3- Level Strategy for Predictive Maintenance of the Insulation Status of Critical Generators and Motors

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The Industry is standing on rotating machines (and growing)

- Example:
  US Steel Slovakia: steel production plant
  4,5 mil. tons of steel per year; 10 000 employees

- **30 000 rotating machines-** from LV motors to big 6kV motors

- Many of them with high criticality for the production processes

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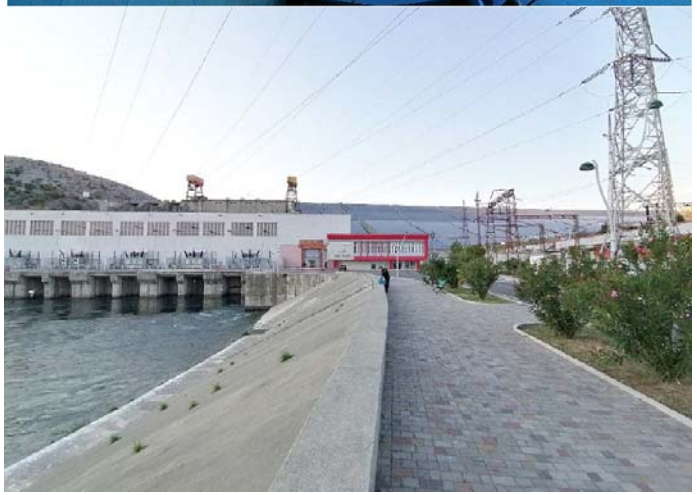
Power Generation with highly critical machinery

- Example:
  Hydro Generators

- **The generators are moneymakers**
  - most valuable and critical assets of the company

- Uncontrolled failure can cause collateral damage
  to the asset, loss from no generation, high replacement costs



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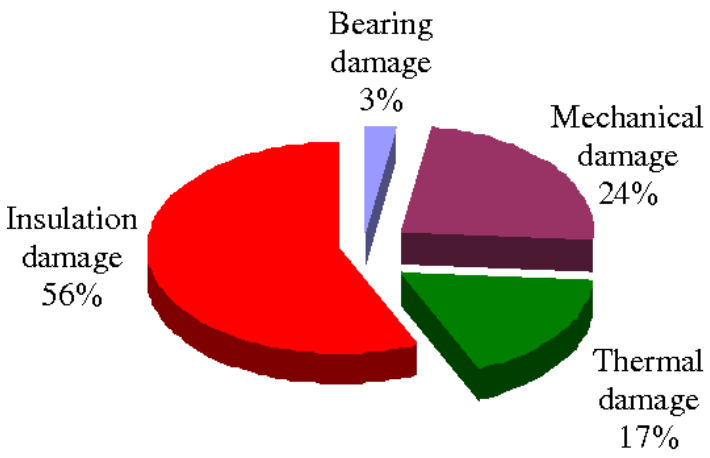
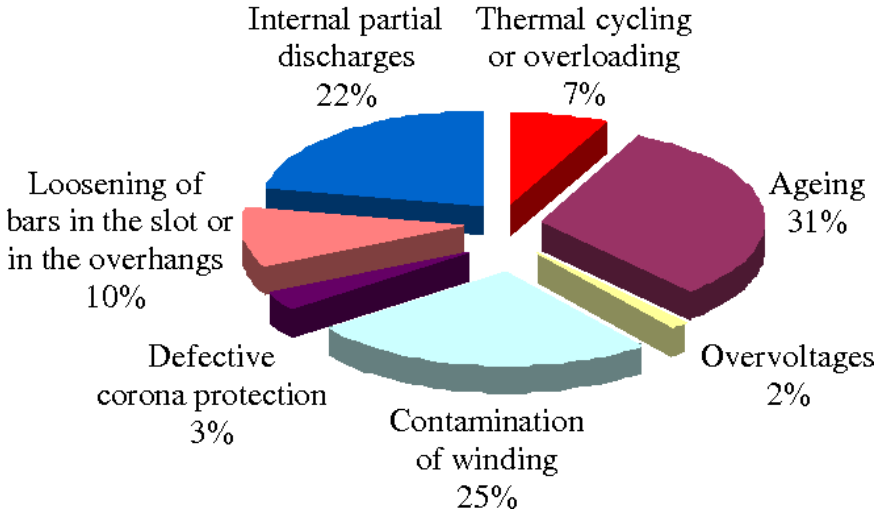
Why testing/ monitoring the stator winding insulation status of critical motors and generators?

Source: CIGRE Study Committee SC11, EG11.02, “Hydrogenerator Failures – Results of the Survey“, (2003)



Damages leading to failure



Root causes of insulation damage

- Electrical diagnosis (static Baker testing + conventional Partial Discharge) of the stator winding is the most important predictive maintenance measure
- Vibration diagnosis detects only 30% of failure root causes

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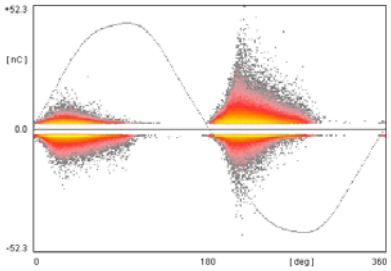
Partial Discharge Diagnosis (offline and online)

- Established and proven method for testing and monitoring of the insulation status of MV and HV assets and components, including rotating machines.
- The insulation of stator windings is by design not PD-free, but the insulation system is considered to be PD-resistant.
- However the impact of so called TEAM stresses in combination with possible production inperfections can lead to a failure mechanism evolving in a critical position of the insulation system, which might lead to a critical insulation deterioration within just a few months.
- The advantage of HF-methods, like PD-diagnosis is the possibility to detect insulation deterioration in an early stage, which allows to perform partial repairs in time and avoid uncontrolled outages.



