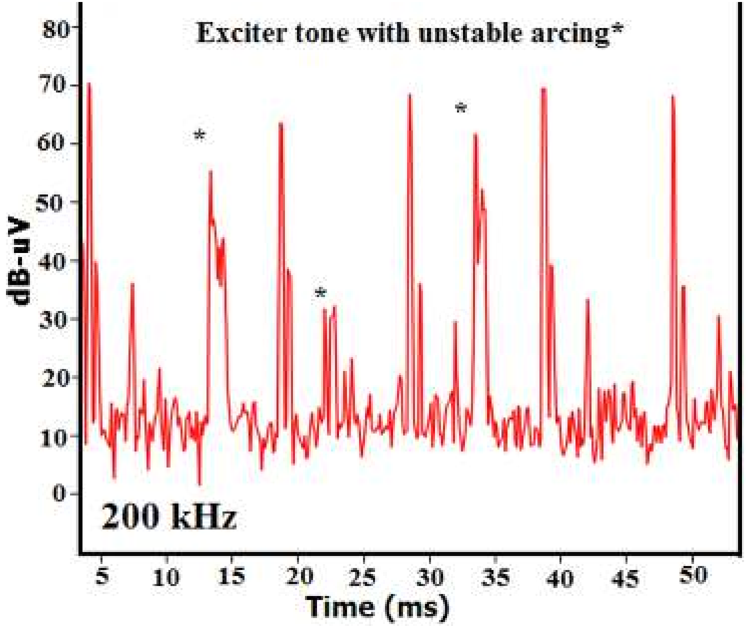
Exciter tone levels were very high with this generator

Arcing also present.



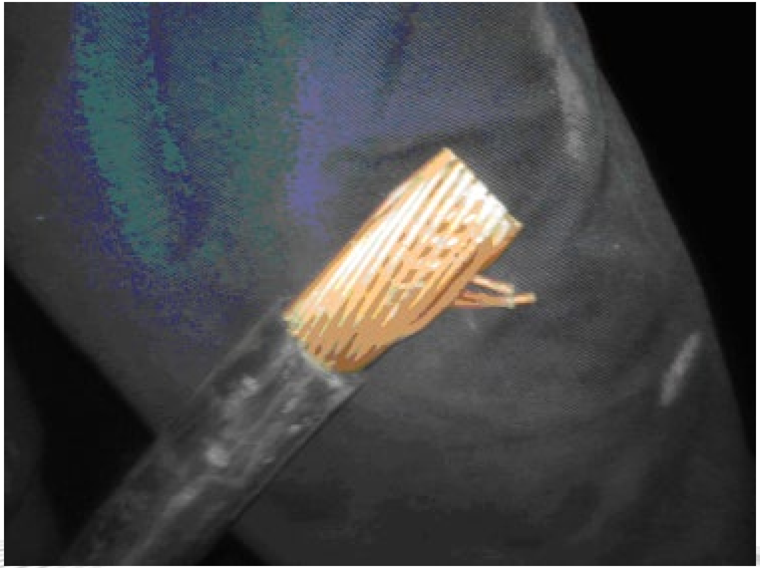
EMI - Case Study #1





EMI - Case Study #1

One of the four static exciter cables had a loose connection

Good end	Loose end
	

Thank you for your time!

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Let’s build the future of energy in Milan