Key Take Away’s Study Committee A1

Paris 2022

For power system expertise

Seminar 10 November 2022

Content

- Introduction
- General discussion meeting (GDM) held on Tuesday 30th of August 2022)
- Advisory Group (AG) and Working Group Meetings (WG's) held on 31st of August and 1st of September 2022
- Technical Brochures Published in 2022

Introduction

- Study Committee (SC) A1 covers all aspects of rotating electrical machines

- SC A1 is concerned with the international exchange of information, knowledge, practice and experience considering the following technologies based on the application of rotating electrical machines:
  - AG.01: Turbo-Generators
  - AG.02: Hydro-Generators
  - AG.05: Wind Generators and New Technologies
  - AG.06: Large and High Efficiency Motors

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Key Take Aways GDM

- Negative Excitation Current - Synchronous Condensers
- Mechanical damage – Fly Wheel protection
- Effect of operating conditions on Partial Discharge Activity
- Pulse Shape Analysis for Complex PD Pattern Interpretation

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Negative Excitation Current

Paper 10431: Case study for Synchronous Condenser Implementation (-320/+400 MVAr).

Special report 1.3: the capacity of reactive power consumption could be increased to -400/400 MVAr by supplying negative current (depending on the machine type) with marginal cost increase. The question was raised whether the application of negative current was considered.

The use of negative current is frequently applied in the past for salient pole generators. Possible issues and precautions to be taken applying negative excitation current were presented by Voith.

Negative Excitation Current

1. Risk of short circuit between phases of the excitation:
   - Rectifier bridge inversion time: time for the thyristor to change from conduction mode to blocking mode. Approx. 200 ms after zeroing
   - Zeroing field current can be approx. 300ms
   - High precision in the field current measurement is necessary: even a small current can cause “re-ignition” and consequently a short circuit. Use of two excitation transformers will reduce this risk of short circuit between the bridges

Negative Excitation Current

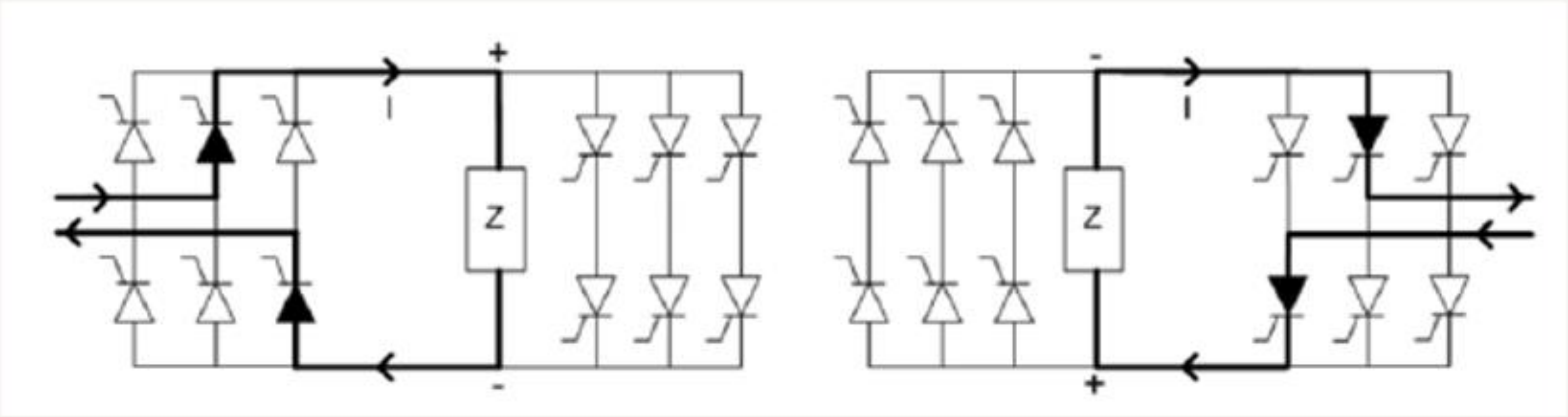


Figure 1: Connection diagram of the positive and negative bridges

Figure 2: Representation of the short-circuit between bridges, if the thyristors start conducting simultaneously.

Negative Excitation Current

2. Losing synchronization

- The “coupling” (magnetic stiffness) between rotor and stator will be quite weak and the load angle will fluctuate. Even considering a constant and very low active power (0.02 x MVA), variations of the load angle due to the inherent voltage variation of the electrical system are unavoidable. Consequently, (large) currents will be induced in the damper winding. The unit will remain synchronous due to reluctance, but the load angle can be large and with low damping. Turbo generators however have a very low reluctance
- The control must be fine tuned to determine how far the field current can be reversed. The ideal would be to invert the field current but keeping some safety margin against slipping.

