Dr. Bernhard Fruth – Maser & Quartzelec

Condition Monitoring of HV Partial Discharge


quartz
tec

CONDITION MONITORING
OF ROTATING MACHINES

AEMT 2015

Quartzelec Group

quartz elec
Electrical Engineering Services

- + 600 employees
- £ 60m sales
- ISO9001:2008
- 8 UK locations
- Abu Dhabi
- Malaysia
- 24/7 Support

quartz coil
Coil Manufacture

Rugby Facility for Coil Design & Manufacture

quartz teq

Swiss Facility for R&D & Manufacture of Test & Diagnostic Tooling

TS metals
Welding and Fabrications

Rugby Facility for Core & Armature Frames

MASER & quartz elec

Malaysian JV for Asian Operations

A leading independent electrical engineering group with a UK and Overseas presence

What is LIFEVIEW ?

- Trade Mark of Quartzteq
- Condition and Monitoring devices for electrical rotating machines
- Online Monitoring
  Permanent Monitoring
  Machine in operation
- Offline Monitoring
  Periodic Inspection
  Machine stopped

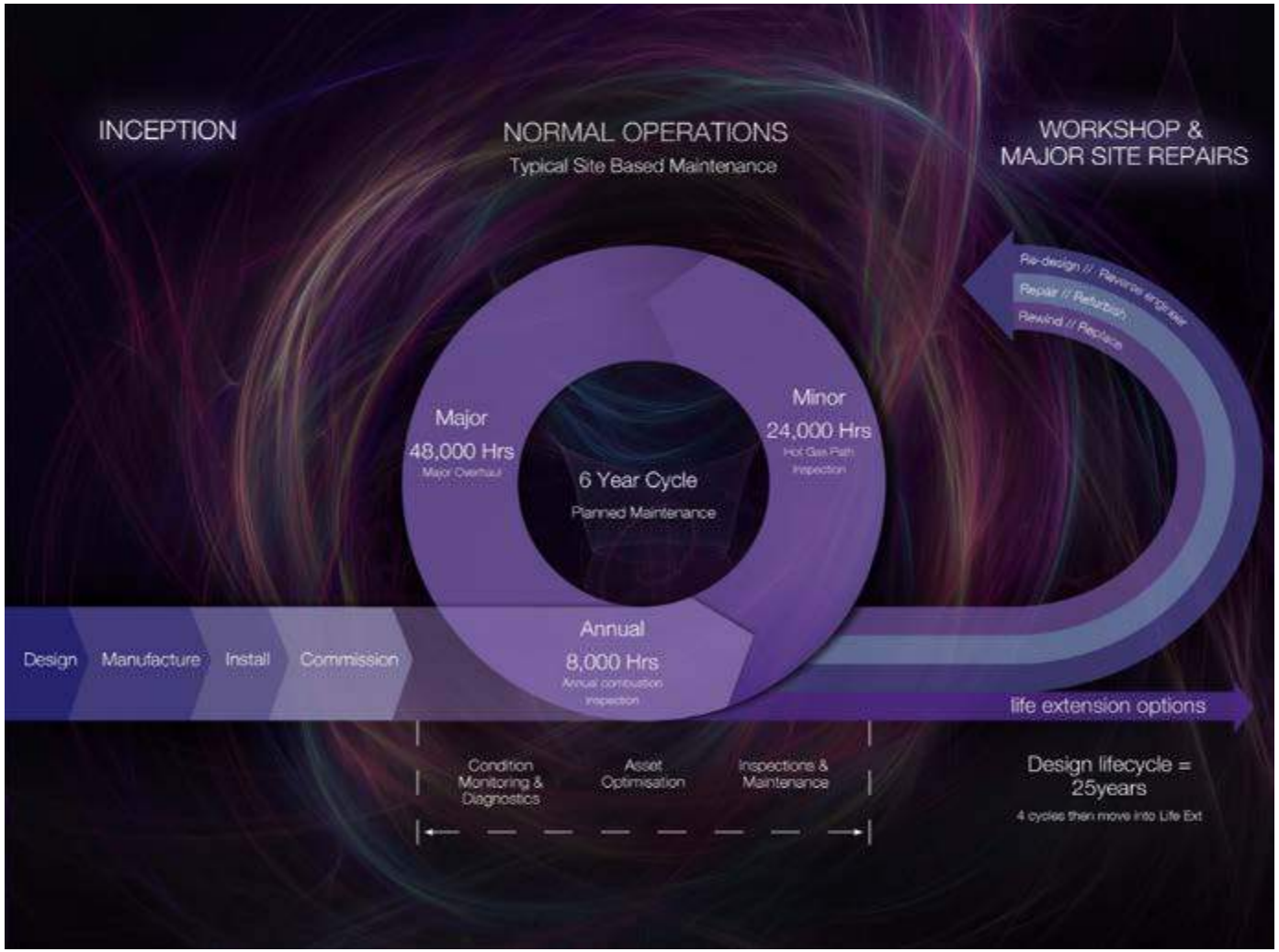
Rotating Plant – Core Competencies

Motors, Generators, Pumps, (Turbines)

Design & machines engineering
Repair, rewind & refurbishment
Installation & commissioning
Site service, ships, platforms
Major overhauls
Maintenance, long-term service agreements **(LTSA's)**
Diagnostics & life assessment testing
New equipment & spares supply
Excitation, AVR, Protection & Control
Bars, Coils, Components
Consulting, Owner's Engineer

Full Life Cycle Support

- Normal Operational & Routine Inspections
- Diagnostics
- Major Repair & Refurbishments



Is your rotating plant in good health?

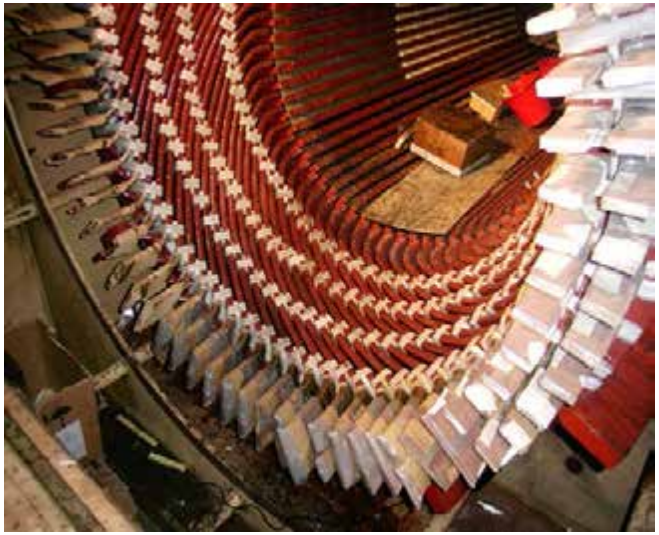
Wear and tear on your machine is inevitable – affected through electrical and mechanical stresses as well as the environment In which it operates.

How can you tell what is going on inside your machine?

When will your machine deliver substandard performance?

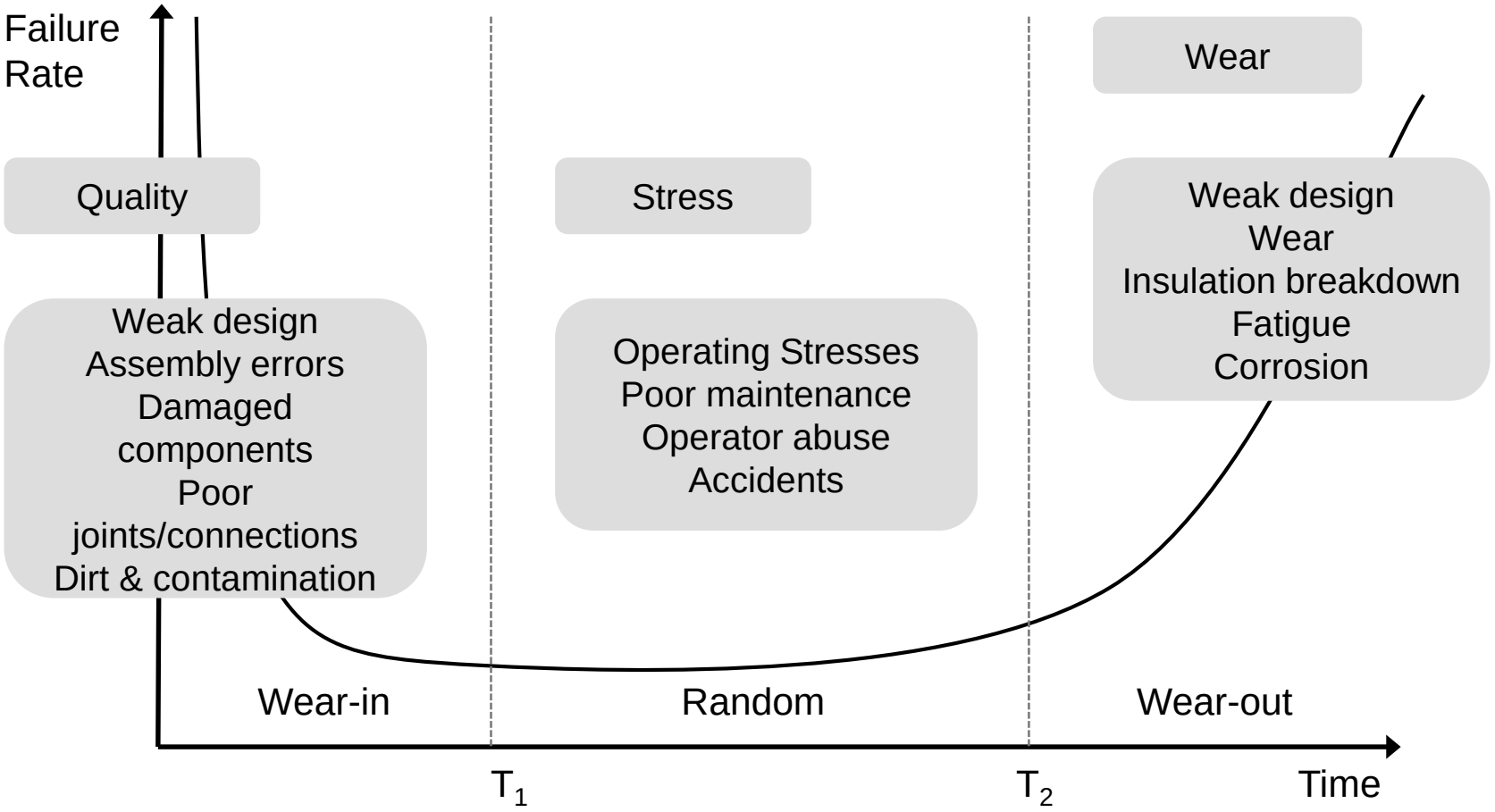
When will it fail?

Why Monitoring: **LIFE**VIEW™



Condition Based Maintenance
Maintenance on Demand

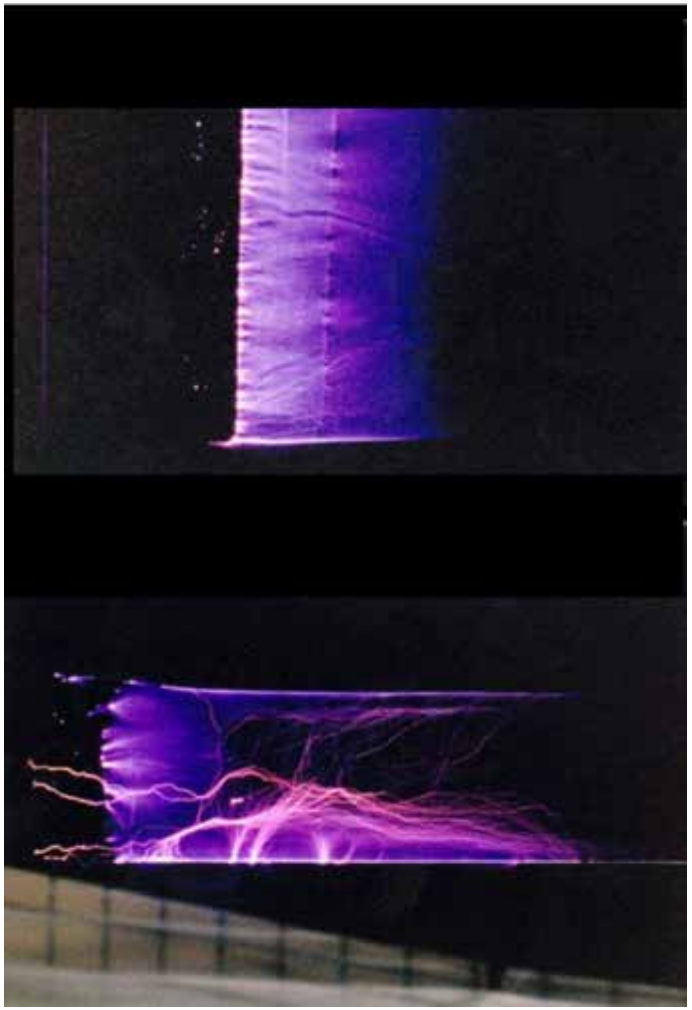
Monitoring vs. Periodic Testing



Why **LIFE**VIEW™

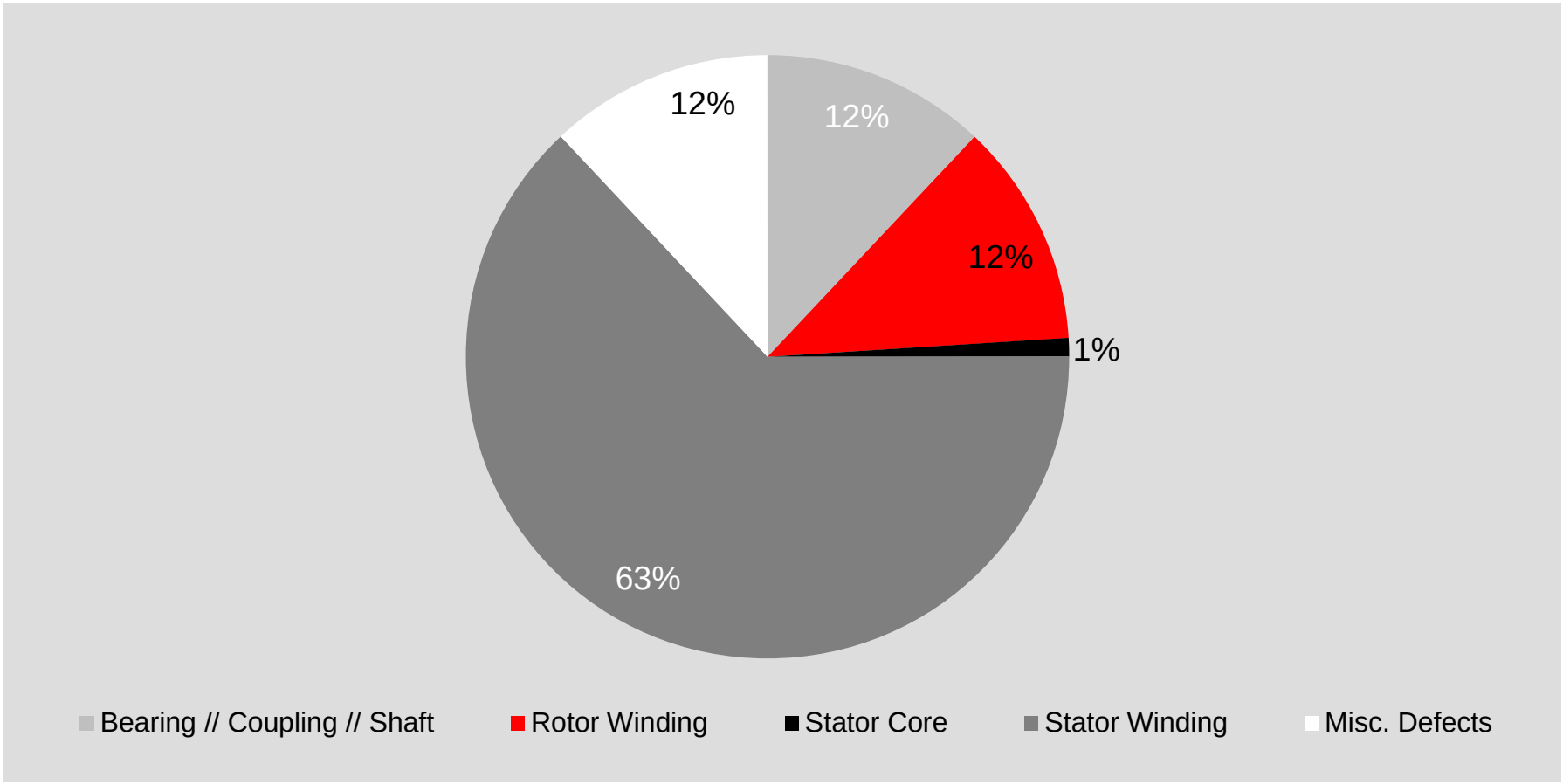
provides continuous information for efficient and safe operation of power generators and motors, allowing you to:

- Take immediate remedial action
- Prevent catastrophic failure
- Plan for outage
- Minimise lost production
- Postpone expensive maintenance
- Plan for investment effectively
- Manage risk for warranty and insurance: predictability
- Enjoy pinpointed, condition based repair and maintenance.



Motor Failure Statistics

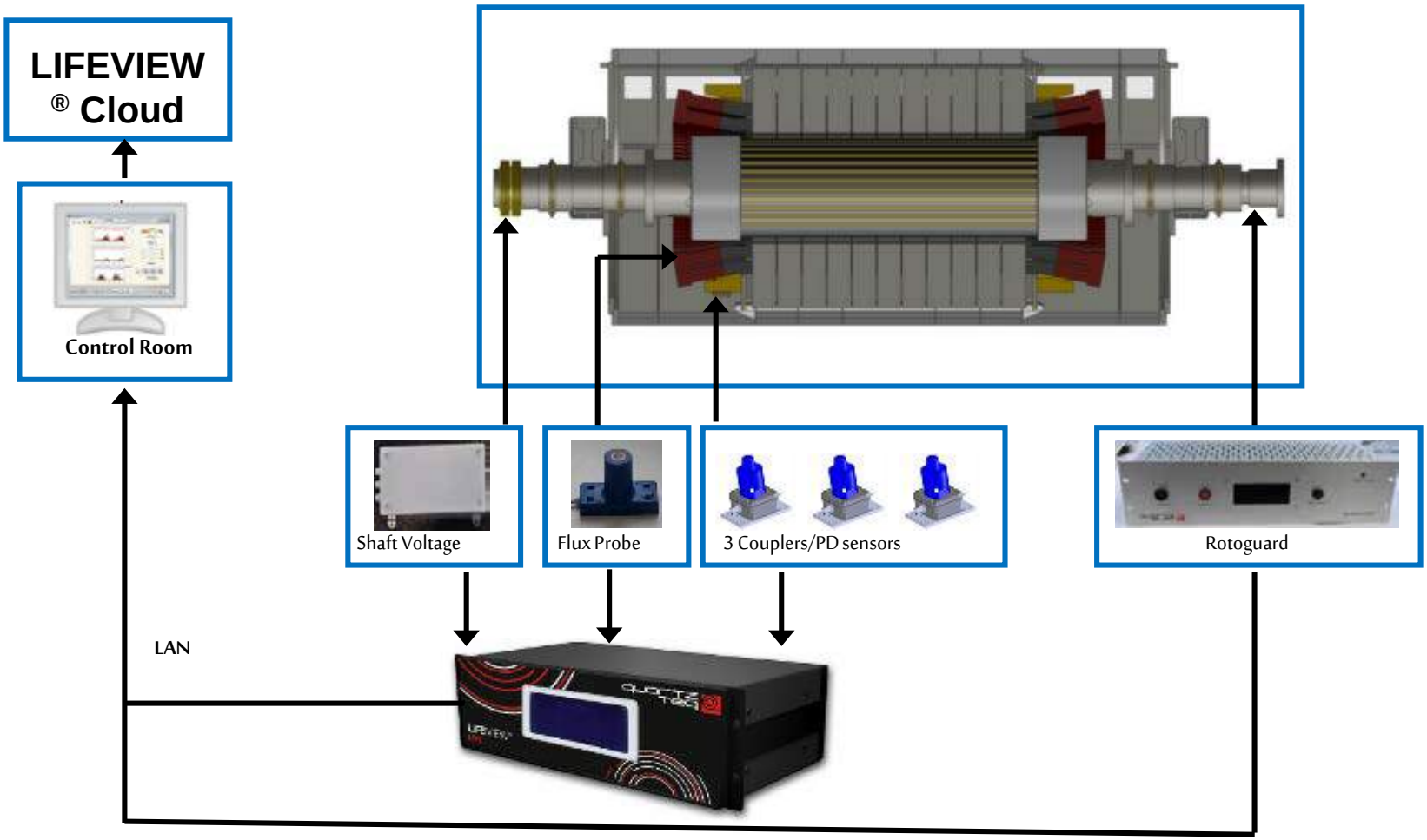
Source: Allianz Insurance, Germany (1996-1999), VDE Colloquium, June 28, 2001



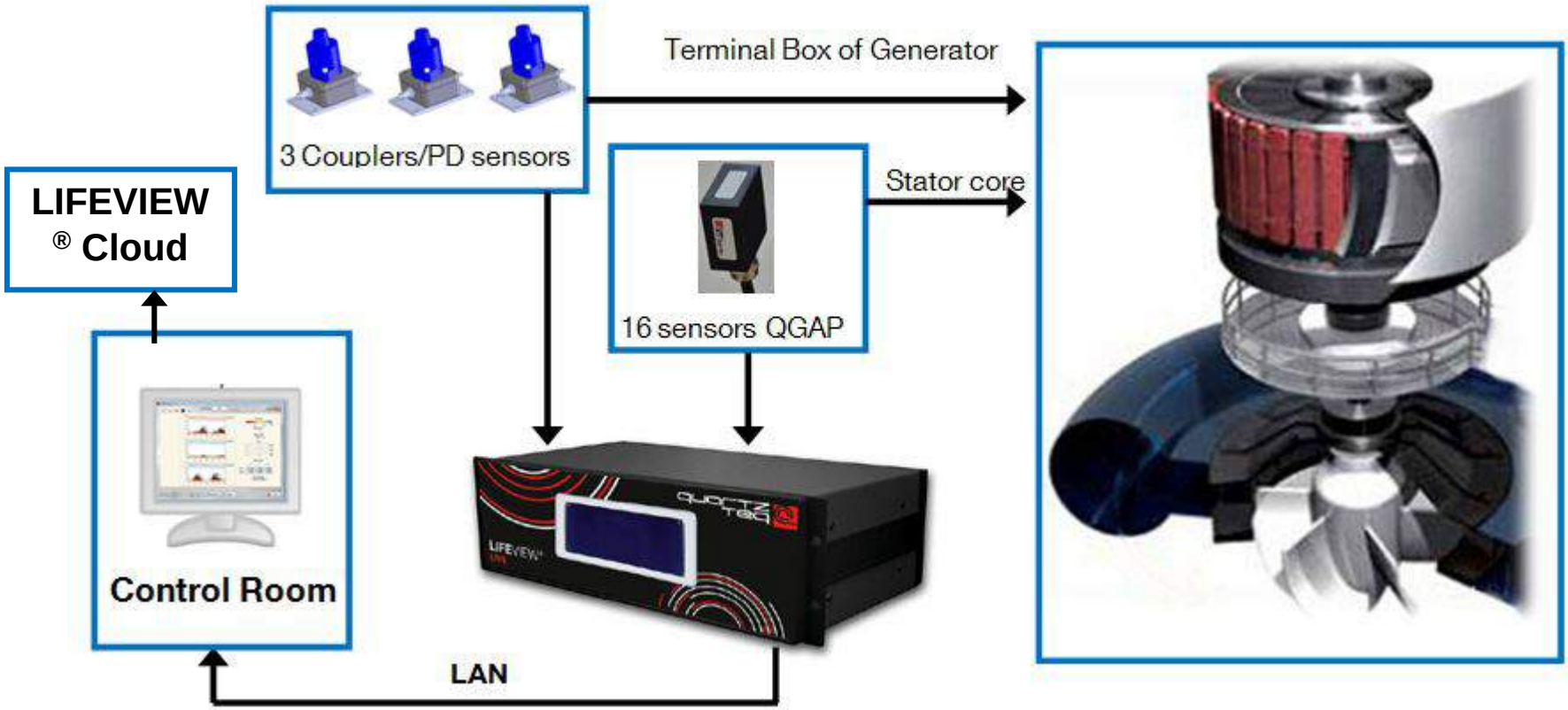
Monitoring/Electrical System/Main Components

- Partial discharge, insulation condition monitoring
- Rotor (flux) monitoring and protection (winding faults, temperature etc.)
- Shaft voltages and currents (bearing protection, rotor faults).
- Air gap and magnetic pull monitoring (typically for multi-pole machines)
- Ozone and gas monitoring (overheating, discharge activity)
- Winding vibration (causing fretting and winding failure)

LIFEVIEW® TURBOGEN system



LIFEVIEW® HYDRO system



Monitoring Devices

Generator System

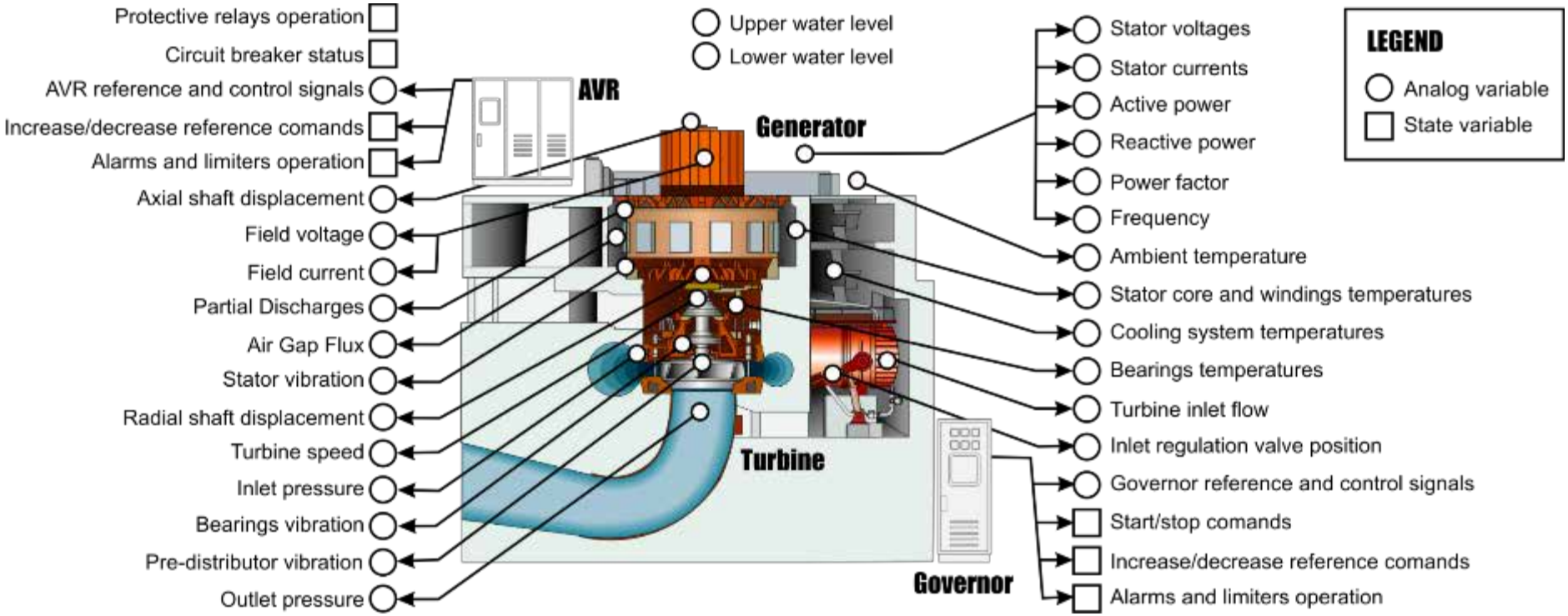
Partial Discharge Measurement
Ozone Detection
Air Gap and Magnetic Flux Monitoring
End winding Vibration
Magnetic Core Vibration
Generator Temperature
Bearing Vibration (absolute) upper side generator
Relative Shaft Vibration upper side generator
Bearing Vibration (absolute) lower side generator
Relative Shaft Vibration lower side generator

Turbine System

Axial Thrust Vibration, Oil Film and Movement
Turbine Headcover Vibration
Turbine Temperature
Relative Shaft Vibration upper side turbine
Bearing Vibration (absolute) upper side turbine
Wicket Gate Vibration
Runner or Labyrinth Gap Monitoring
Cavitation Monitoring

Online monitoring system

Hydro Generator



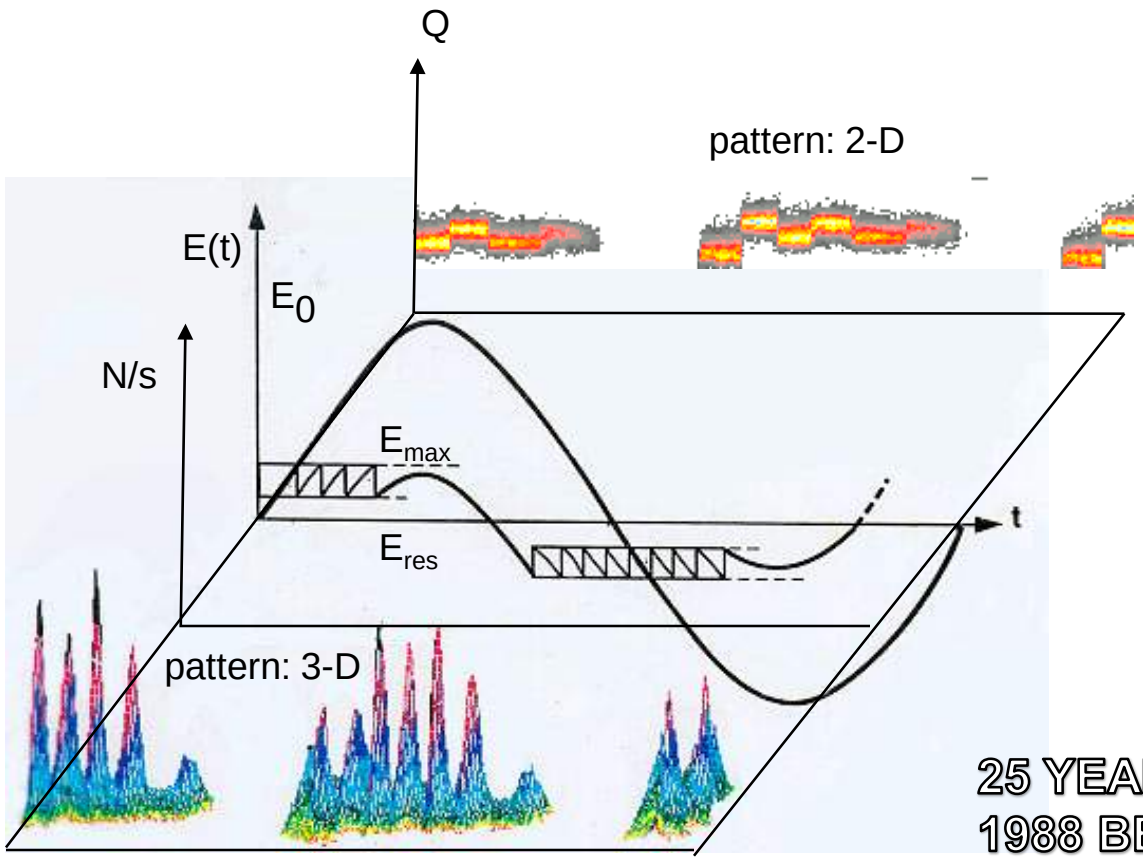
What is partial discharge?

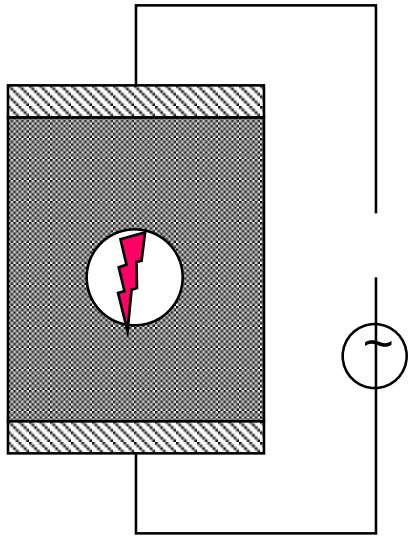
Partial Discharge is a local breakdown phenomenon which short circuits a part of an insulation and leads to ageing and accompanies ageing! Partial discharge takes place in defects of the insulation.

- formation ionised species
  - formation of corrosives,ions, acids, nitrogen oxides, ozone
  - light, sound and electromagnetic waves are emitted

- we use these effects for identification and localization of partial discharges (=insulation defects):
- antennae, chemical sensors, ultrasonic devices, cameras..

Analysis: partial discharge patterns



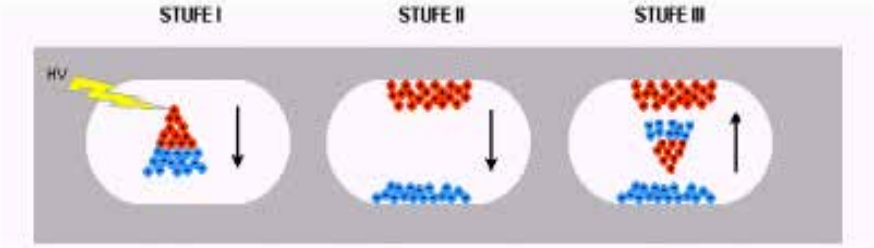


pd in a bubble

25 YEARS OF PRPDA:
1988 BBC, B. FRUTH

phase angle

Statistical Effects/Physics



Start Elektron and discharge
E>Estr

Estr=f(GAS)

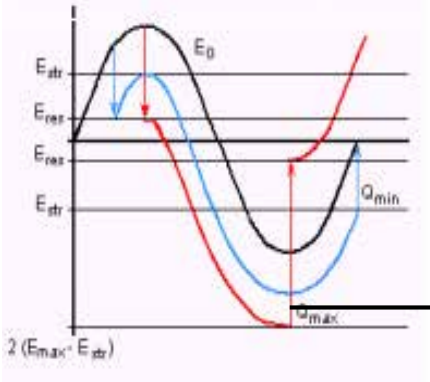
Creation of a surface Charge
E=Eres

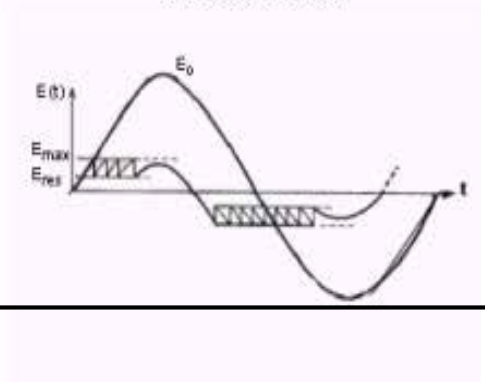
E_{res}=f(Gas)

Ignition from surface Charge
E>Estr

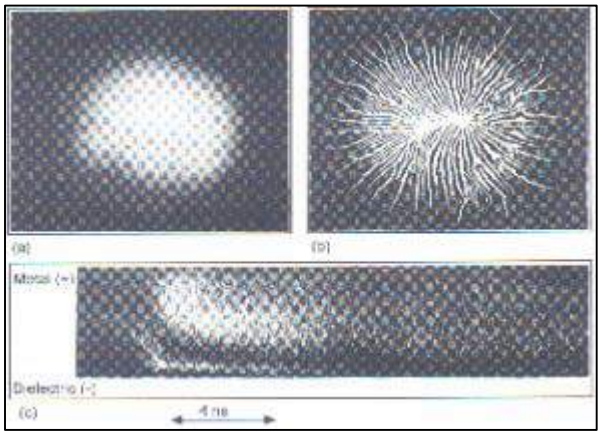
p(el)=f(E, Oberfläche)

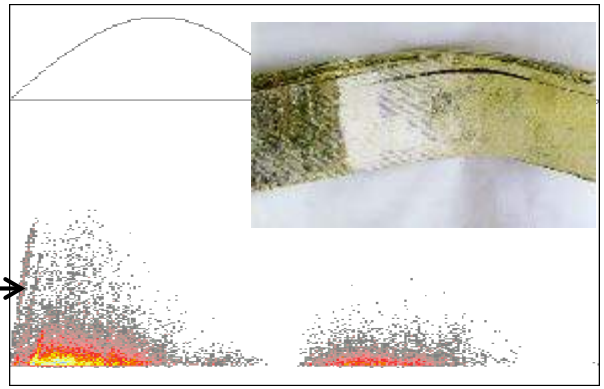
Polarity change





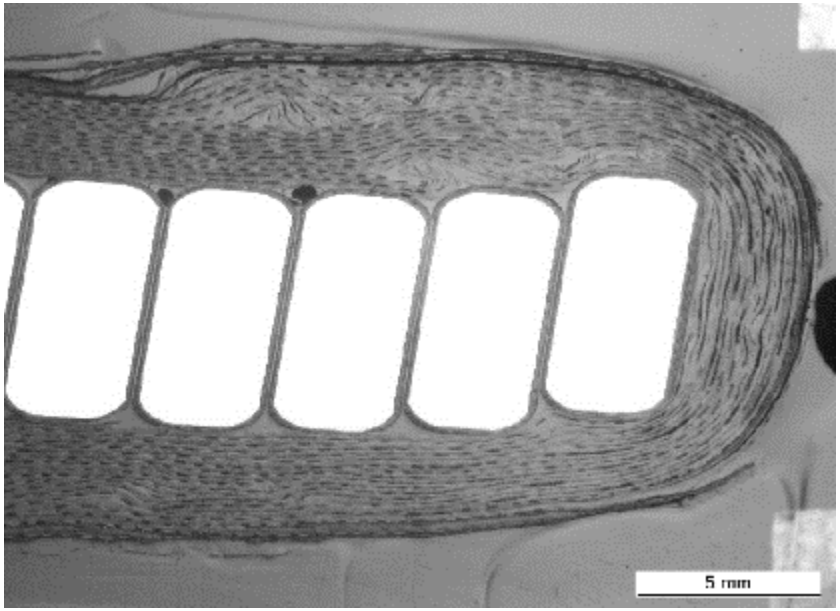
Delamination from Conductor

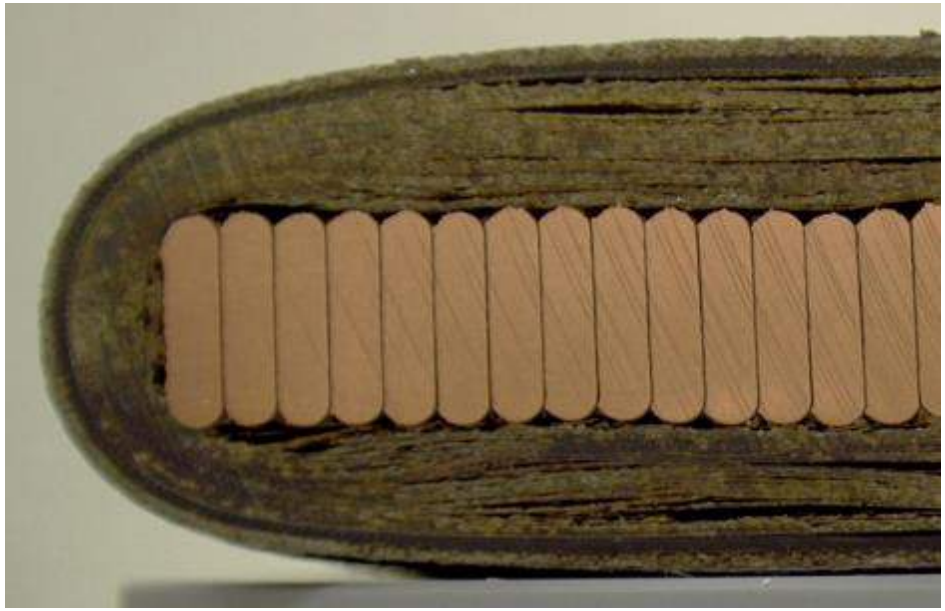




Amplitude Scatter:
Statistical Effects
Asymmetry:
Gas Discharge Physics

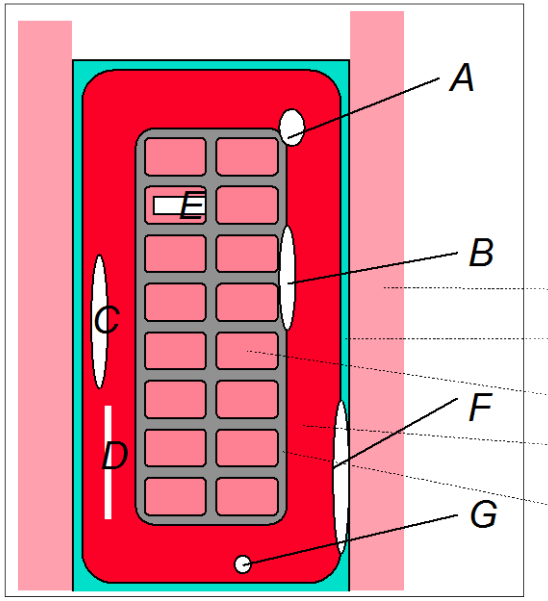
Detectability: Void vs. Delamination?