Mechanical damage – Fly wheel protection

Special report 1.4: Increasing penetration of renewable energy results in new components in the grid such as synchronous condensers. What are the advantages and challenges?

Mechanical protection of the fly wheel in case of failure should be assessed. The results of a project concerning this topic were shared by ABB and discussed.

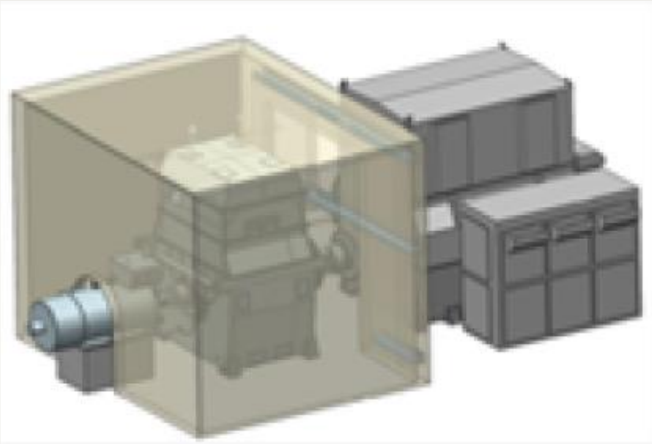
Mechanical damage – Fly wheel protection

Risks:

- Hugh amount of energy is stored in the Fly Wheel (FW)
- Potential catastrophic failures need to be considered
- Two main risks were identified:
  - Loose rotor event
  - Burst of FW

Risk control:

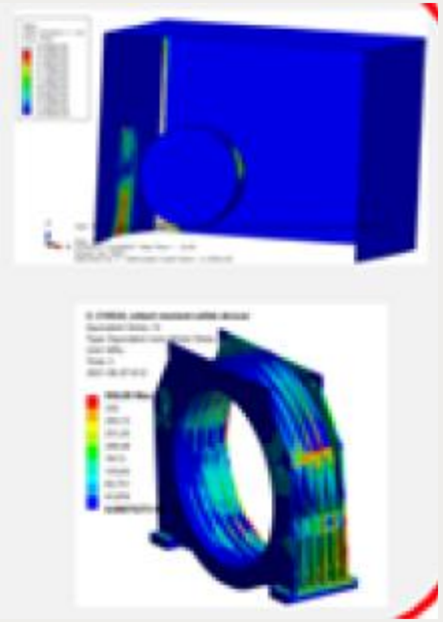
- External safety enclosure



Mechanical damage – Fly wheel protection

Assessed load cases:

1. FW jumps out of bearings
2. Disc failure creating a projectile

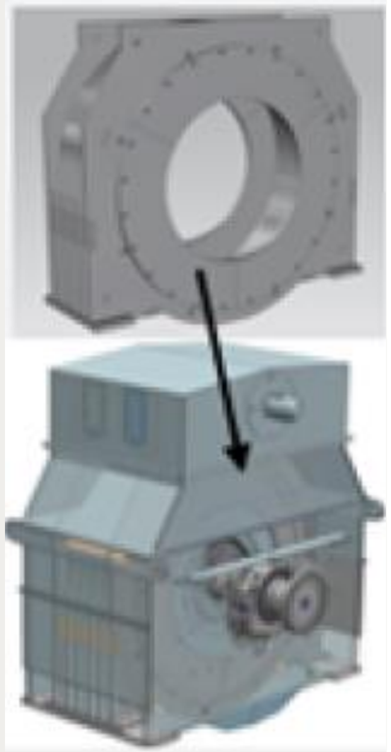


Calculations:

- FW burst case
- Cage strength
- Anchoring stress
- Foundation stress

Manufacturing of protective enclosure:

- High quality forged steel
- Divide shaft and FW
- 2x “tandem” FW disc
- Utilize an integrated protection cage



Operating Condition versus PD activity

Paper 10125: Construction of the Partial Discharge Measurement History According to IEC 60034-27-2

A paper was presented showing the results of on-line PD measurements performed over a two-year period of operation of a new installed generator. The authors concluded that the results showed a strong relation between PD magnitude and relative vibration.

IRIS/Qualitrol showed their experience from >5500 continuous on-line PD monitoring systems installed on stator windings. The PD data was tagged with the operational and environmental information from the plant computers.