Defect Type	Inception Voltage Ui	Apparent Charge @ Ui	Apparent Charge @ 2xUi
Void	30 kV	0.64pC	2.6pC
Delamination	10 kV	38pC	600pC

Defect Pattern



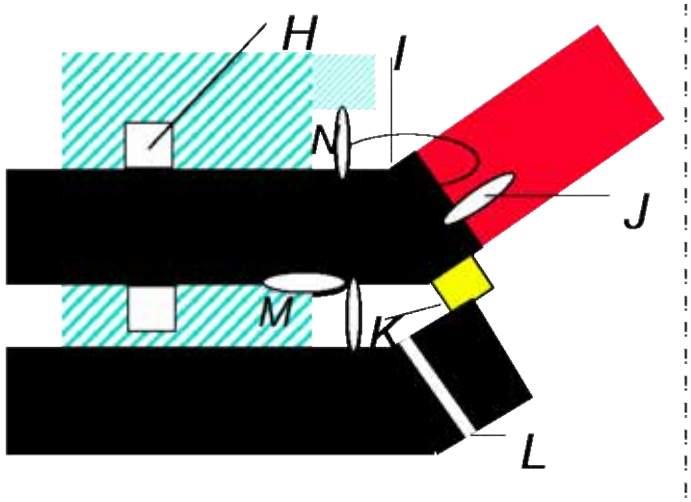
Slot/iron

Semiconducting Layer

Conductors, copper

Main insulation

Winding insulation



The letters A to G describe typical defects:

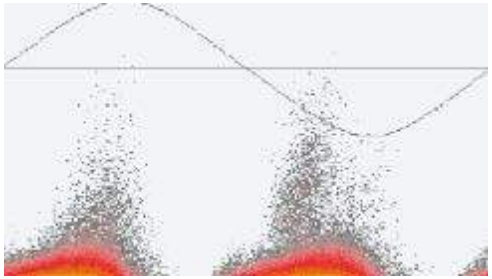
- **A:** highest electrical field - usually pd - e.g. field calc. E = 20 to 30 kV/mm
- **B:** delamination: winding - main insulation, $E = \varepsilon E_0 = 10$ kV/mm
- **C:** delamination of tape layers, E see C
- **D:** treeing in layers, unknown, very high locally
- **E:** broken strands
- **G:** voids, $E = 1.3 \times E_0$,
- **F:** slot discharge, semicon paint abrasion, E see C

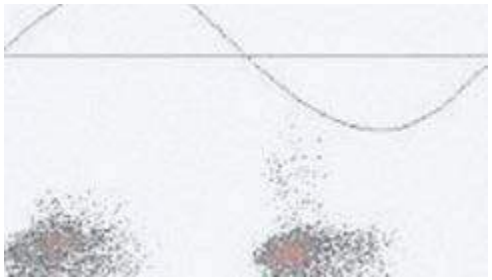
- **H:** Discharges in Cooling Duct, mainly created by vibration and abrasion of corona protection layers
- **I:** Delamination of Insulation in elbow (especially when manually manufactured)
- **J:** endwinding surface discharge (contamination etc.)
- **K:** Insufficient spacing, tracking, especially between bars with big voltage difference, different phases
- **L:** Connection area between slot corona protection and endwinding corona protection
- **M:** Slot exit discharge (similar to H and F, pd between iron and eroded semiconducting coating)
- **N:** PD between bar surface and core clamps
- **O:** Bar to Bar discharge (see K)
- **P:** Vibration Sparking, due to winding looseness and bar movement

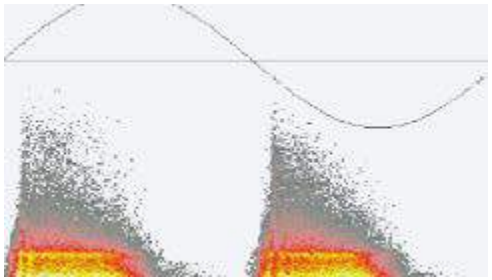
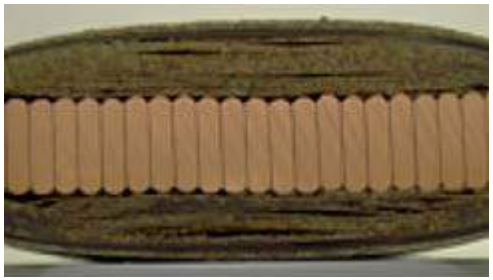
LIFEVIEW^{TM} / Partial Discharge

Partial Discharge:

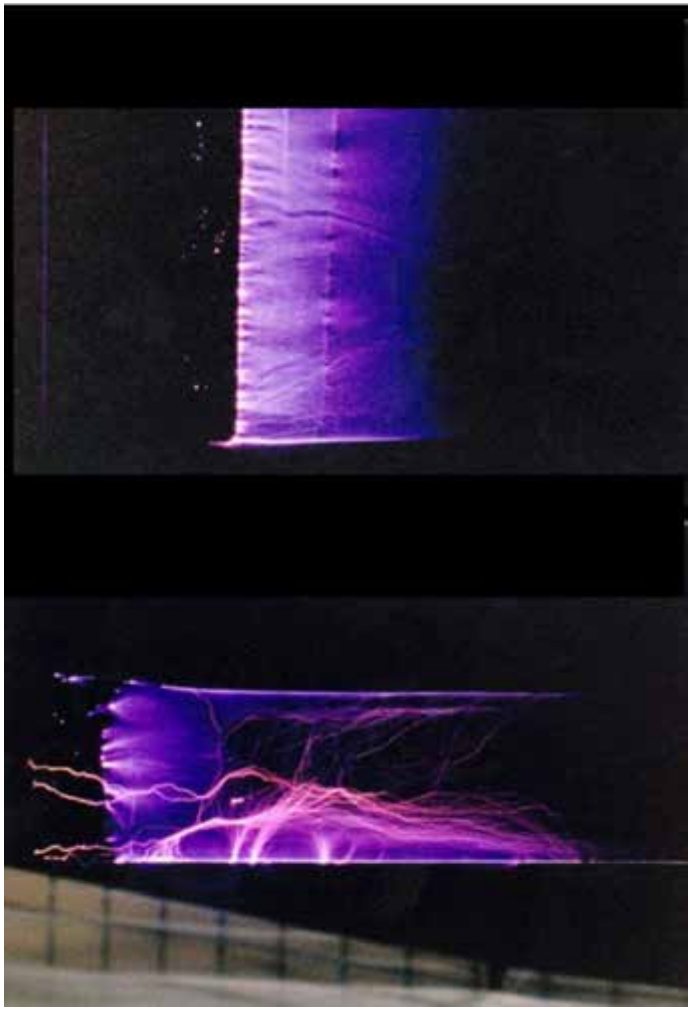
- monitors insulation damage
- pattern identifies defect type
- Quartzelec staff has field experience of more than 5000 successful diagnoses
- technology development based on field experience

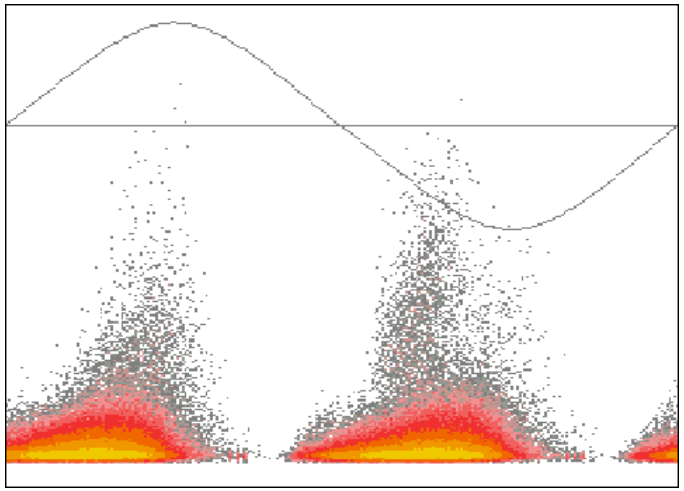


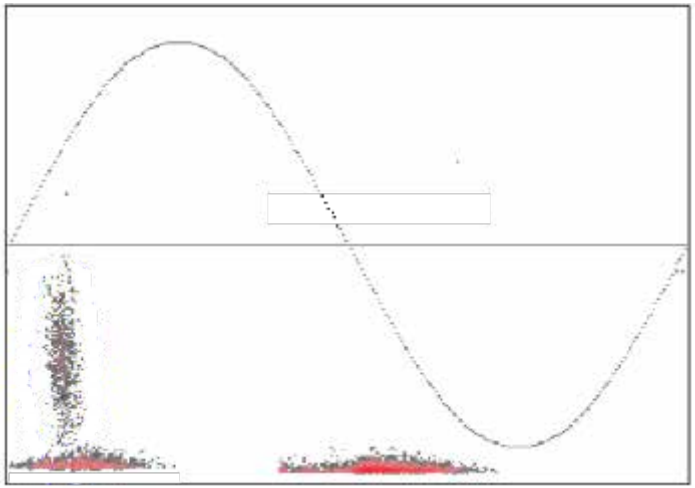


Partial Discharge: End Winding

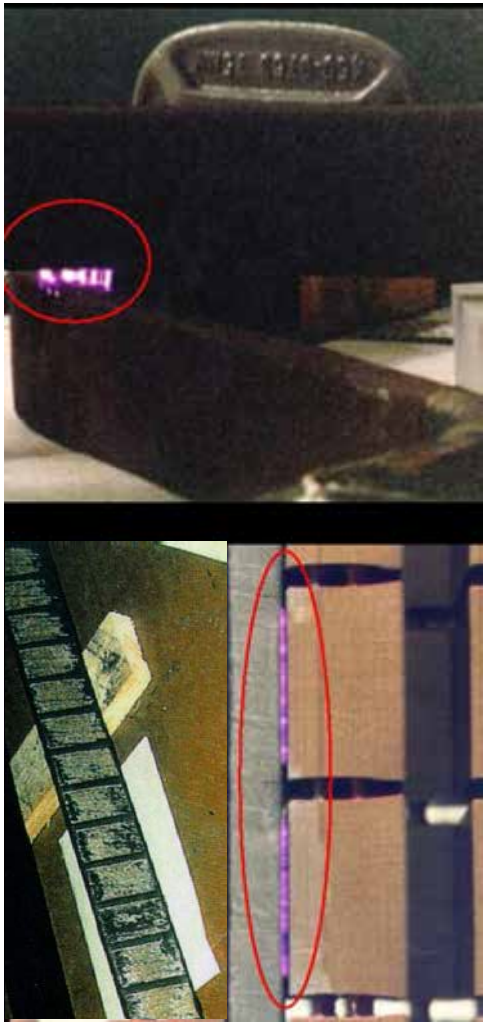


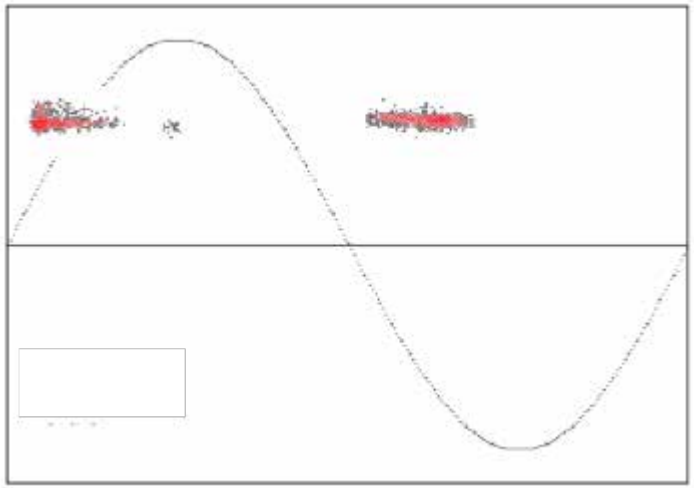


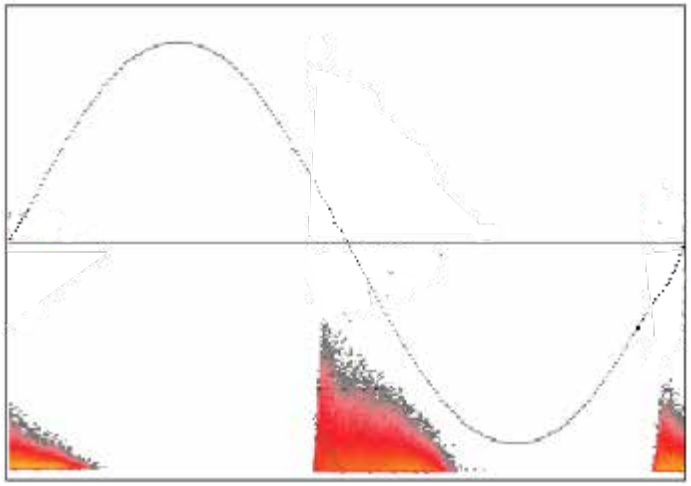


Damage by PD

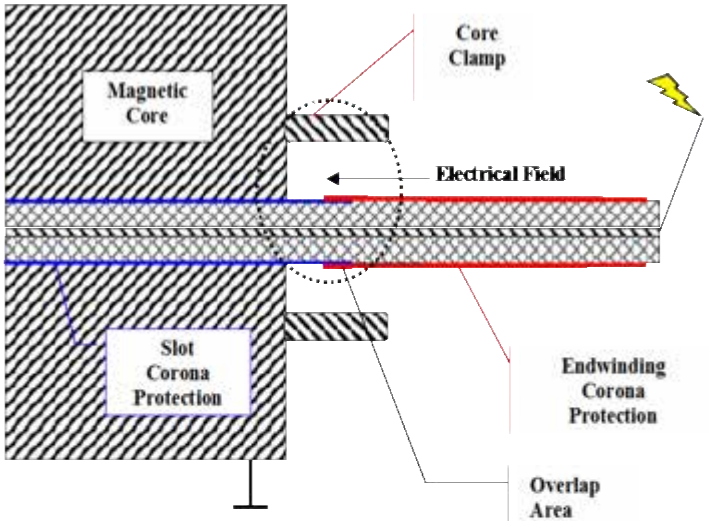
Partial Discharge: Phase to Phase



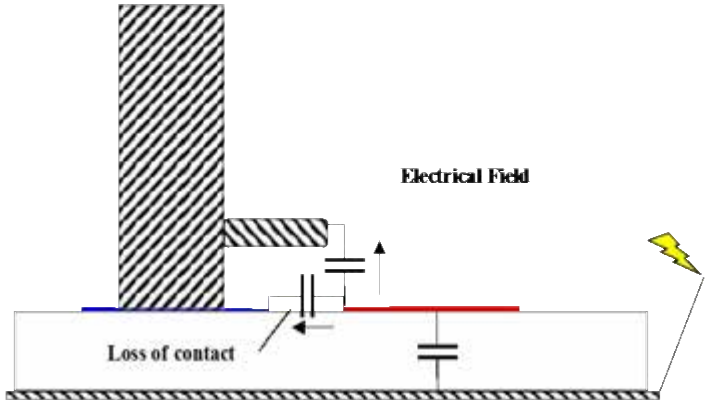


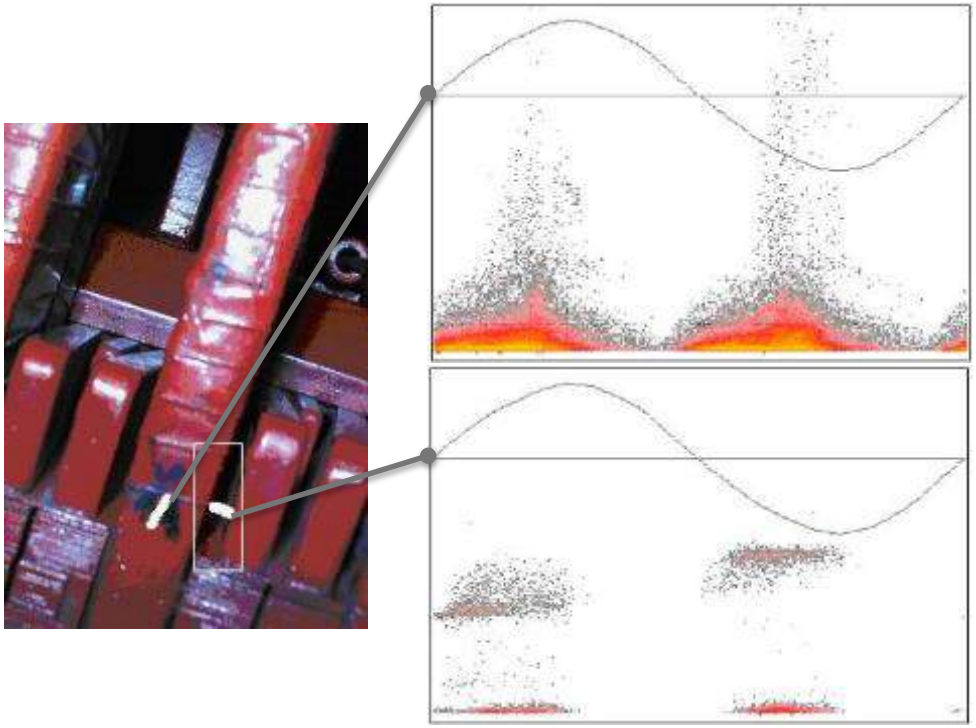


The Electrical Field



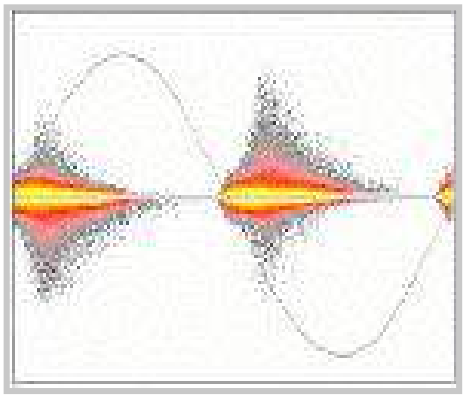
Degraded Overlap Area:
Loss of Contact Between Endwinding and Slot Corona Protection