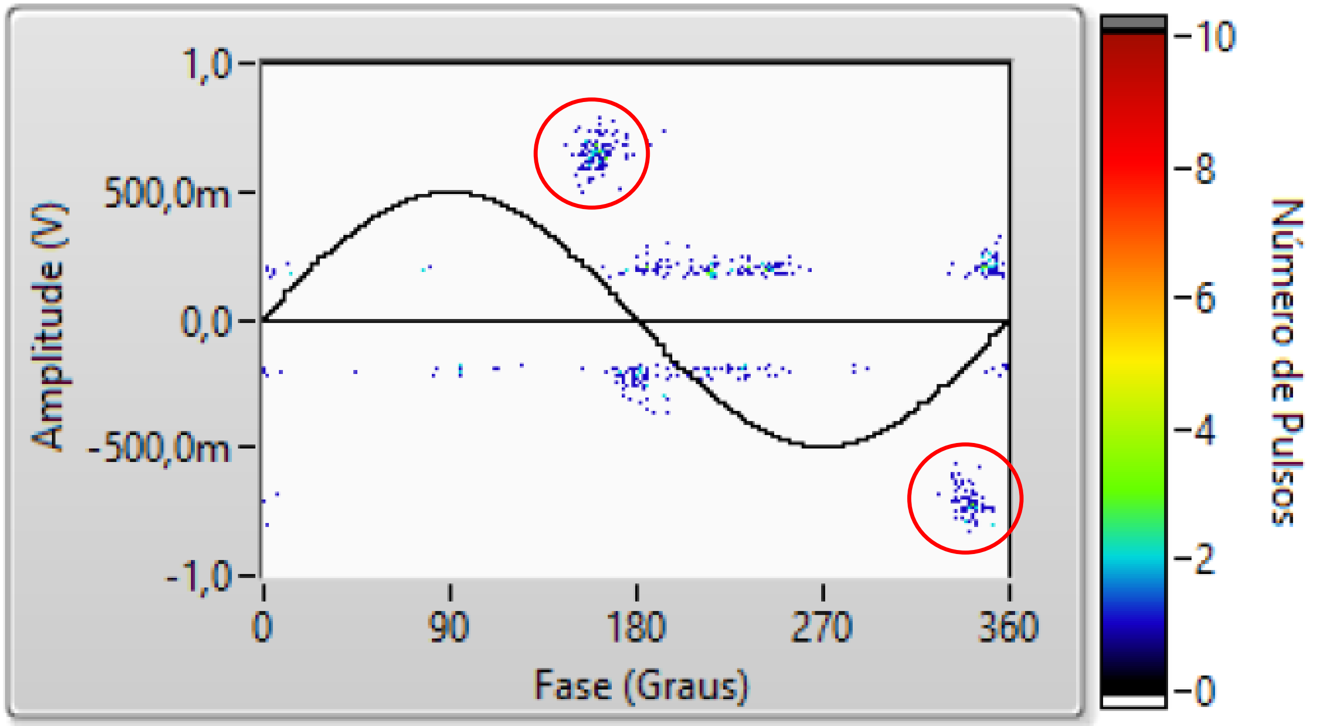
Operating Condition versus PD activity

Observations from IRIS/Qualitrol:

- The natural variation of the PD magnitude is ± 25%, even with the same operating conditions. Changes less than 25% may mean nothing
- Humidity can have a strong effect on stator endwinding PD
- With moderate or low PD magnitudes, MW, T and humidity have little effect
- The effect of load, stator winding temperature & humidity can help identify a dominant ageing process. If 2 or more processes take place (which is common in older machines), no strong conclusions can be made
- IRIS has never seen a causal relationship between bearing vibration and PD activity

Operating Condition versus PD activity

Discharging from a poorly bolted joint on the machine terminals?



(a) Phase A PRPD – before.

Pulse Shape Analysis for complex PD patterns interpretation

Paper 10125: Construction of the Partial Discharge Measurement History According to IEC 60034-27-2

Special report 2.3:
A paper was presented showing the results of on-line PD measurements performed over a two-year period. The authors and others were invited to comment on the assessment described in the paper

Cepel raised the question: How closely, or not, do the phase resolved PD patterns in one of the informative annexes of IEC TC 60034-27-2, correlate with actual PD test results?

Pulse Shape Analysis for complex PD patterns interpretation

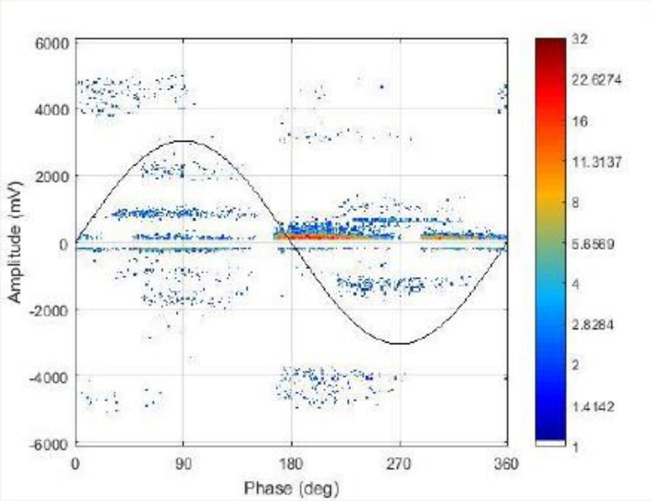
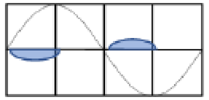
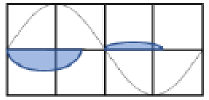
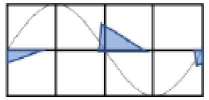
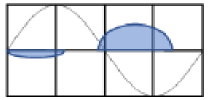
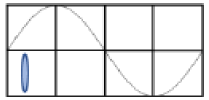
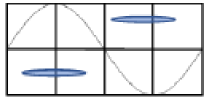


Table 2 - Typical PD Patterns in Rotating Machines.

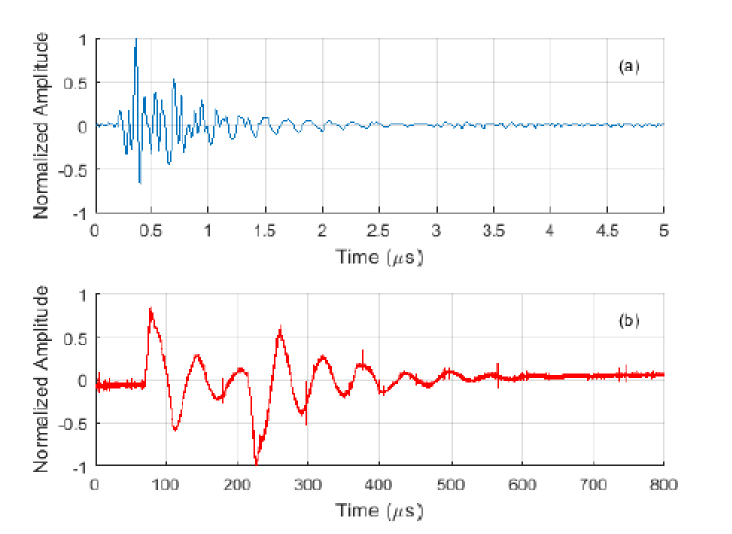
PD Source	Pattern Description	Typical PD Pattern
Internal Voids and Internal Delamination	Positive and negative pulses equally distributed in the two half-cycles, with low to medium amplitudes.	
Delamination Between conductors and insulation	Negative pulses of greater amplitude and with greater concentration in the positive half-cycle, with higher amplitudes.	
Slot Discharges	With a characteristic triangular pattern, there is a concentration of positive pulses in the negative half-cycle, with medium to high amplitudes..	
External PD at the stress control coating	There is a concentration of positive pulses in the negative half-cycle, with medium to high amplitudes.	
Surface tracking	Usually accompanied by the pattern, there is formation of a vertical cloud of negative pulses in the positive half-cycle, with very high amplitudes.	
Gap Discharges	Horizontal clouds in both half-cycles, with medium to high amplitudes.	

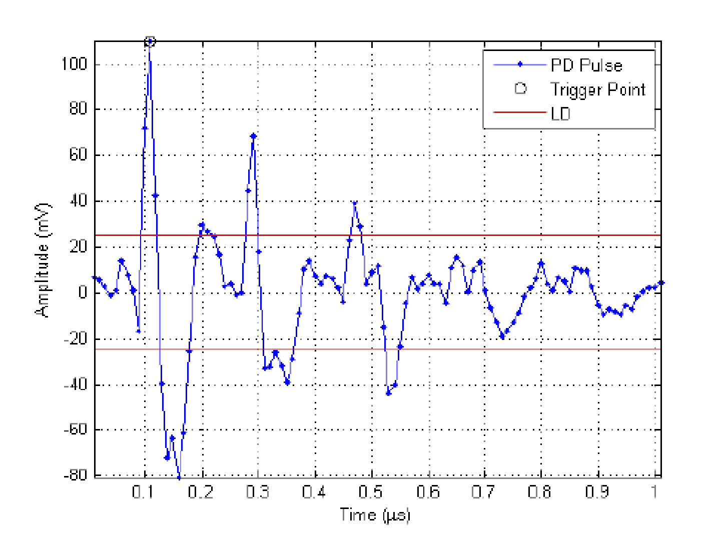
According to IEC TS 60034-27-2 PD pattern interpretation is difficult due to multiple PD sources, cross coupling between phases, noise and interferences, including thyristor signals.