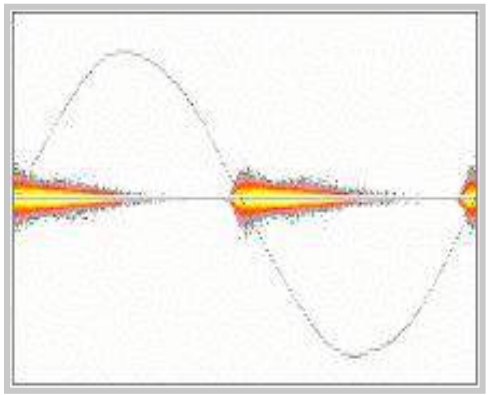


Example: Cleaning Efficiency>QA

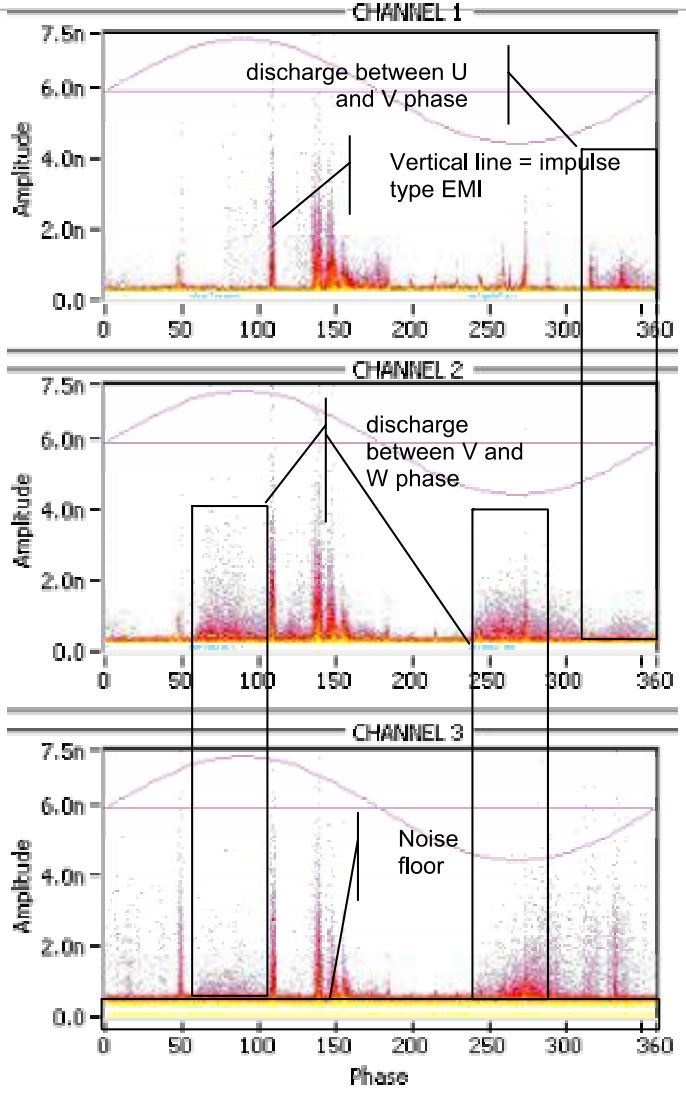
Diagnosis:
Pollution

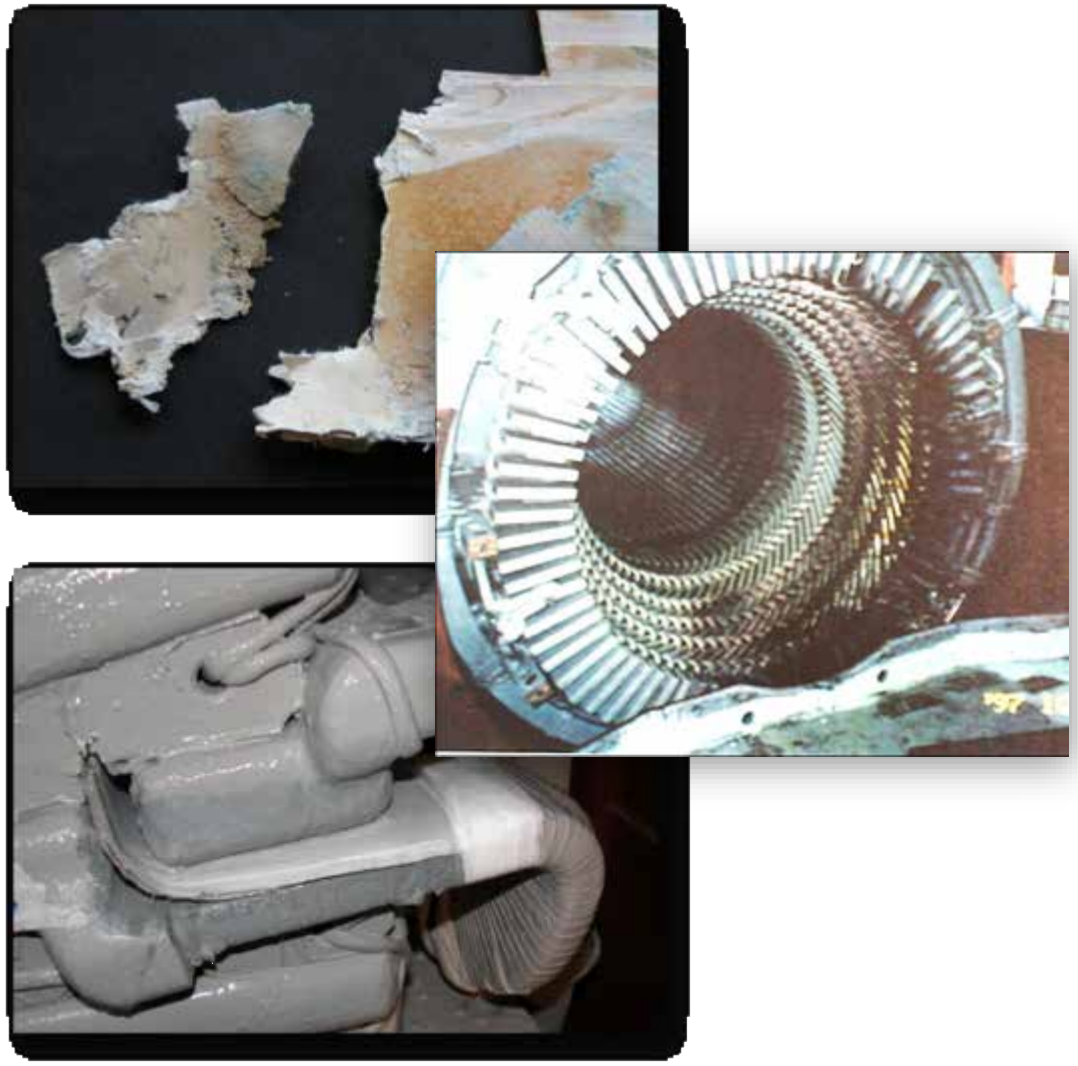


Measurable
Success

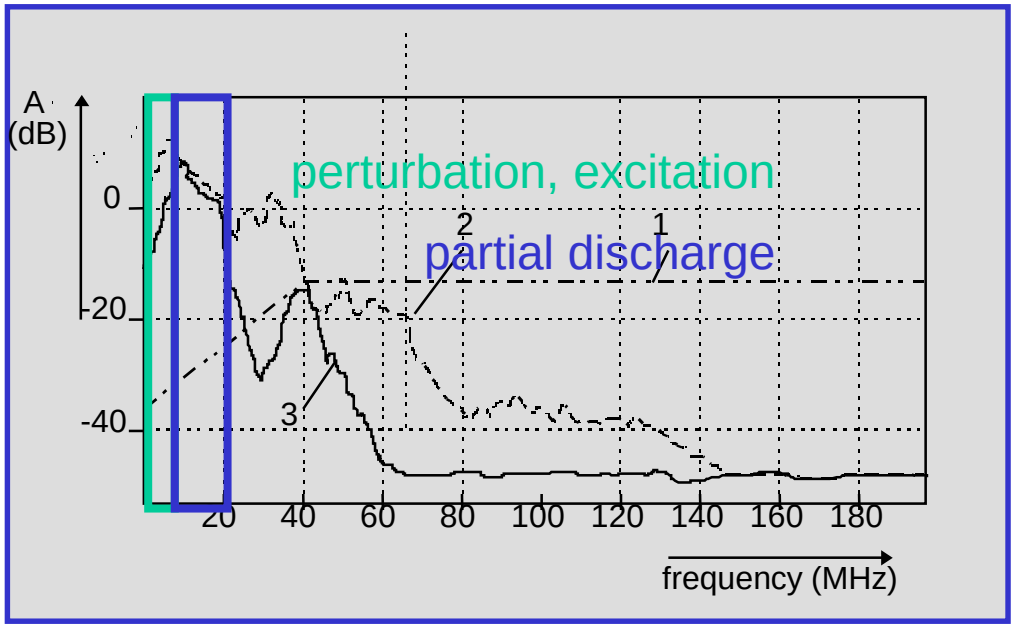


Phase to Phase Fault Avoided





PD Monitoring

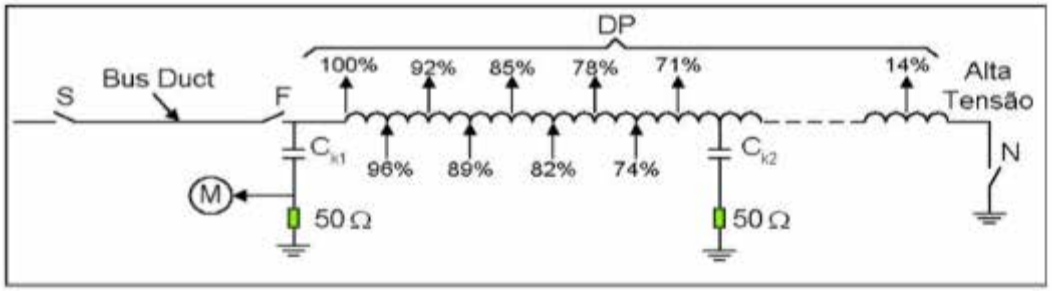


1: theoretical response of coupler (e.g.80pF)
2: partial discharge signal spectrum
3: transmission of pulse from neutral to HV

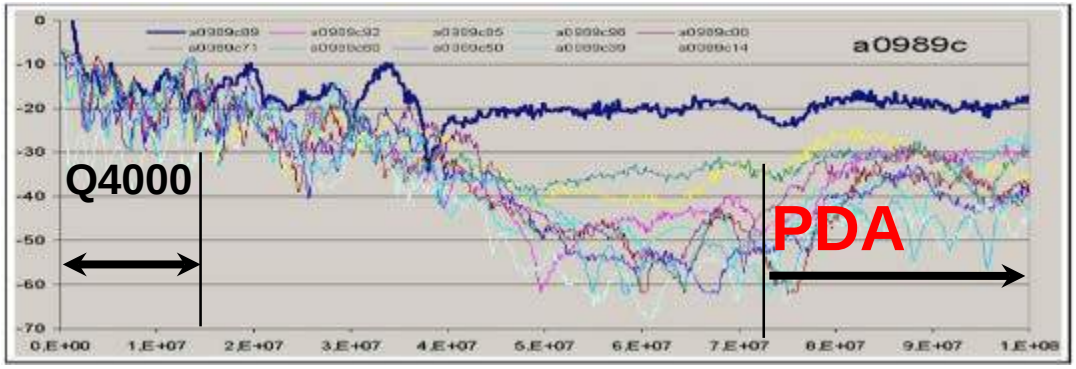
- most of the signal energy is transferred in the sub 20MHz Band
- most of the winding covered using sub 20MHz band
- some PDA instrument and coupler together use a frequency range of 40 to 350 MHz

29

Signal Transfer: ITAIPU/700MVA

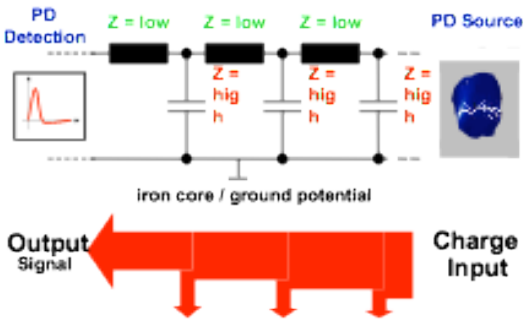


Signal Injection

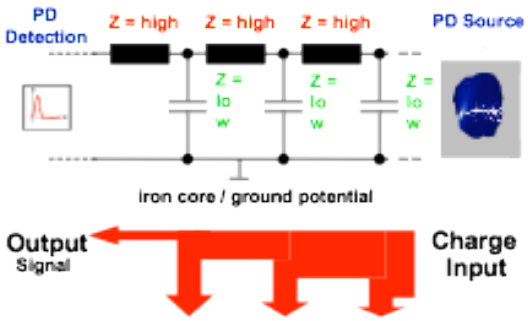


Frequency Spectrum

Detection of LOW Frequency Components

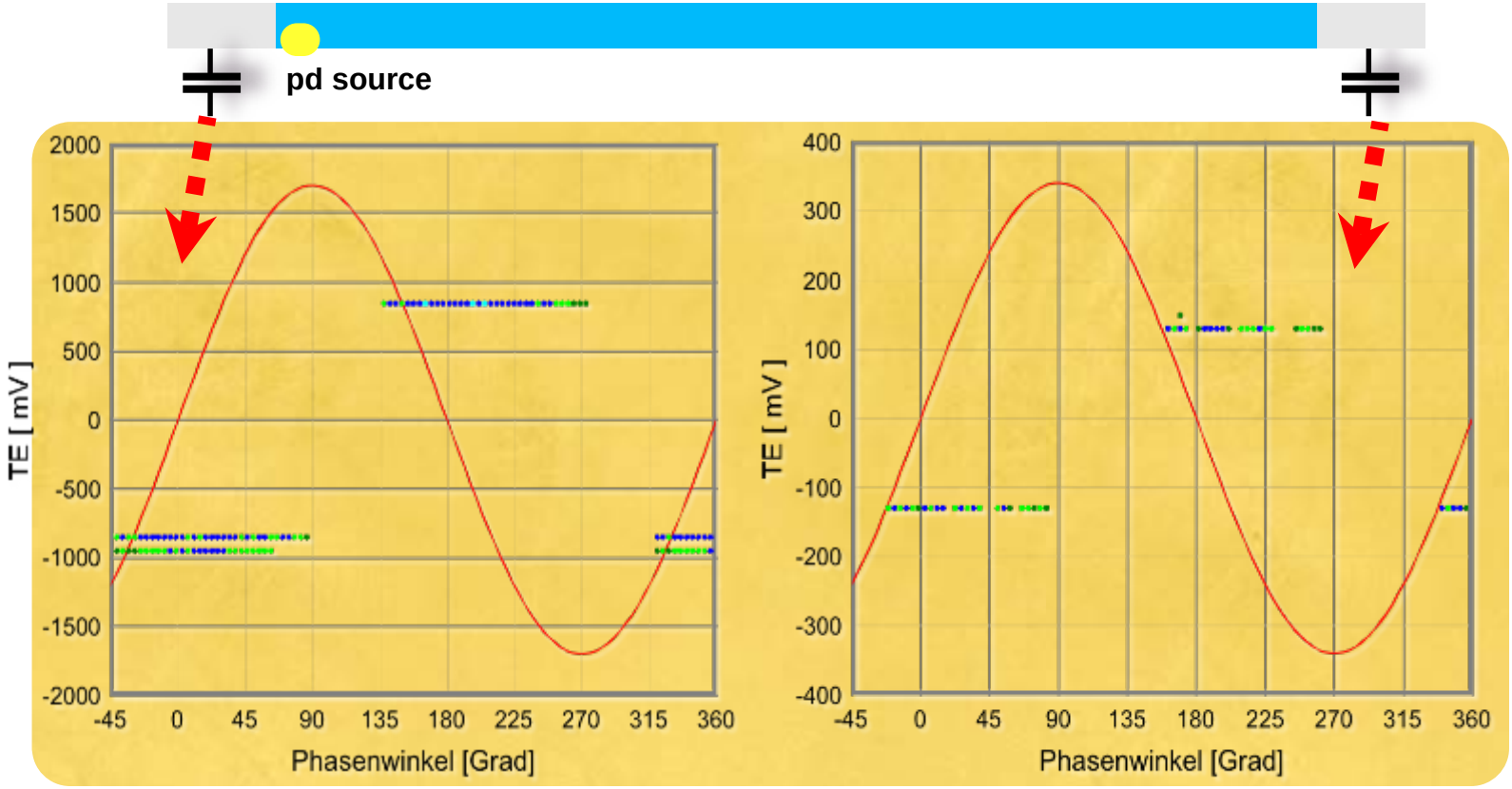


Detection of HIGH Frequency Components



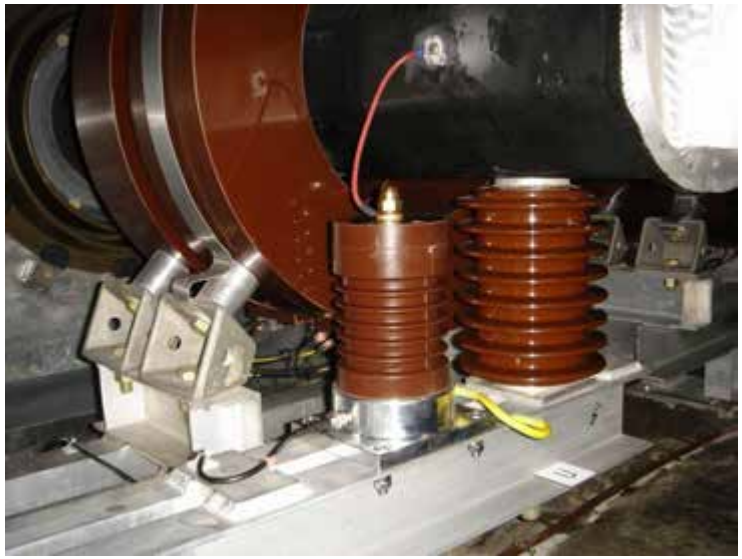
IEC TS 60034-27

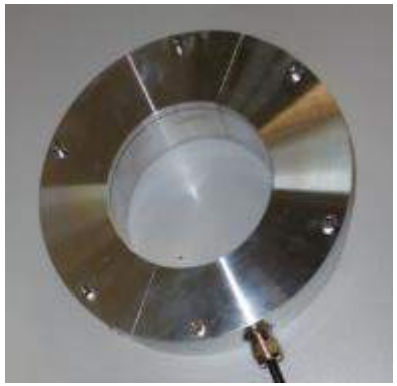
Attenuation Error of “Ultra High Bandwidth Method” and mV Units



mV: 10x attenuation over 1 slot of a turbine generator limit 350 MHz
pC: none, limit 10 MHz

PD Sensors





LIFEVIEW® PDA

LIFEVIEW® PDA an ideal partner for operators who do not want to be bothered by complex software:

- Data normalisation compliant to IEC 60270 & IEC TS 60034-27
- Pre-set warning thresholds and simple analogue (4-20mA, relays)
- Programmable filters for use in noisy environments
- Easy to understand data

LIFEVIEW® PDA

Software displays graphical user interface for:

- Partial discharge pattern & discharges trend
- Various display options for crosstalk and phase to phase PD recognition
- Calculation of apparent change according to above IEC standards
- Instrument acquisition control panel

LIFEVIEW® PDA

Software displays graphical user interface for:

- Partial discharge pattern & discharges trend
- Various display options for crosstalk and phase to phase PD recognition
- Calculation of apparent change according to above IEC standards
- Instrument acquisition control panel