Pulse Shape Analysis for complex PD patterns interpretation

According to the respondent the interpretation difficulty can be overcome by more sophistical signal processing techniques like “pulse shape analysis and classification”

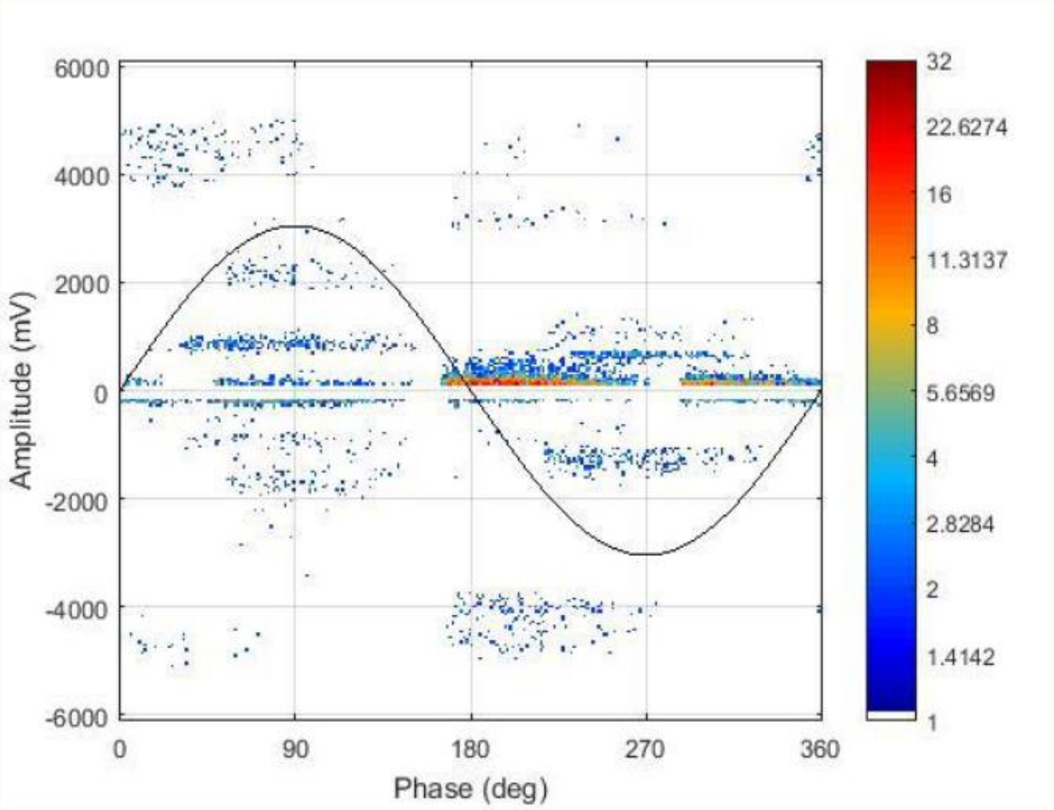
Different PD sources have different pulse shape:

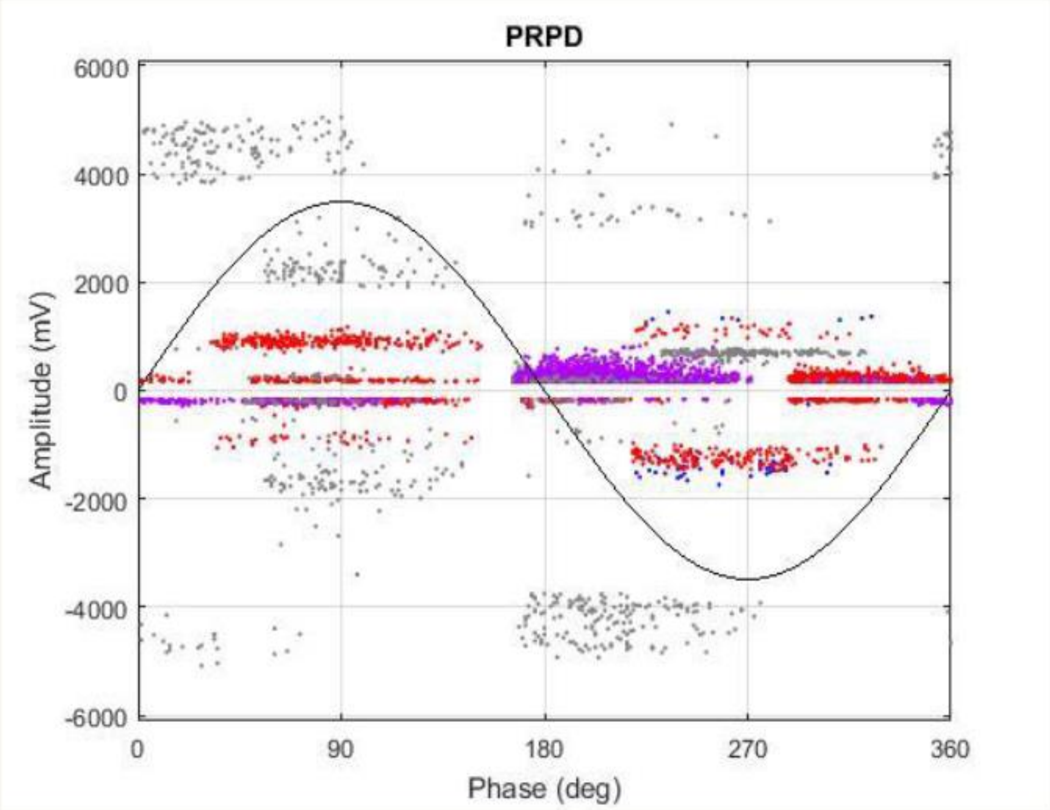




Pulse Shape Analysis for complex PD patterns interpretation

Example: PRPD pattern of a 13,8 kV Hydro generator stator winding



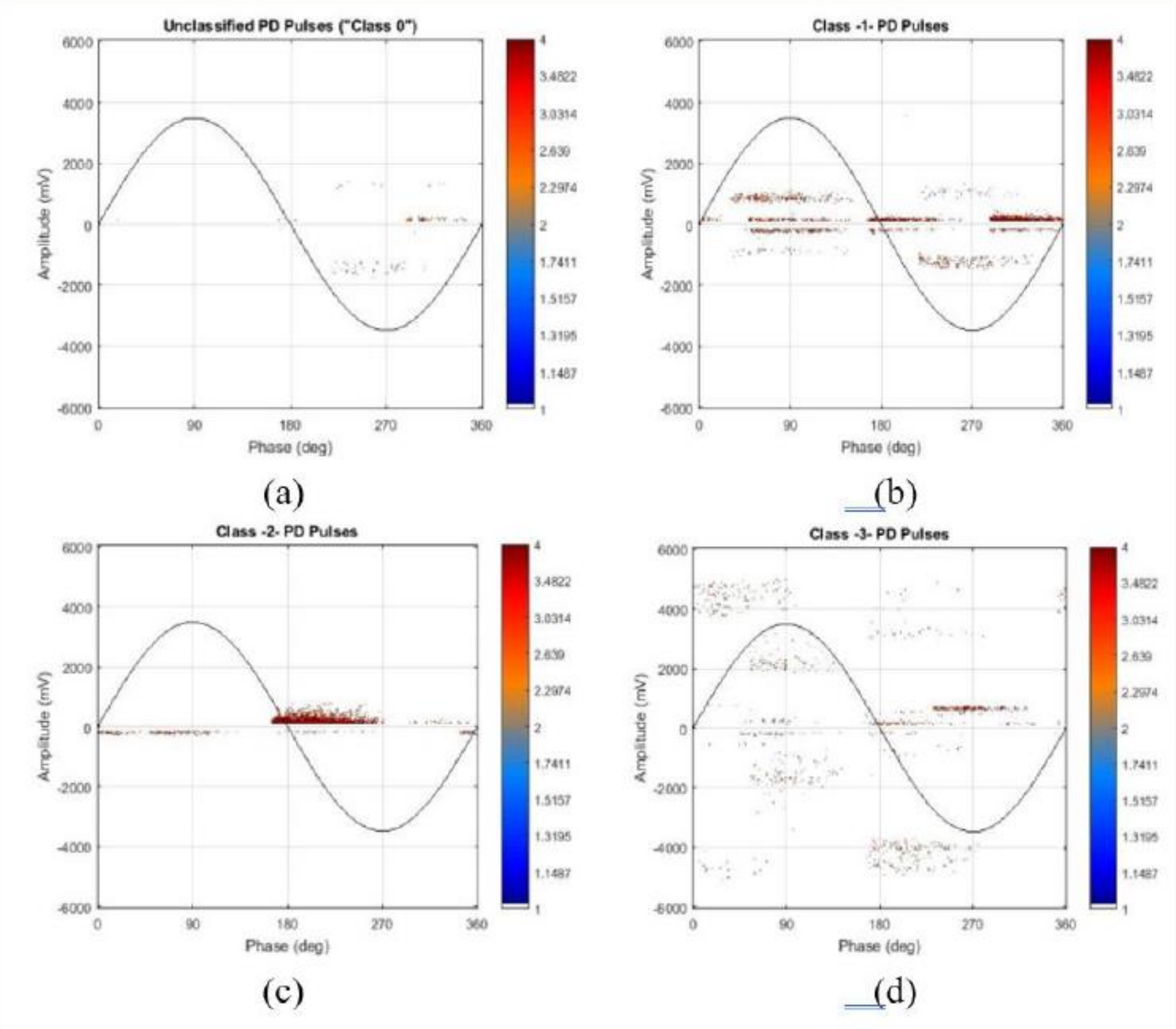


Pulse Shape Analysis for complex PD patterns interpretation

Due to application of pulse shape analysis one PRPD patterns results in four PRPD patterns resulting in an easier interpretation:

(b): gap discharges

(c): external PD at stress control coating



Pulse Shape Analysis for complex PD patterns interpretation

Pulse shape analysis is applicable in the HF frequency range

Band	f (MHz)	Characteristics
LF/MF	< 3	• Processes pulse envelopes • Necessary calibration • Unit: pC • Very sensitive to external noise in the field • Very good sensitivity to PD along the winding
HF	3 – 30	• Processes pulse waveforms • Calibration not allways possible • Unit: pC or mV • Good signal to noise ratio in the field • Good sensitivity to PD along the winding
VHF	30 – 300	• Processes pulse wavefronts • Impossible calibration • Unit: mV • Very good signal to noise ratio in the field • Little sensitivity to PD along the winding

Key Take Aways AG & WG meetings

- WG A1.58 Selection of Copper versus Aluminium Rotors for Induction Motors
- WG A1.70 Dielectric Loss Factor measurement on Stator Windings

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WG A1.58 Selection of Copper versus Aluminium Rotors for induction motors

Working group has investigated what grounds exist for choosing copper or aluminum as cage material in asynchronous cage induction motors.

Results:

- Owners/users don't really care
- Manufacturers chose according to their production capabilities
- Cost of material and process is further of influence

Issues with report:

- Statement about availability of materials in the long term (copper much more problematic than aluminum) is missing
- Environmental impact is being downplayed (particularly for copper)
- Impact choice on efficiency and therefor operational cost not addressed

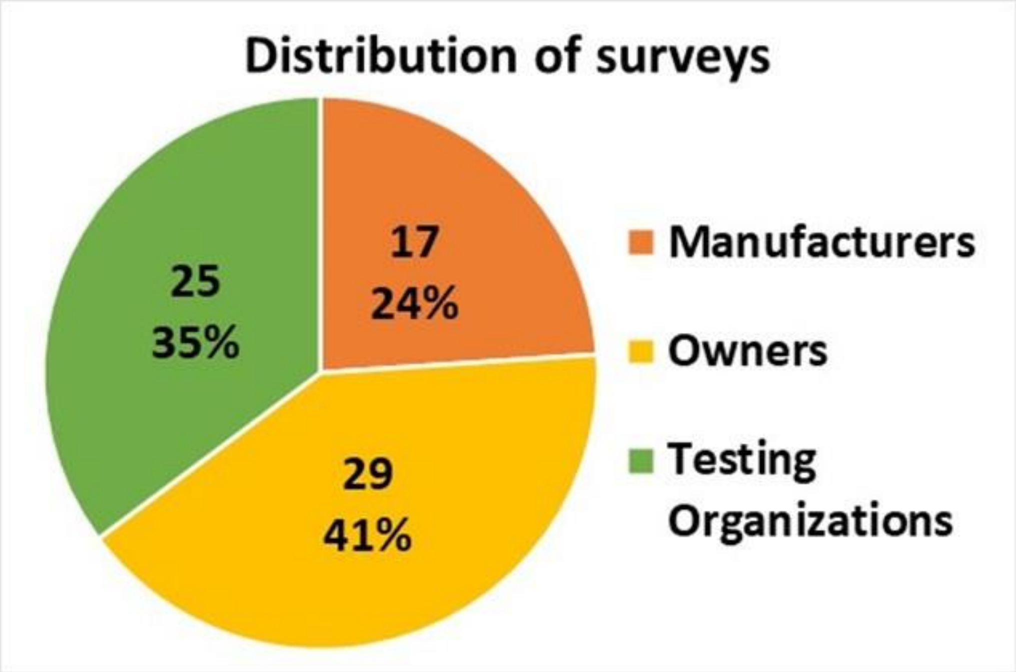
Response Survey

Received	
Total number of filled surveys	71
Number of measurement sets	4466
Number of countries of manufacture	32
Manufactured (year)	1950 - 2021
Voltage (kV)	1,1 - 27
Power (kVA/kW)	129 - 1992000
Core length (mm)	300 - 7900

WG A1.70 Dielectric Loss Factor Measurements on Stator Windings

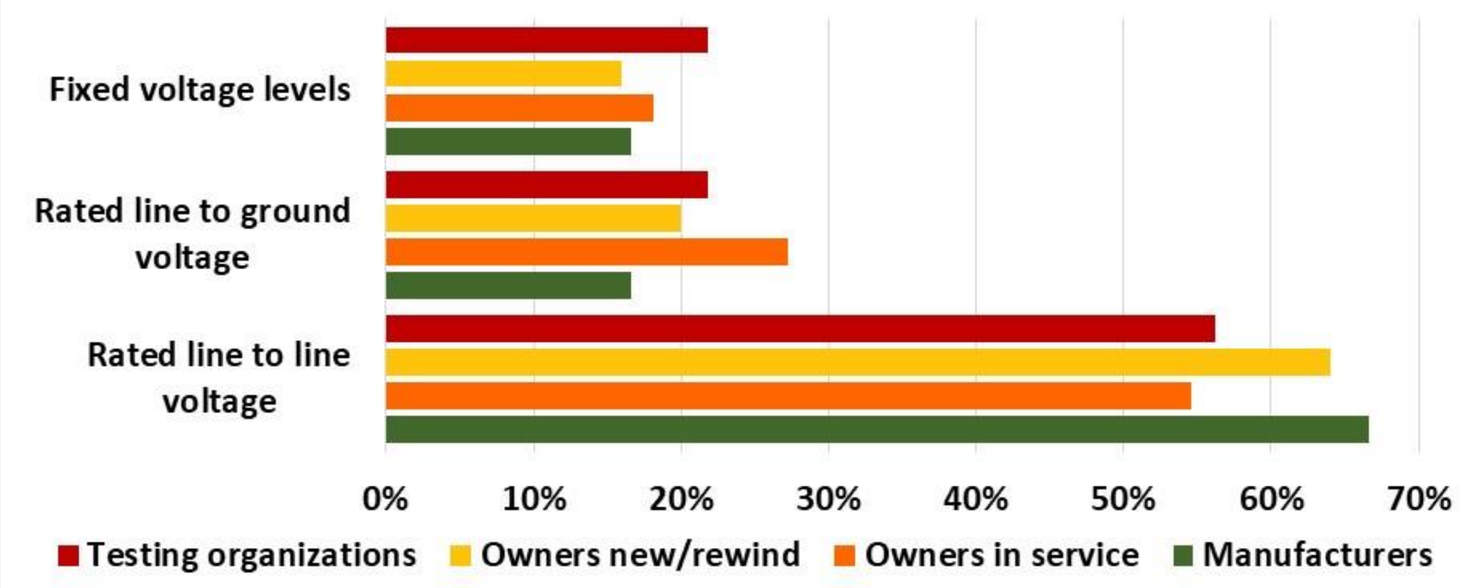
Response Survey

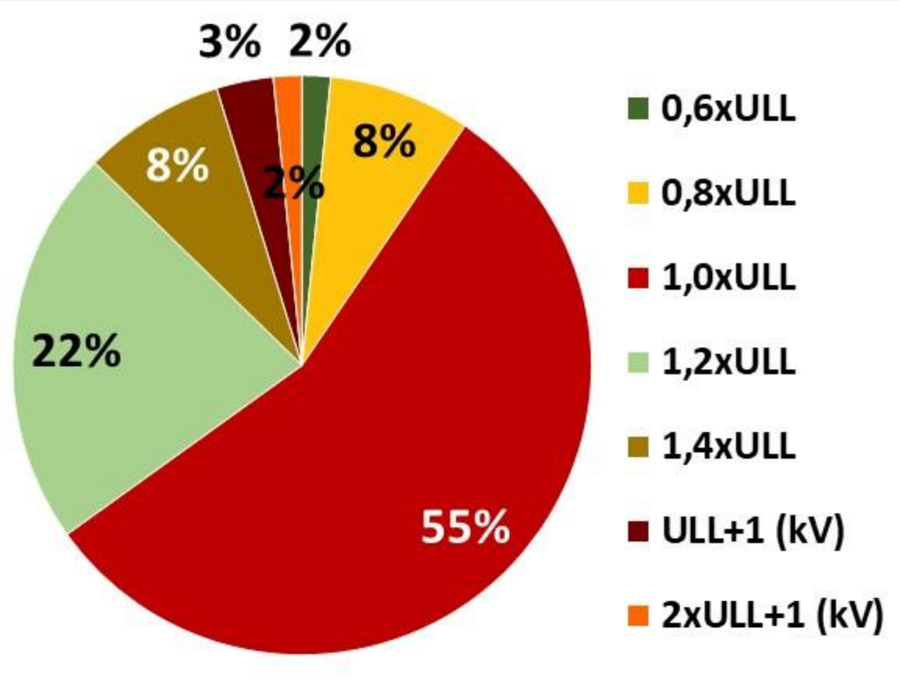
Kind of questionnaire	Number of filled questionnaires
For testing organizations (T)	25
For users / owners (O)	29
For manufacturers (M)	17



WG A1.70 Dielectric Loss Factor Measurements on Stator Windings

Response Survey – Used Voltage base and Final Voltage Levels





For 90% of the responses related to U_{LL} the applied final voltage level is ≥ I,0 U_{LL}

Technical Brochures published in 2022

- TB 860 Guide for Cleanliness and Proper Storage of Generators

  January 2022

- TB 878 Guidance on High-Speed testing of Turbo Generator Rotors

  August 2022

- TB 879 Guideline on Testing of Turbo and Hydro Generators

  August 2022

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THANK YOU FOR YOUR ATTENTION