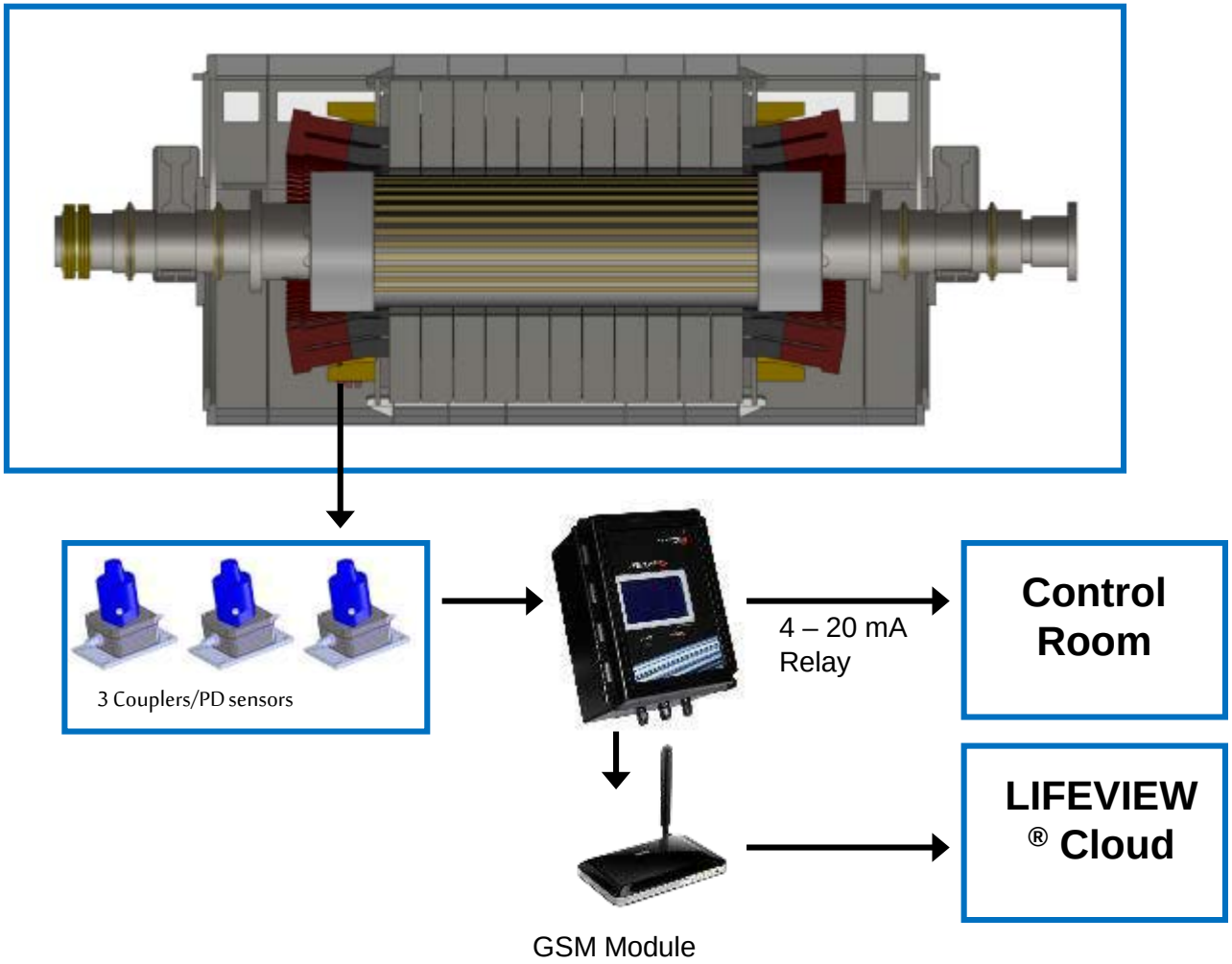
LIFEVIEW® PDA – ATEX

Class 1, Div 1,
Zone1
Groups, C & D

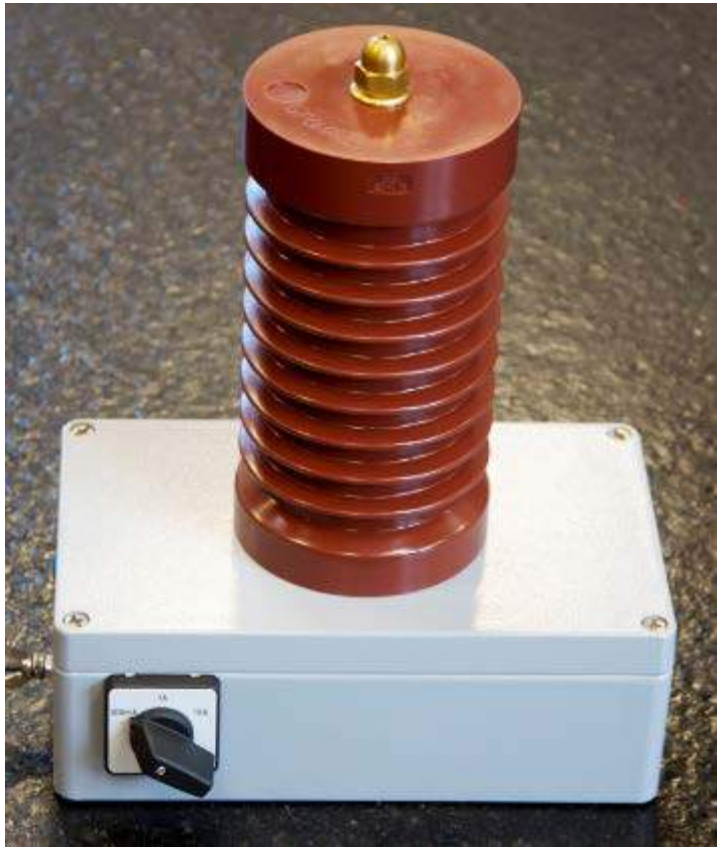
ATEX
ZONE 1

LISTED

LIFEVIEW® PDA



LIFEVIEW® QTD Kit



HV Flashing Set

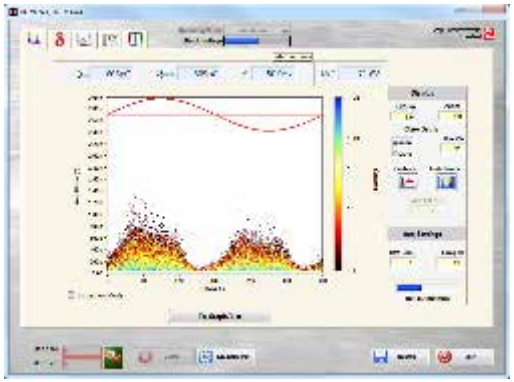
LIFEVIEW QTD: PD, TD

Off-Line PD and TanDelta

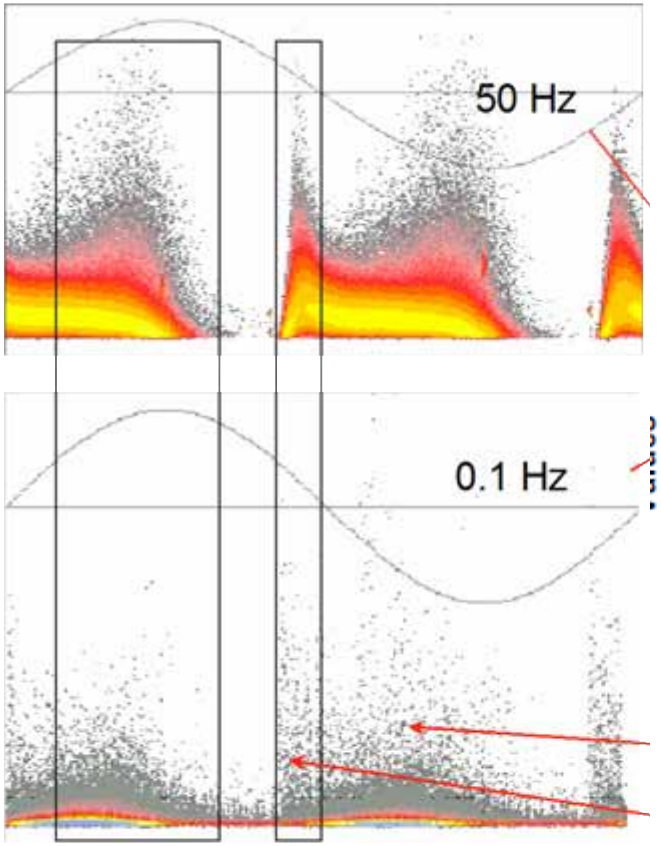
High Voltage VLF: PD, TANDELTA, DC Leakage

- **Field Test Equipment made to measure by Quartzteq**
- **Weight Reduction & Greater Portability**

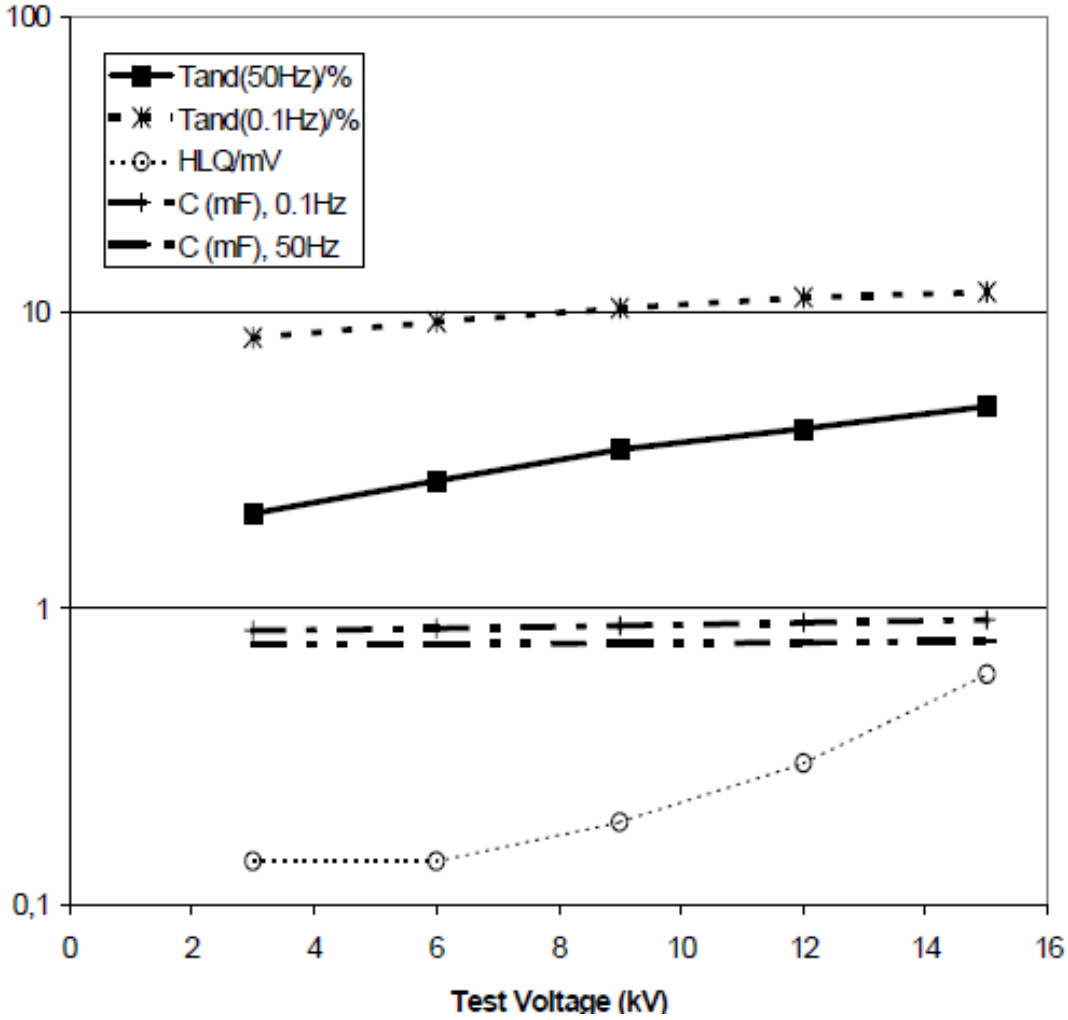
LIFEVIEW® QLF kit



Highly Portable HV TESTS



PD Pattern



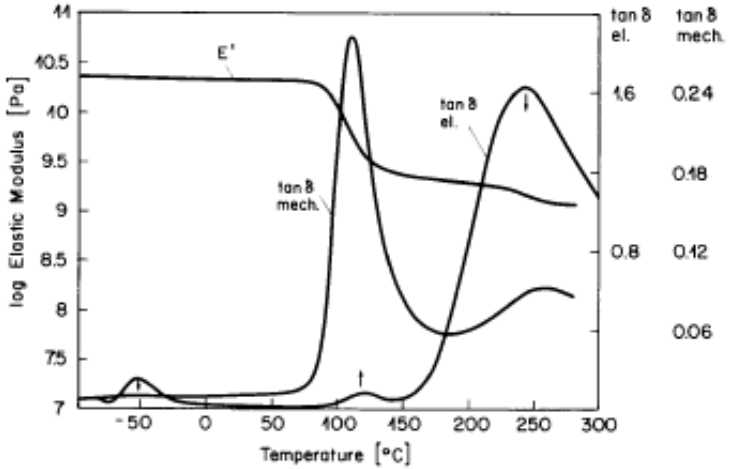


Fig. 1: Correlation of the mechanical and electrical relaxations (mechanical measurements in dual cantilever mode at 1Hz oscillating force). Linear heating at 1 K/min

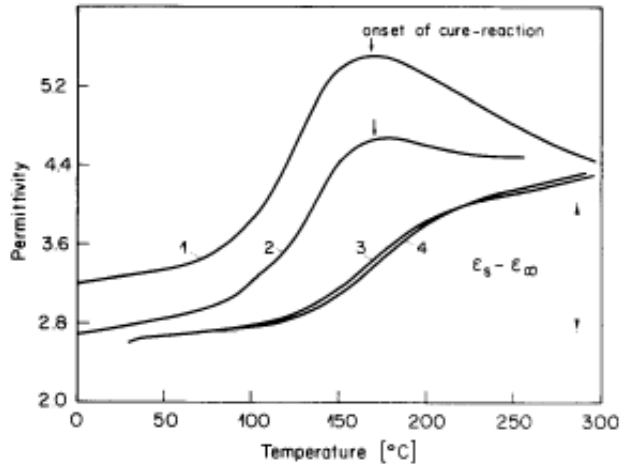
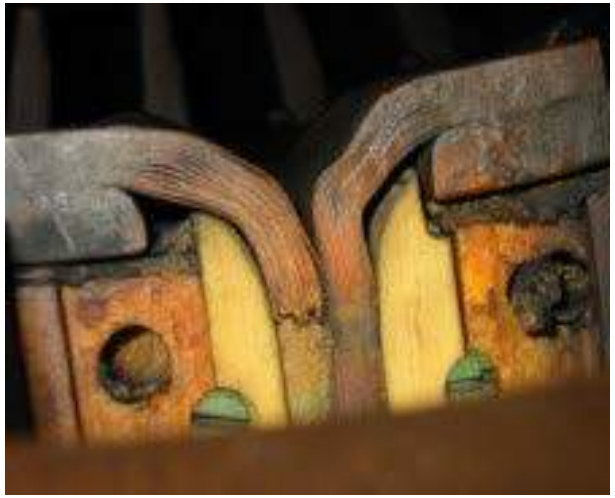


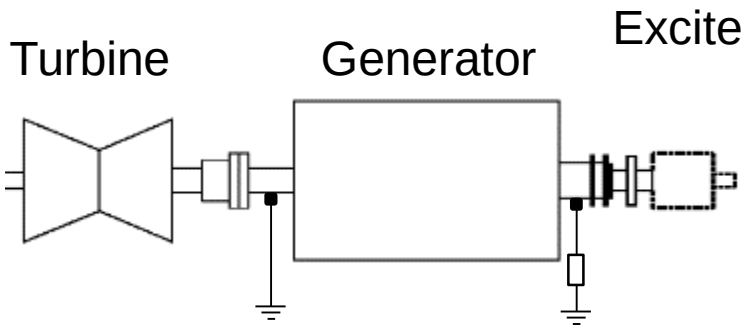
Fig. 2.: Temperature dependence of the dielectric constant of the epoxy resin (100 kHz ,1V/mm) (1: freshly cured, 2: 1 h at 300°C, 3: 16 h at 300°C, 4: 32 h at 300°C.)

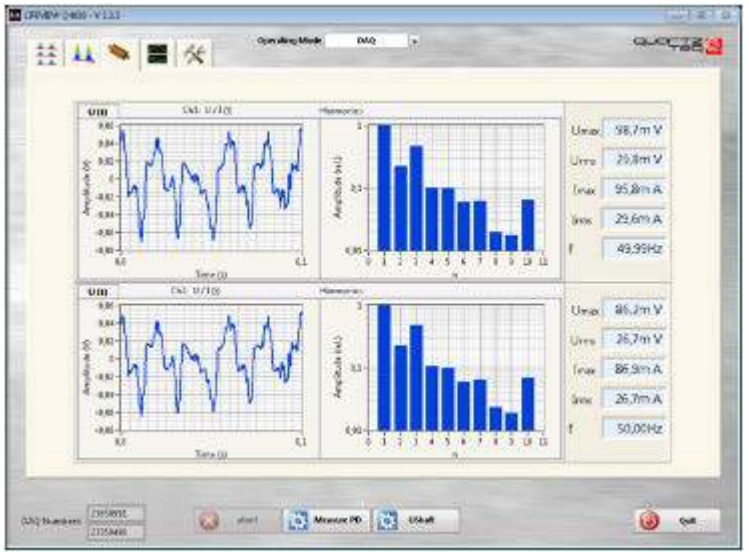
Rotor Condition



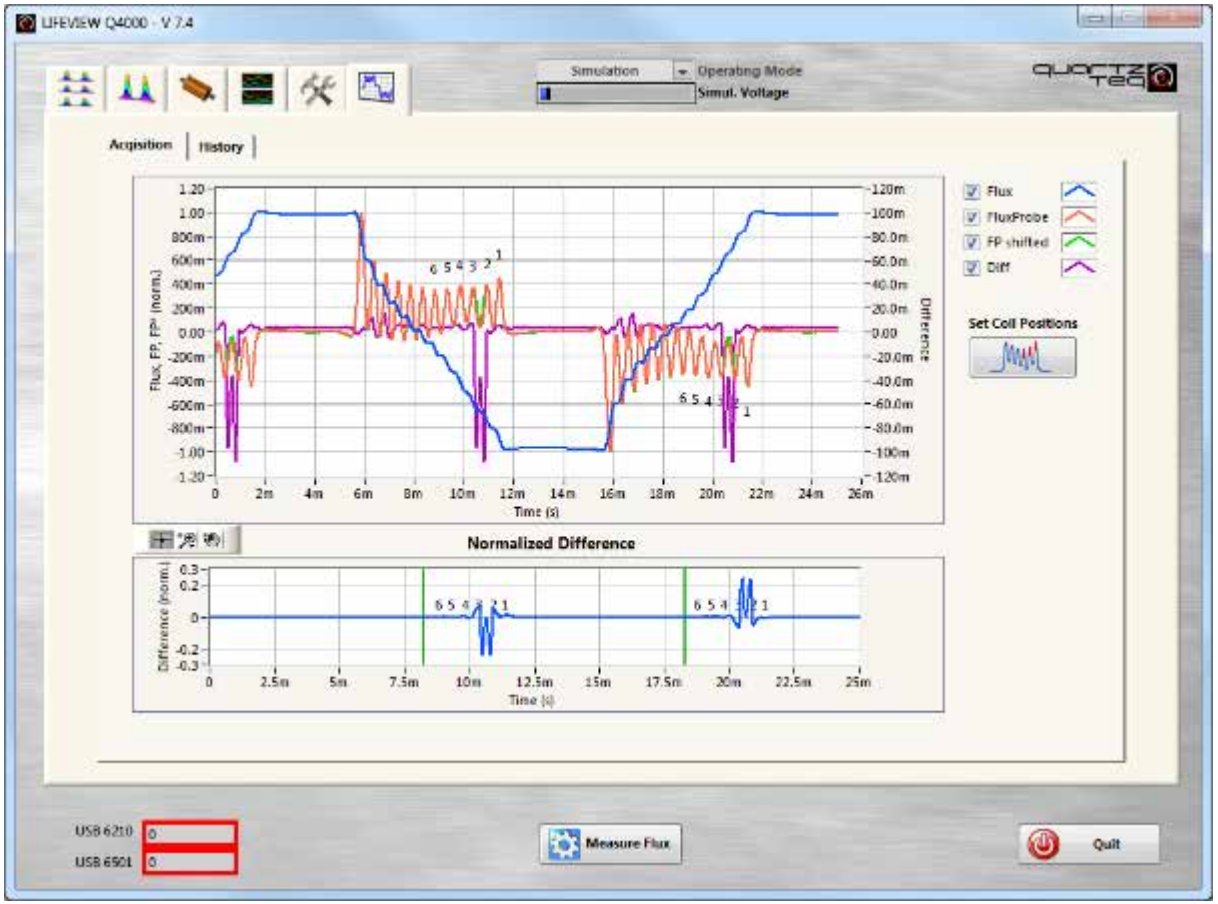
Measured parameters : Shaft Voltage

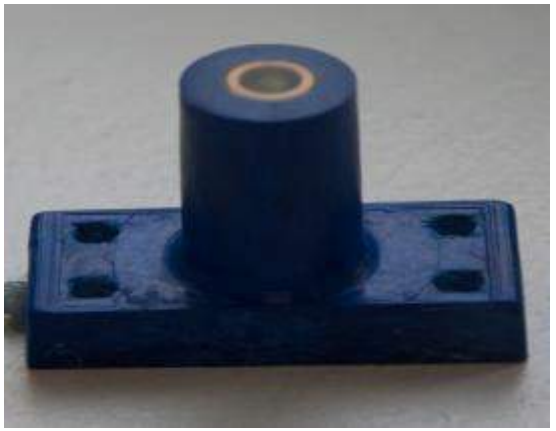
Spectral analysis identifies fault



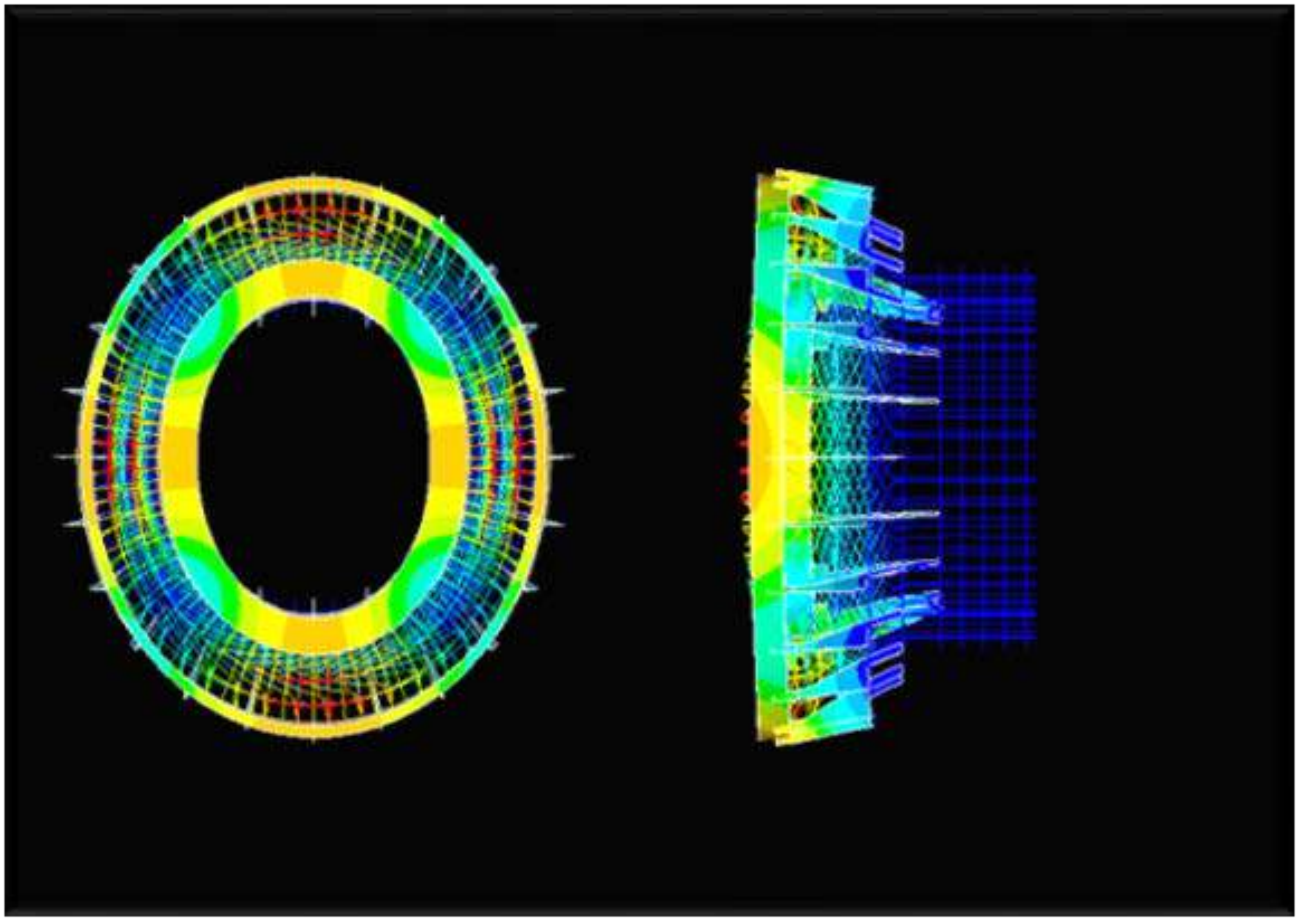


Measured parameters : Air Gap Flux

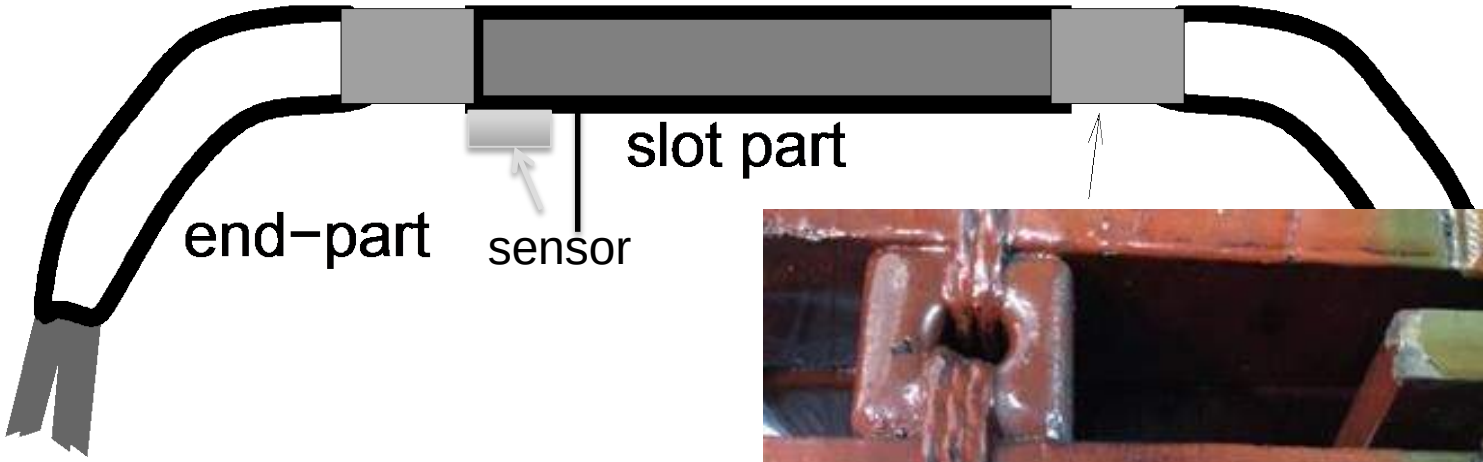




Head Winding Resonance



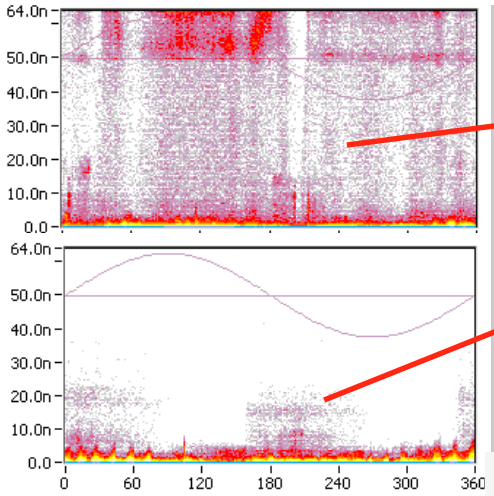
MOUNTING QVIBE

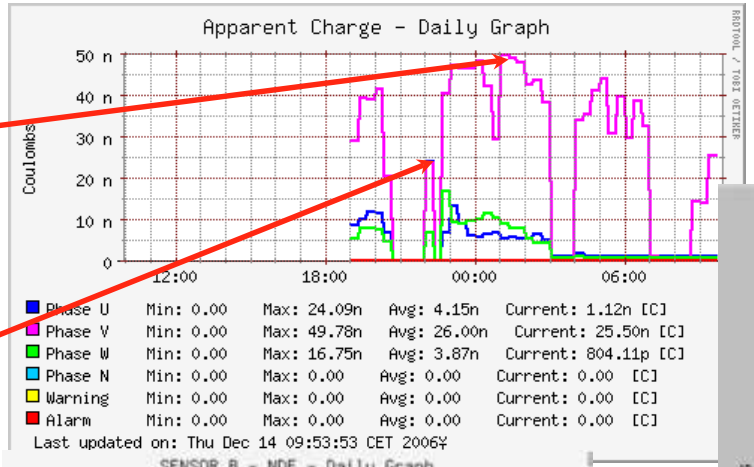


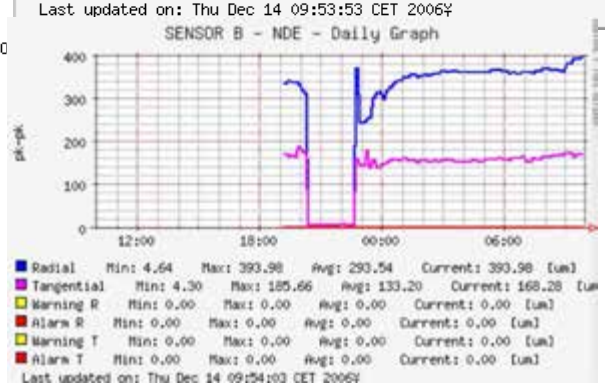
The sensor is mounted on the slot corona protection (the electrical field is 0, as it is grounded), the power supply is routed to the back). This is to measure the critical slot exit vibration.

Head Winding Resonance

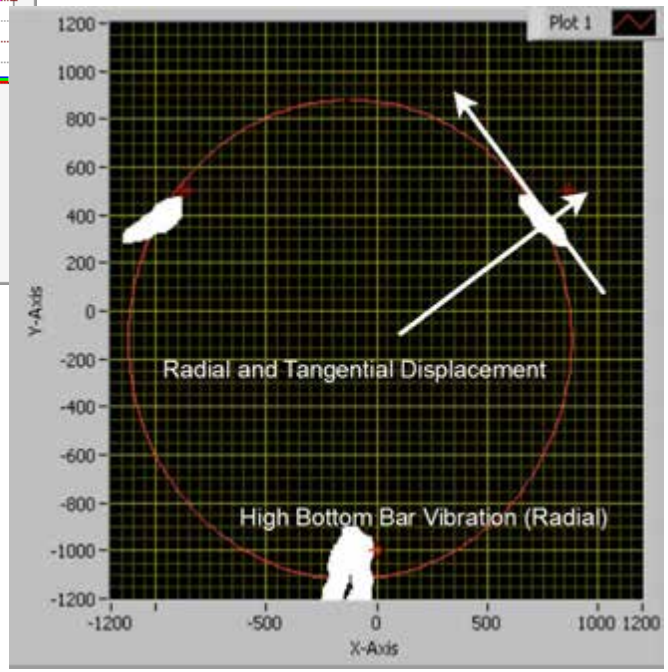
Turbine Generators (PD and Vibration)







Radial & Tangential



Monitoring/Mechanical Structure

- universal intelligent wireless sensor system was designed to monitor vibration and temperature in critical locations
- not easily accessible
- installation of wiring may be difficult
- more than one interesting axis for monitoring
- have strong electromagnetic interference that would deteriorate wired signals.

All components and accessories of rotating machines are vibrating. Analysis of these vibrations can be vital in the early detection of defects

Application Range

- Various atmospheres and environments (ex, humidity, due to hermetic encapsulations and high temperature design)
- Winding and core vibration (generators and motors)
- Classical mechanical vibrations in pumps, fans gear boxes (alignment, bearing defects, unbalance etc.)
- Applications outside the „classical“ rotating machinery, as transformer bushings, conveyor belts etc..

Wireless Sensors

Electrical and operational	Sensors: Acceleration	Sensors: Temperature
Power consumption: ≤ 80mW	Axes: 3 (x,y,z)	Sensitivity: ±1 ◦C
Power supply range: 4 to 36VDC	Range: +/-12 g	
Operating temperature: -20 to 105 ºC	Sensitivity: 3mg	
Dimensions: 3.5 × 2.5 × 0.4 cm	Burst sample rate: 3.2KHz	
Network: 2.4 GHz, 100m, more than 60000 nodes possible, 250kb/s	Resolution: 13 bit	

Sensor features

Application Range

sensors can be powered up by different power supplies :

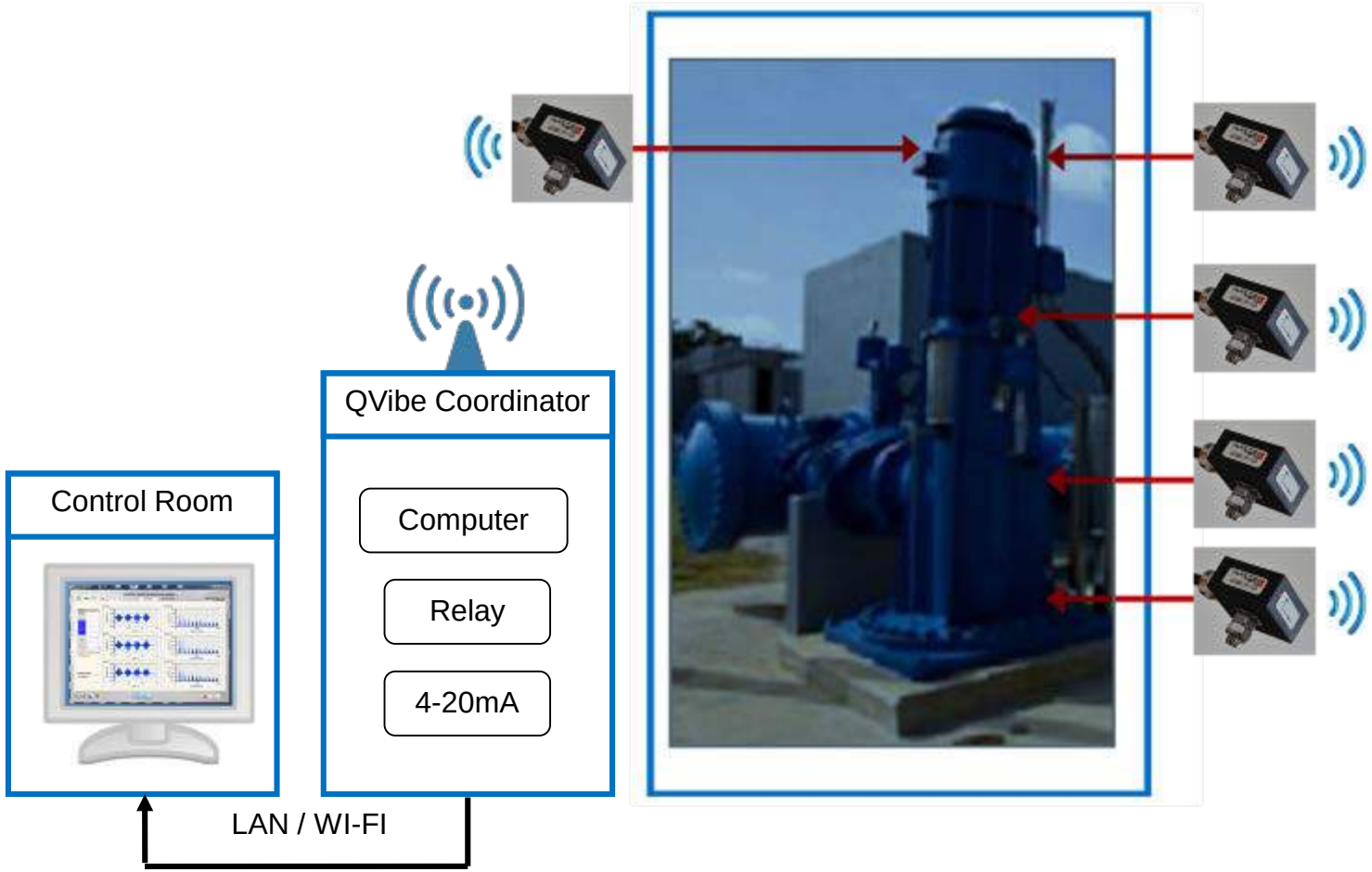
- battery pack (must be replaced every six month)
- Solar panel pack including battery
- wired DC power supply
- energy harvesting

LIFEVIEW® Connect

LIFEVIEW Connect

- Remote Access using 3G Network
- No connection to the customer Network (IT restriction)
- Full access from computers, laptop, tablet, smartphone

Application Pump Monitor



Vibration Sources in Pumps (DIN Handbook)

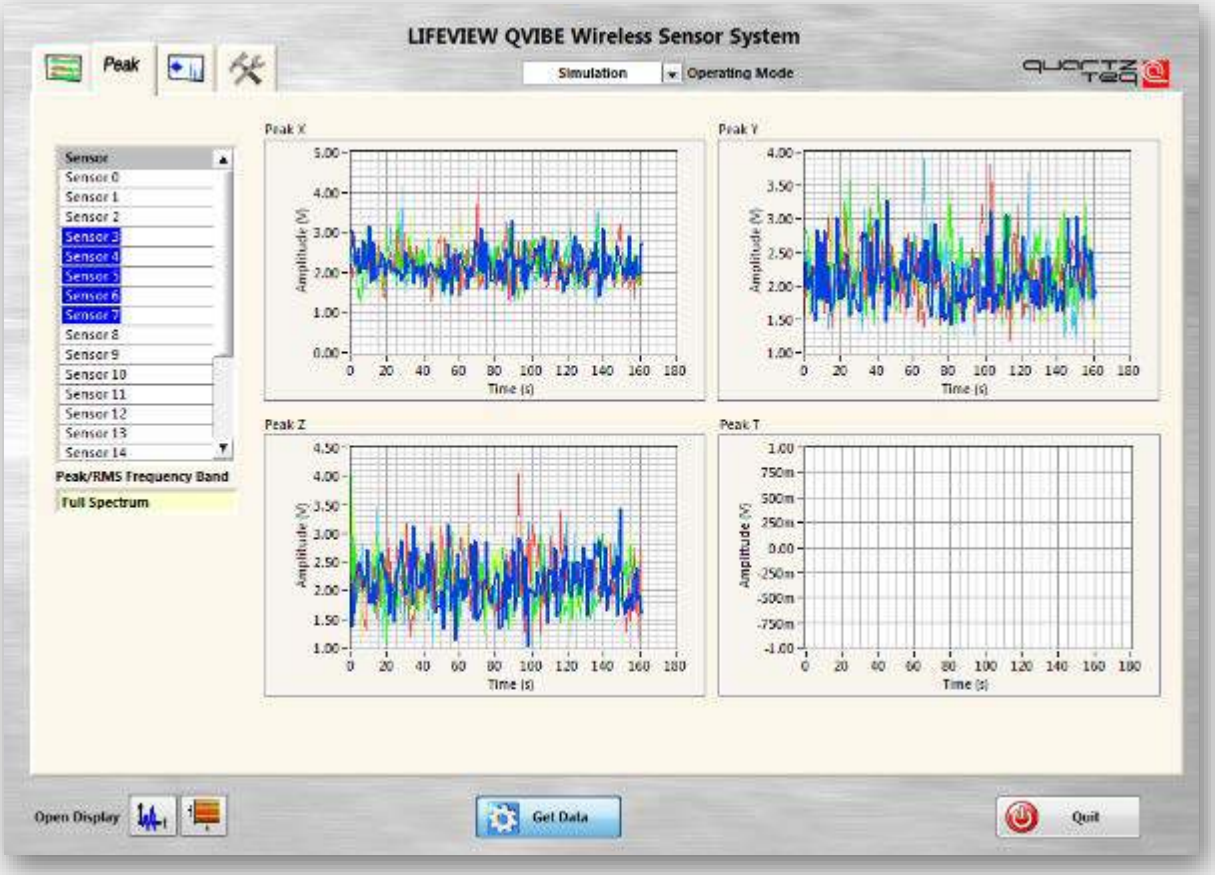
- Vibrations as a consequence of imbalances
- Vibrations due to component, installation and impeller resonance
- Vibrations resulting from shaft bending of the driveline
- Vibrations from play in bearings and other components
- Vibrations resulting from the effect of imbalance in rotating liquid rings
- Vibration excitation due to the unbalanced inertial forces of crank drives and other oscillating masses
- Vibration excitation due to flow and pressure pulsation in oscillating and rotating positive-displacement pumps
- Excitation due to blading rotation noise and other pressure pulsations in centrifugal pumps
- Excitation due to cavitation in centrifugal pumps
- Excitation due to cavitation in positive-displacement pumps
- Excitation from flow cavitation in pump nozzles and connected pipes
- Excitation due to pressure surges with two or multiphase flow
- Excitation due to partial-load operation in centrifugal pumps
- Vibrations due to roller bearing damage in pumps
- Vibrations due to standstill vibrations in pumps fitted with roller bearings
- Vibrations due to plain bearing damage in pumps
- Vibrations due to dry running in process-fluid-lubricated plain bearings and face seals in pumps (frictional vibration excitation)
-

The whole system is controlled by a “GUI”, graphical user interface, which is accessible also from remote.

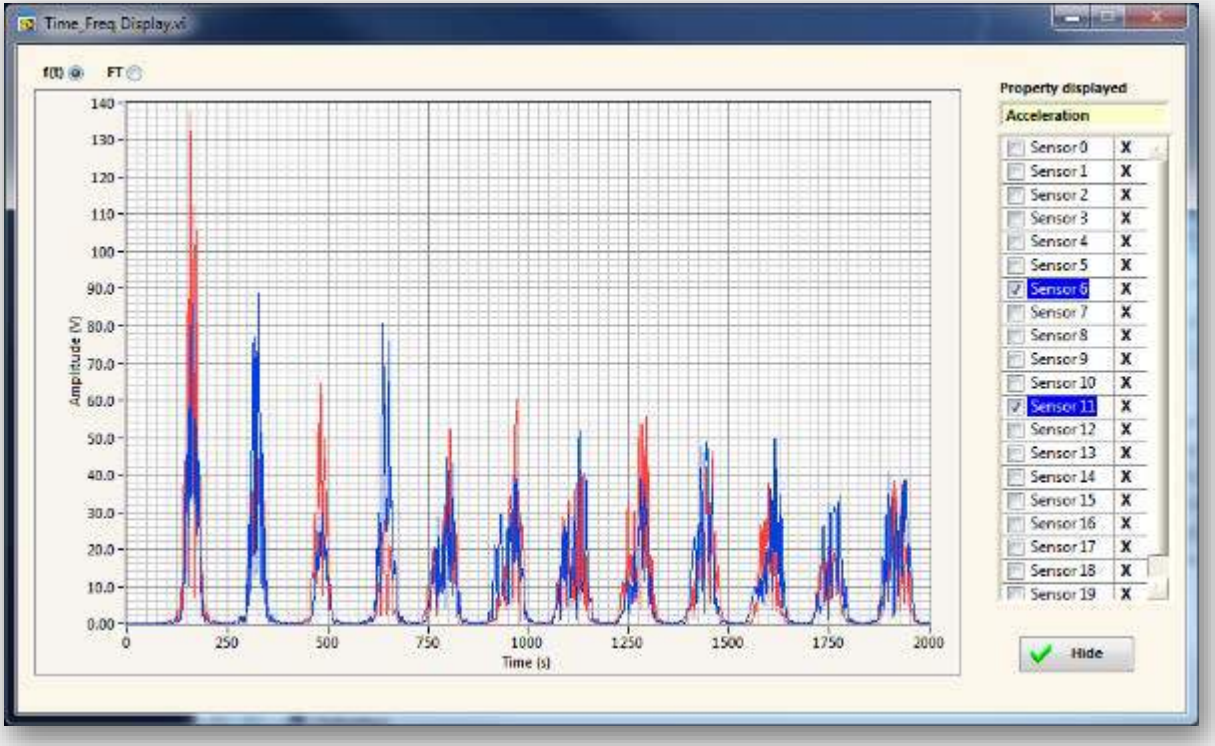
The vibration monitoring software is installed in the sensors and in the so-called network coordinators. Any PC or tablet can be used for visualising.

The software(s) can be configured for many applications and a virtually unlimited number of pumps, fans or sensors.

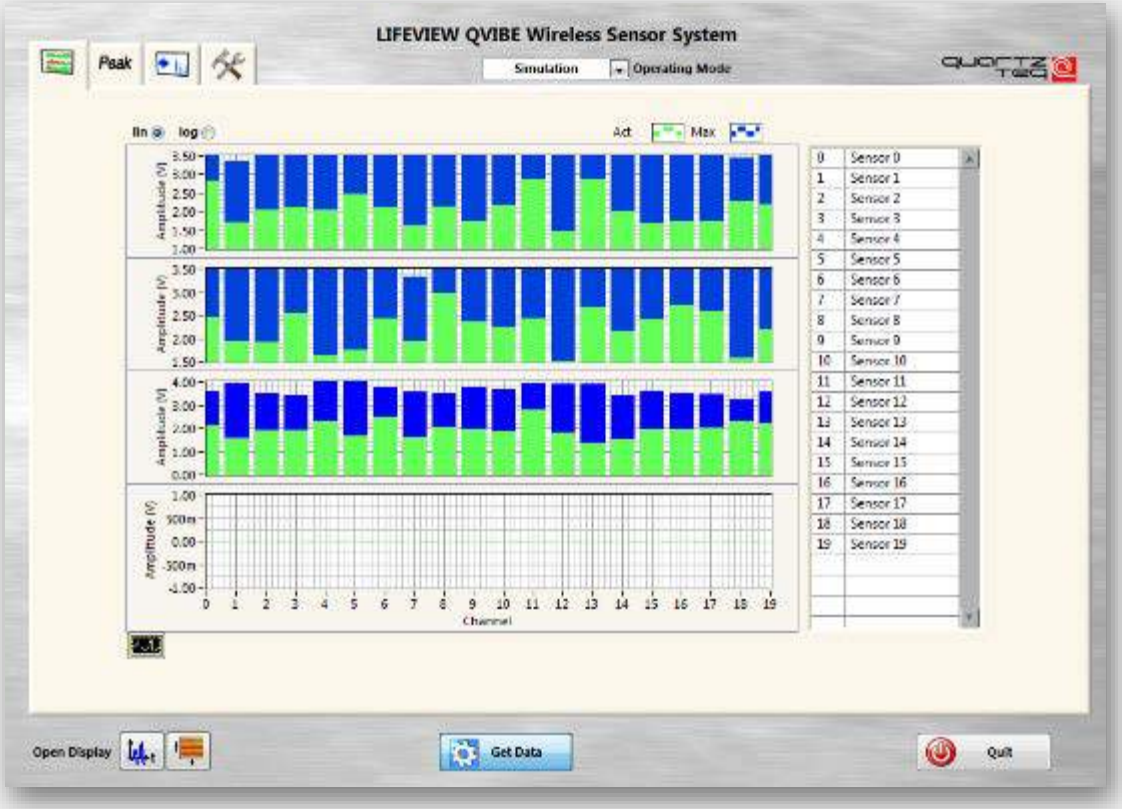
GUI Trending



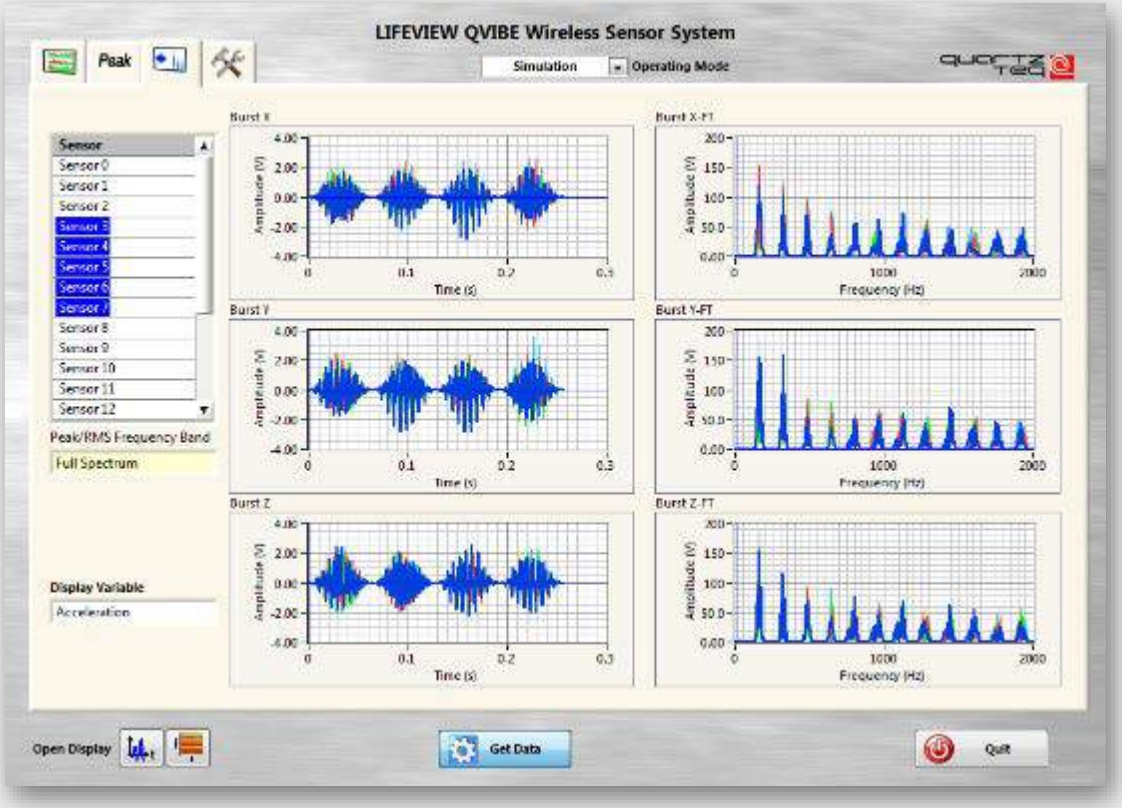
GUI/Spectral Comparison



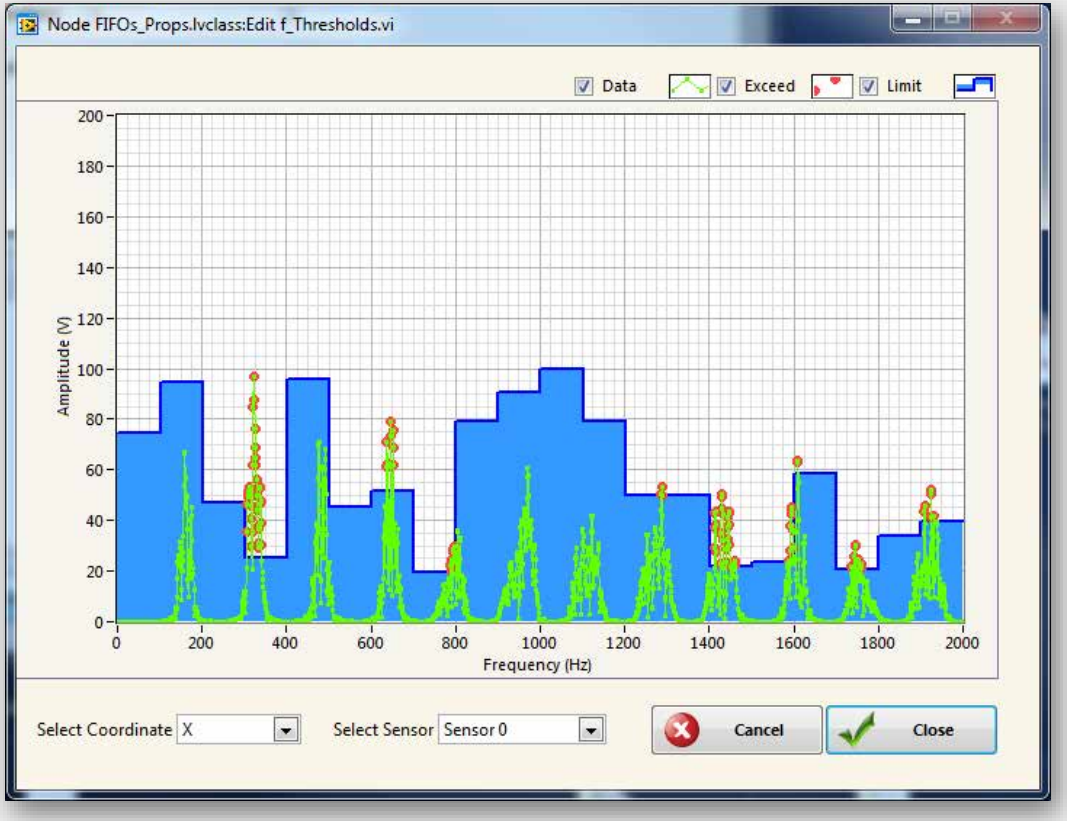
GUI/Level Monitor



GUI/Waveshape Analysis



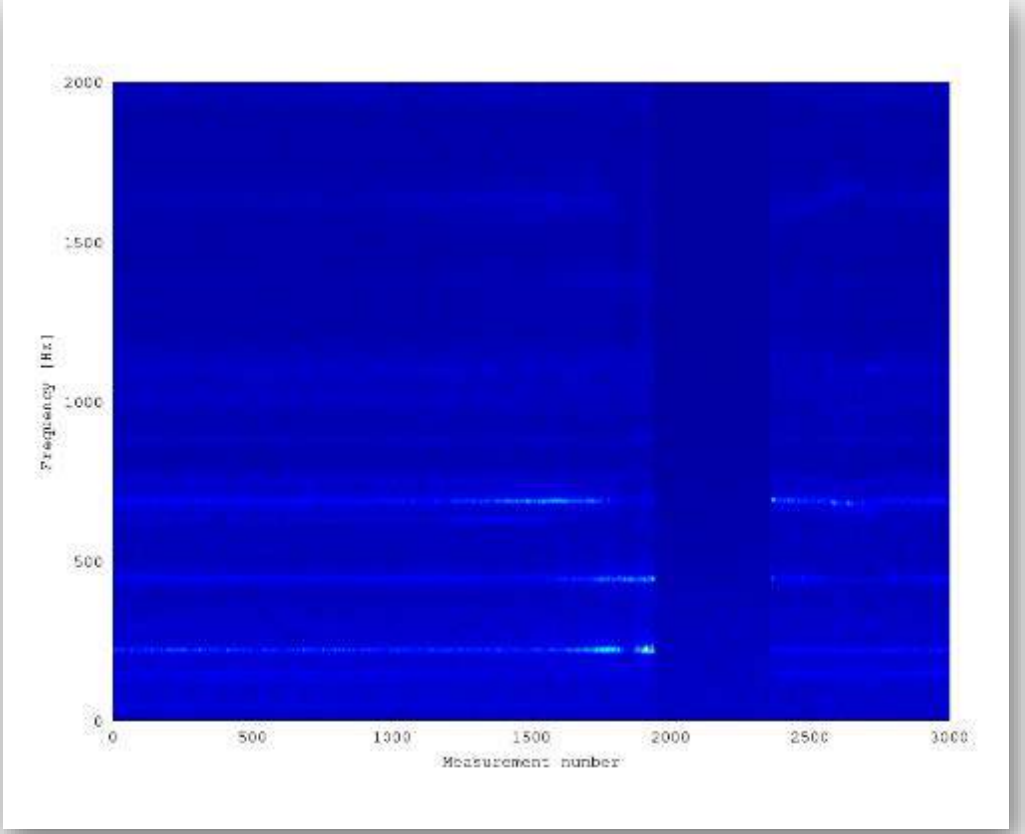
Frequency Sensitive Alarm Setting



Wireless Sensors General Apps

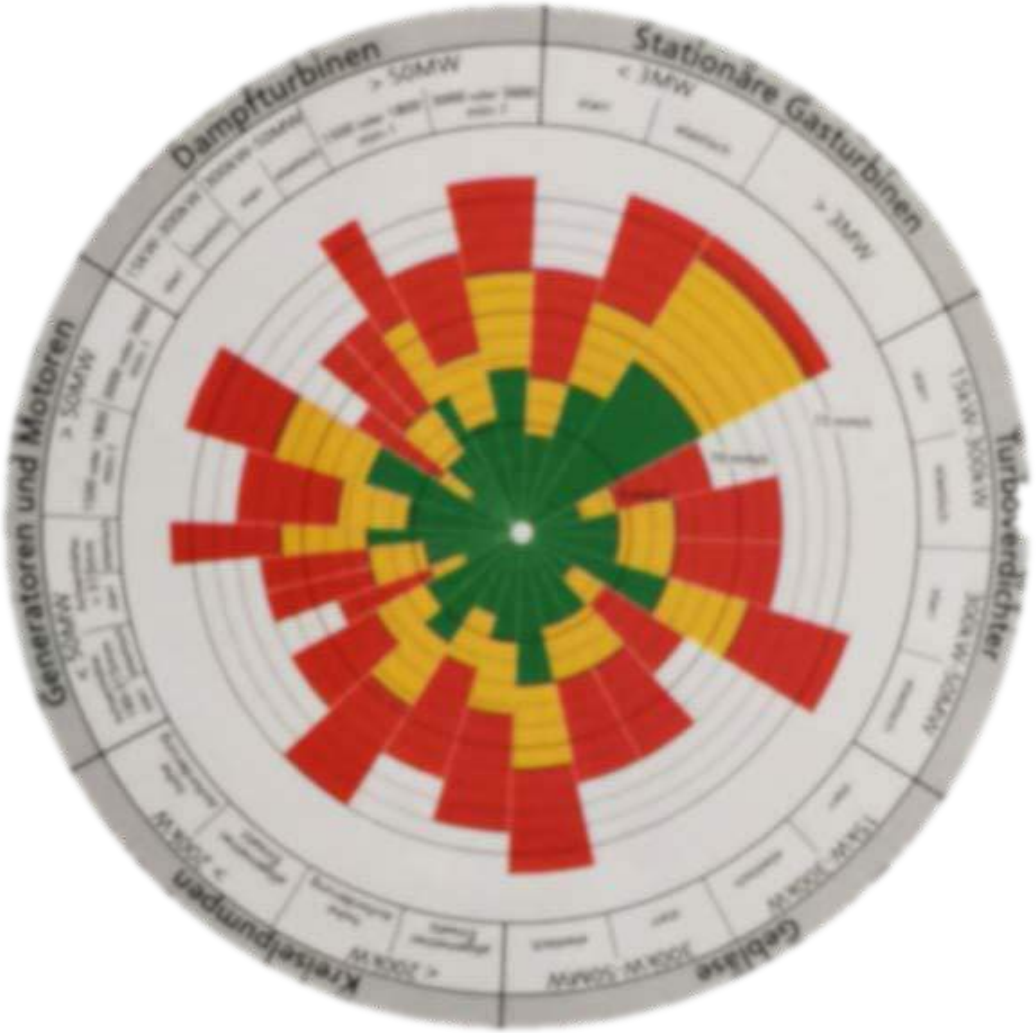
Vibration Examples

Time Frequency Plot



Machine stop due to excess vibration, probably gearbox

Critical Values



PD identifies problems/aging processes

TEAM stresses of the insulation

- **T**hermal, temperature
- **E**lectrical, electric field
- **A**mbiant (environment)
- **M**echanical, vibrations

lead to:

- electrical discharges (PD) which in consequence are an indicator for such stresses
- these indicators are not the cause but the consequence of stresses (TEAM).
- **diagnosis and monitoring analyses causes & effects of defects or aging.**

AIRGAP MONITOR QGAP

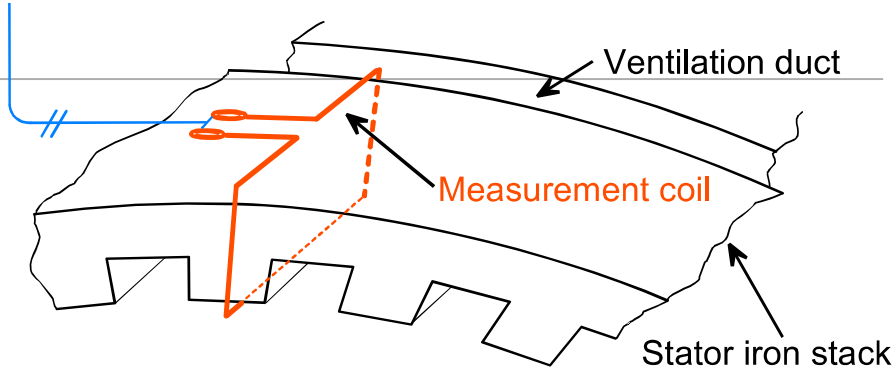
Protects and Monitors
Generators

LIFEVIEW™ QGAP MONITOR

complete information regarding the condition of the magnetic circuits related to the air-gap:

- relative effective static and dynamic deformation of the stator magnetic circuit;
- magnitude and direction of static and dynamic eccentricities;
- magnitude and direction of magnetic pulls;
- air-gap magnetic flux.

QGAP SENSORS



simple and very low cost

Sensor set-up

Easy, minimal intrusion

no direct access to the air-gap necessary; no gluing;

No mechanical disassembling/reassembling;

fast with simple tools

easy to remove.

QGAP SENSORS

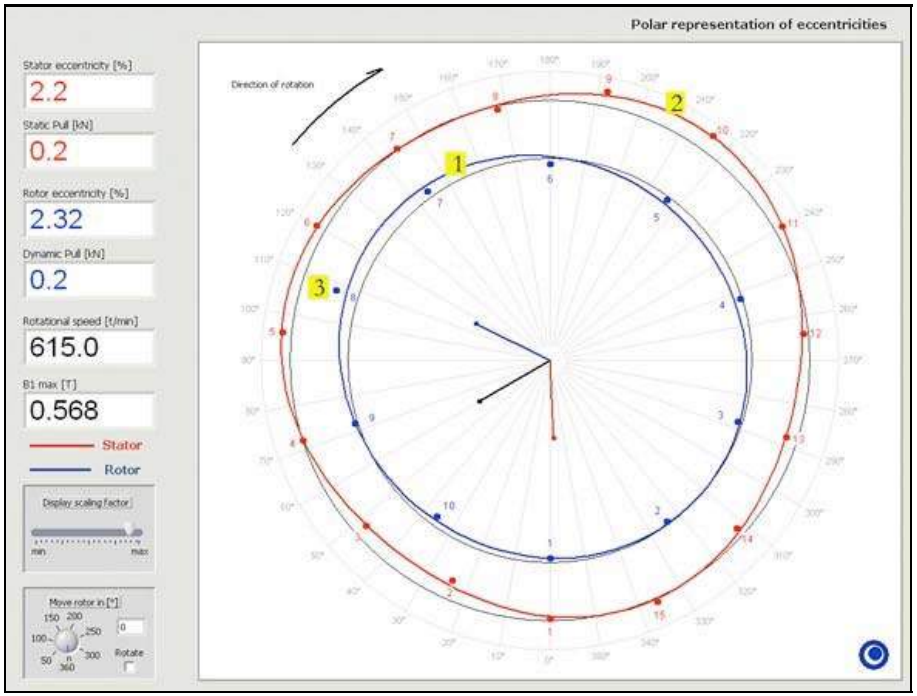
Innovative features of the system:

- low cost sensors
- insensitivity to external conditions (humidity, temperature, etc.)
- measurement of static and dynamic unbalanced magnetic pull;
- capability to recognize deformation of any shape;
- arbitrary number and disposition of sensors
- real-time assessment of air-gap condition
- no influence of the cables on the measurement
- no need of linearization.

monitoring equipment provides a numerical and graphical representation of:

the rotor magnetic circuit state
stator deformation
combination of these two states
harmonic analysis of the deformations.

Machine with 3 Defects (LAB)



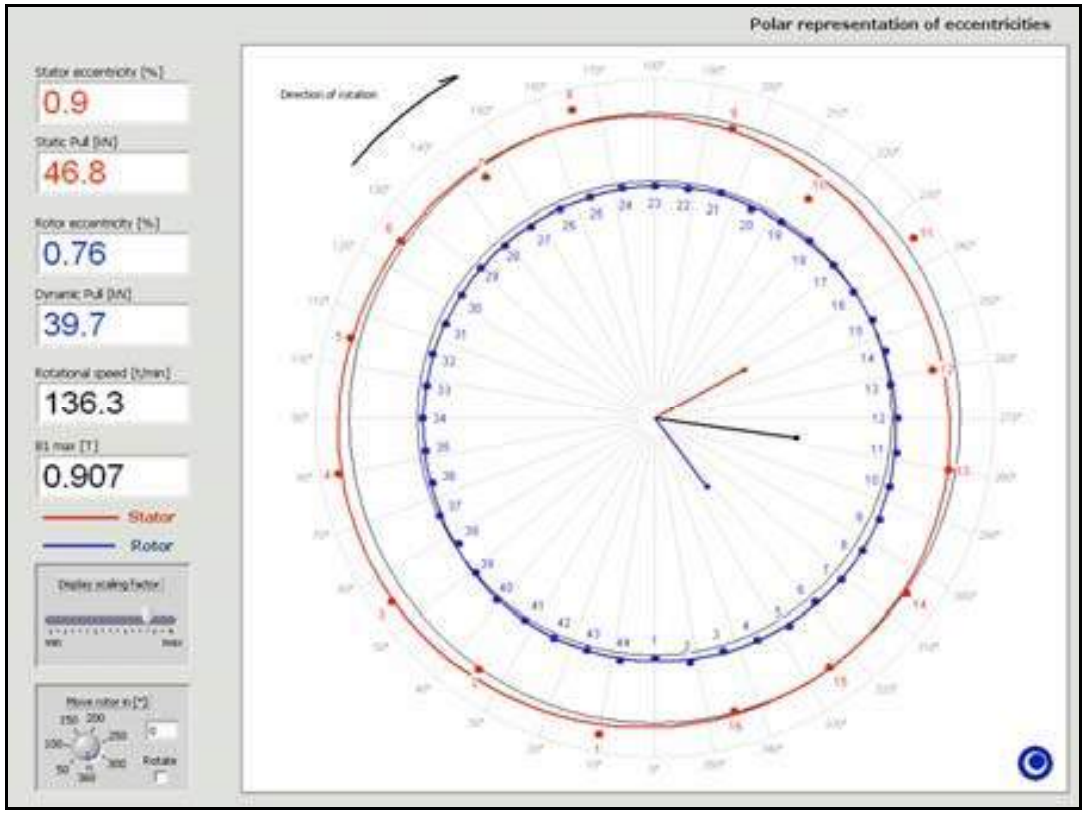
1. Static eccentricity. 2. Third order deformation of the stator bore. 3. Pole n° 8 displaced.

- wrong positioning of the rotor,
- mechanical unbalance,
- mechanical deformation of the stator,
- partial short-circuit of the field coil, magnetic circuit defect

REAL WORLD MONITORING

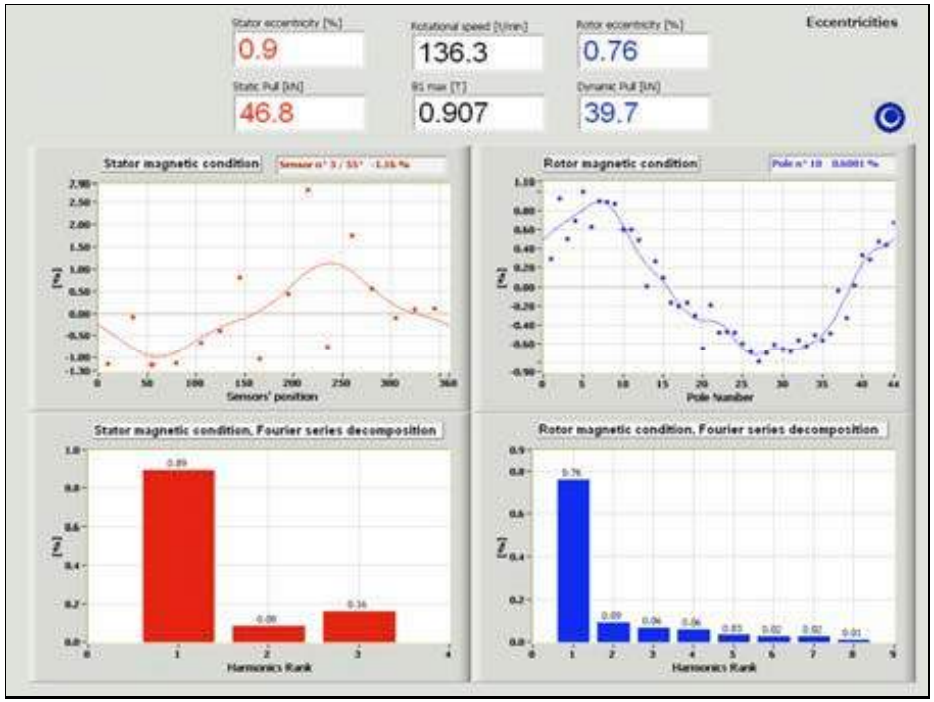
Nominal power	25.75	MW
Voltage	9	kV
Nominal current	2'117	A
Power factor	0.8	
Speed	136.4	rpm
Stator magnetic circuit		
Internal diameter Ø	5'992	mm
Total length	1'371	mm
Ventilation aperture	10	mm
Stacks	60	mm
Air-gap	12	mm

Generator 1



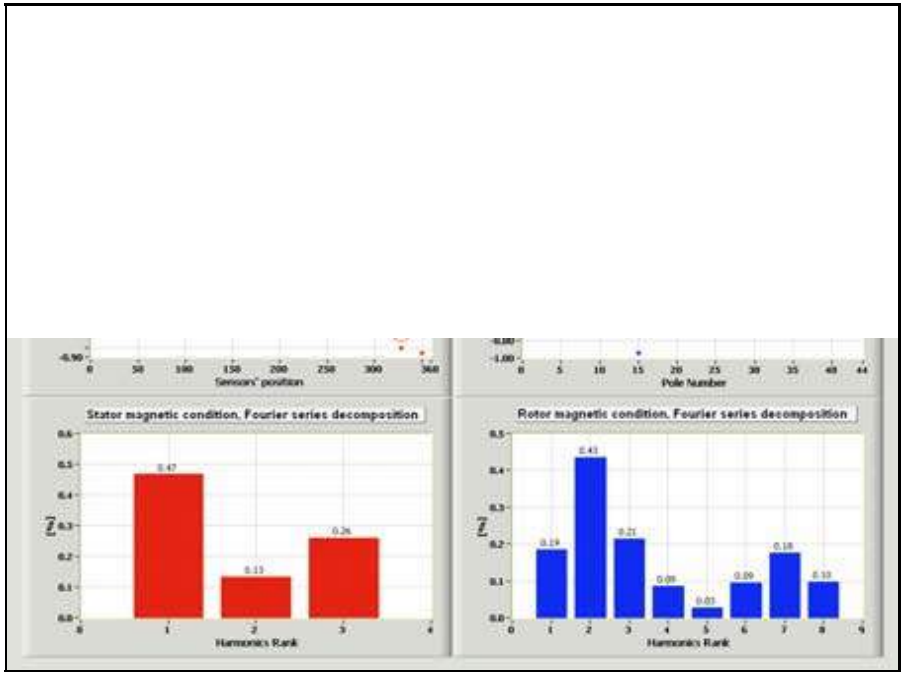
- Slightly deformed stator bore
- Static eccentricity
- No dynamic eccentricity

Generator 1/16 sensors



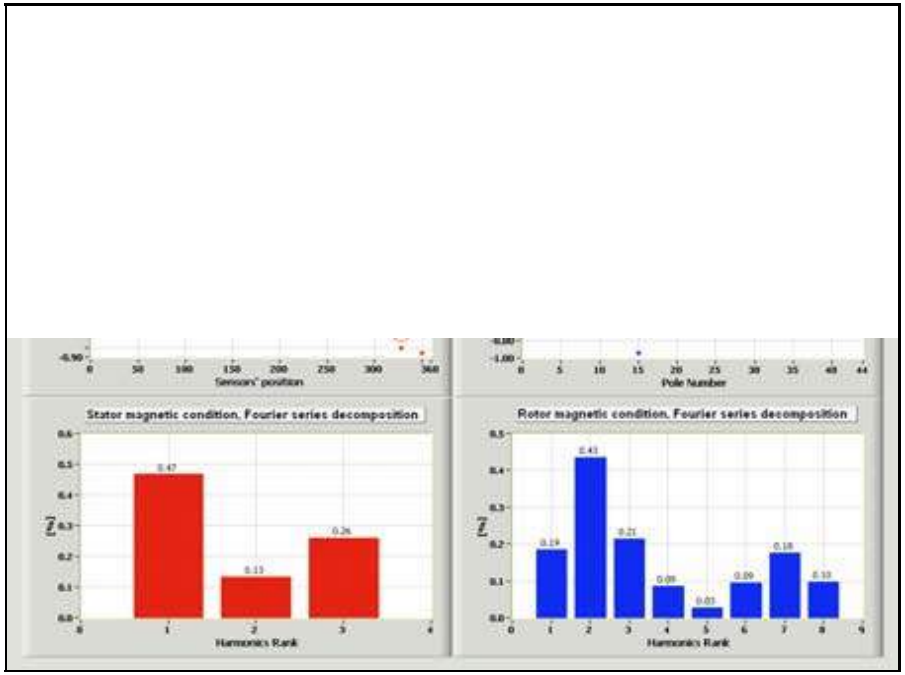
- Slightly deformed stator bore
- Static eccentricity
- No dynamic eccentricity
- Unbalanced magnetic pull

Generator 2/16 sensors



- Slightly deformed stator bore
- No static eccentricity or dynamic eccentricity
- low unbalanced magnetic pull

Generator 2/16 sensors



- Slightly deformed stator bore
- No static eccentricity or dynamic eccentricity
- low unbalanced magnetic pull

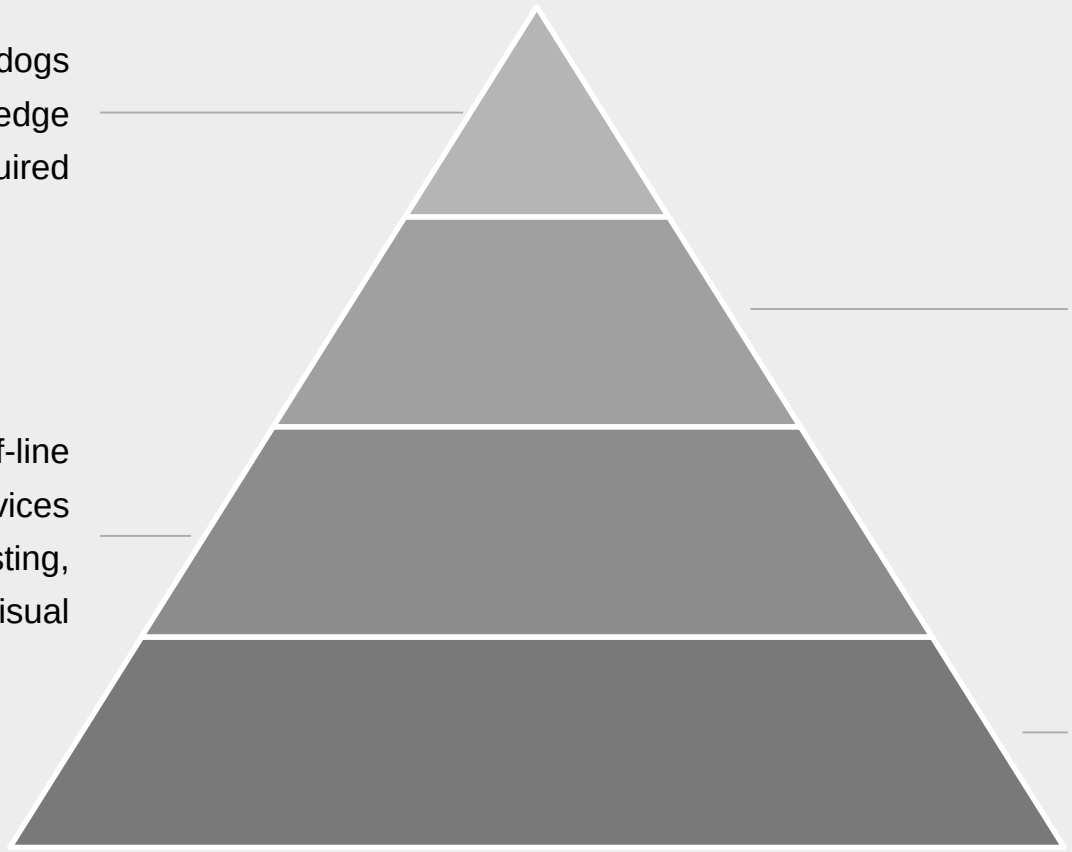
DAQ Units


quartz teq
LIFEVIEW
PSA


quartz teq
LIFEVIEW
DSX


quartz teq
LIFEVIEW
LIVE

Diagnostic Pyramid



LIFEVIEW™ Structure

- Operating History
- Maintenance History

- Inspection Data
- Monitoring Data
- Operating Data

- Expert System
- Stochastic Models
- Data Mining
- Artificial Intelligence
- Pattern Recognition

- Machine Data
- Customer Data
- Document Storage

LIFEVIEW
Field Service

LIFEVIEW
Monitoring System

Remote Diagnostic Support (RDS)

Assessment Support Warnings

100%
Client Information

Mail
Webserver

LIFEVIEW Cloud

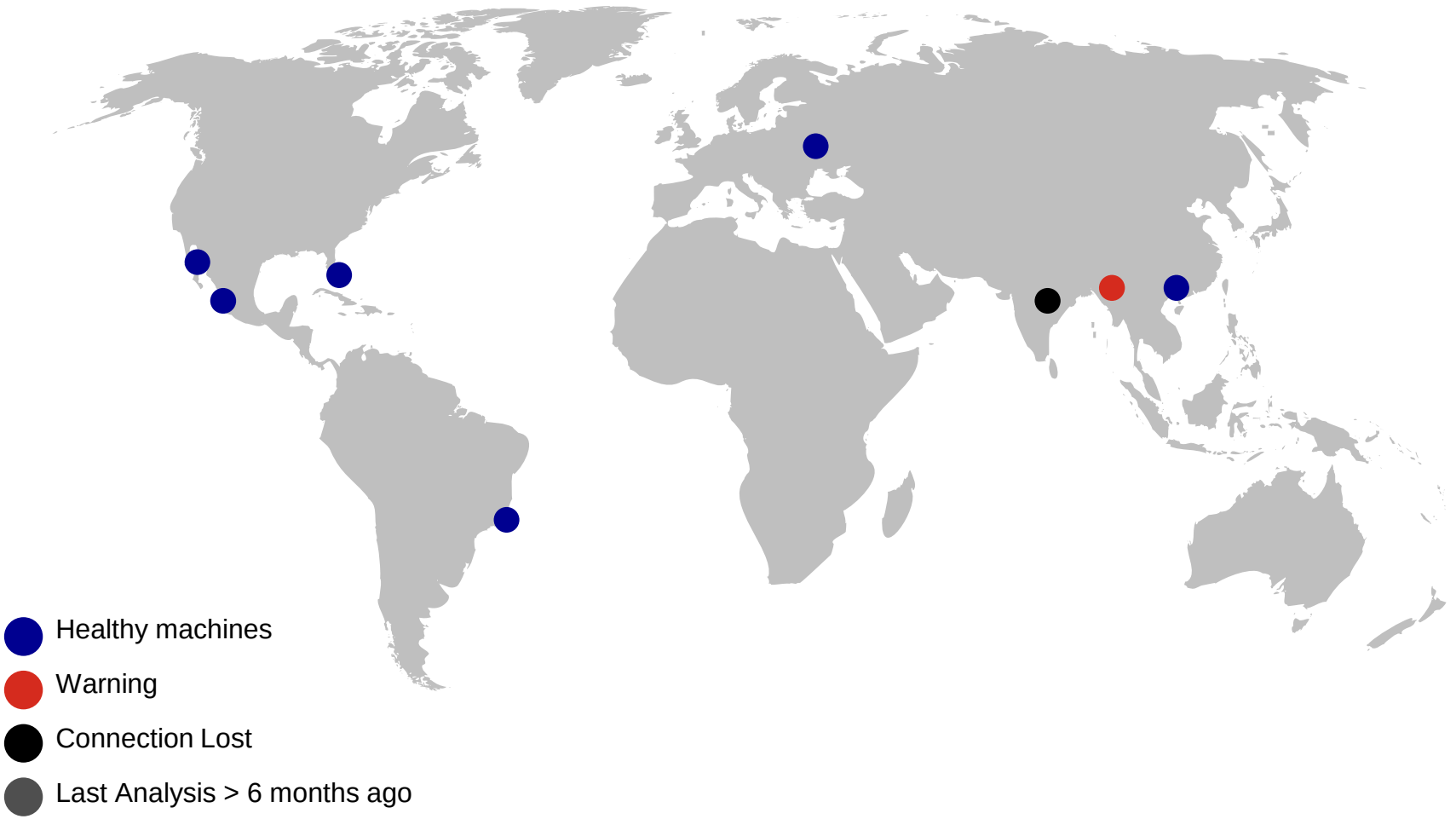
- Ability to add unlimited new devices.
- Set up device information, customer details, emergency contacts and even photos in-situ for each installation.
- An easily understood colour coded alert system.
- Regular and ad-hoc reporting.
- An interactive map showing all installations, including those on alert, in test mode and requiring service.

Cloud Functionalities

Customer:

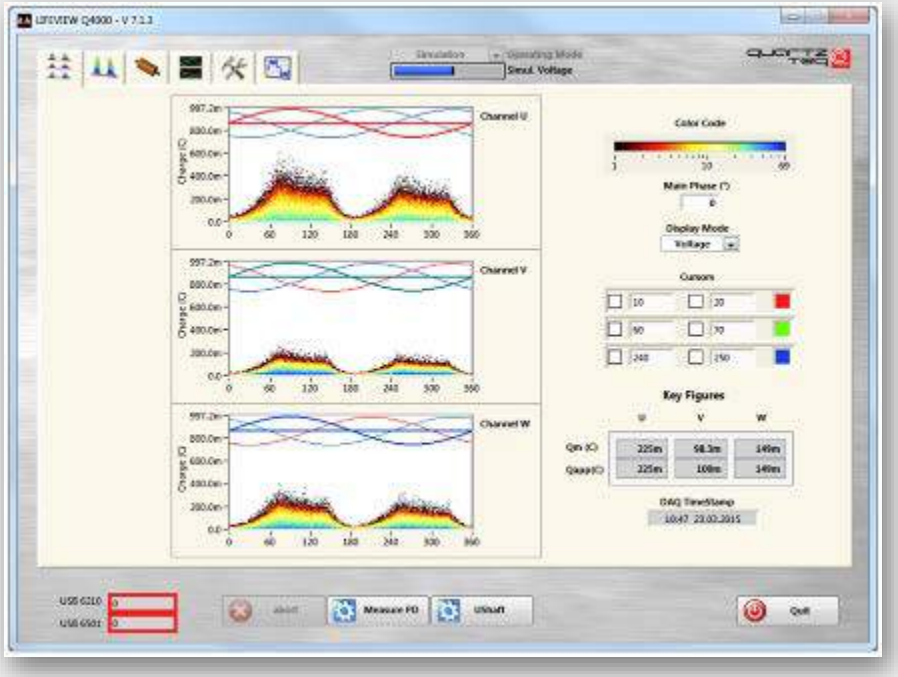
- Immediate access to his own machines
- Status Information: (green :ok, red : warning, black : no signal, orange : last inspection overdue, ….)
- Overview of all machines/powerplant from one location
- The **LIFE**VIEW device can be connected to an internet server, and the users can see the measurement by accessing this server (secure cloud)
- The device is not necessarily connected to a customer local network → no IT security problem. (possible to use GSM, 3G, or customer Network if authorised)

LIFEVIEW Cloud



GUI/Waveshape Analysis

Quartzteq Lifeview Cloud: Machine 1: Remote access



Further Possibilities:

- Simultaneous access of several users to the same machine (e.g. for discussion of results)
- Server storage of values, parameters, alarms, data (machine related raw data is stored locally in each **LIFE**VIEW monitoring unit, and accessible without CLOUD. It can be optionally mirrored on the server).
- Server (CLOUD) stores, reports, drawings, documents and other machine related data.