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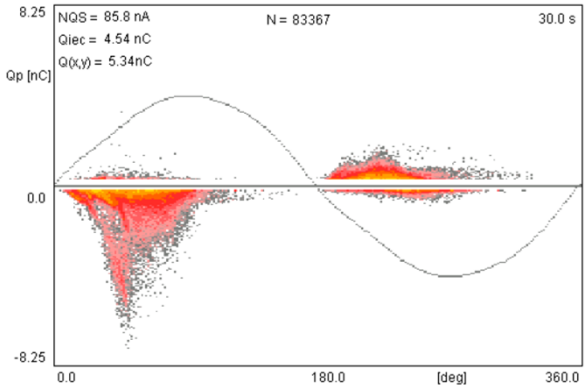
Each failure mechanism has its own fingerprint

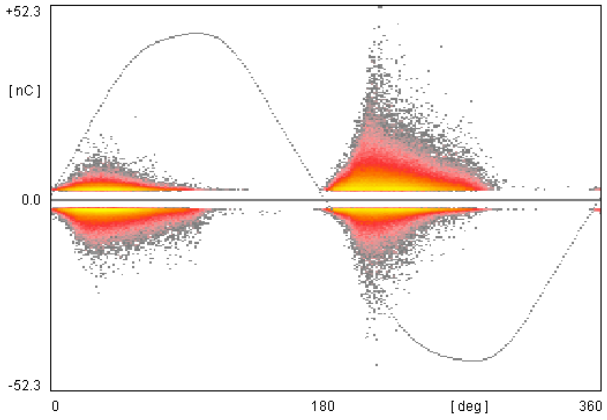
- Another advantage of PD-diagnosis (offline and online) is the fact, that each of the known failure mechanisms in the stator winding insulation system has their own fingerprint in form of so called PRPD (Phase Resolved Partial Discharge Patterns).
- Therefore the PD-diagnosis can not only detect insulation deterioration in an early stage, but can also give an indication about the failure mechanism and the position within the insulation system, in which the degradation occurs.

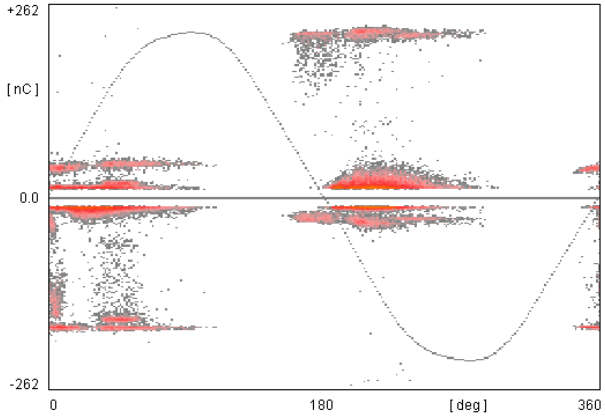
PRPD-examples:



Conductor bound delamination

Slot exit discharges (early stage)





Slot exit discharges (final stage)

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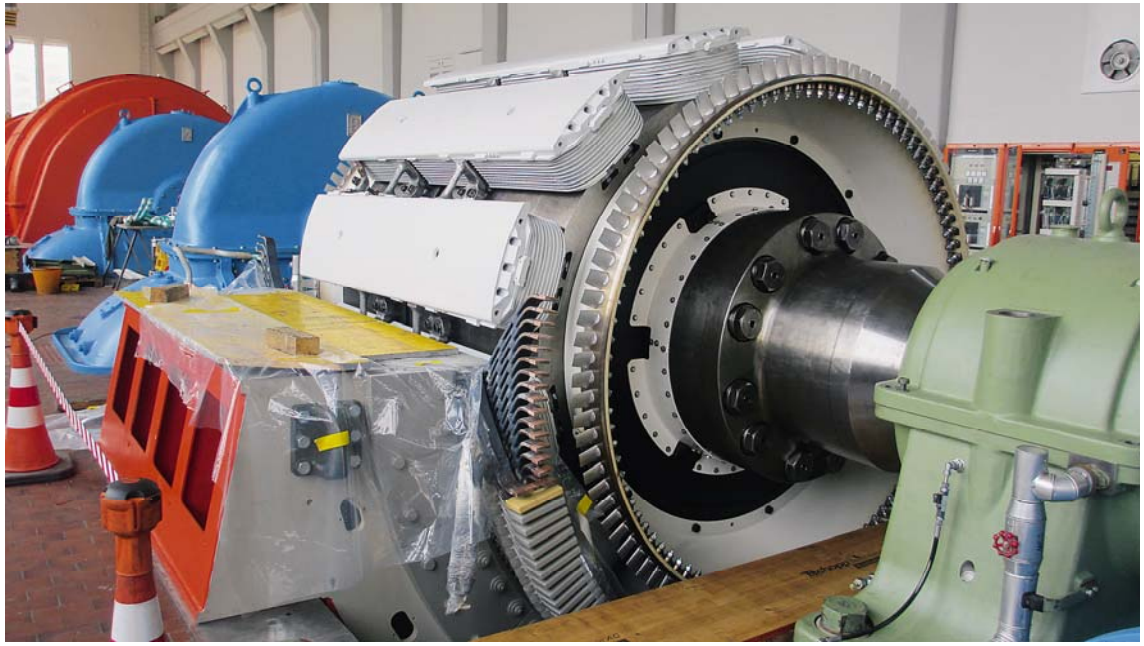
Level 0

FAT testing of the critical rotating machine (procedure identical to Level 1) - to be used as base measurement for future comparison and trending



Pictures source: https://www.andritz.com/

Level 1

Offline Testing of critical motors/ generators (f.e. every 2 years; first offline inspection ideally 6-12 months after commissioning)

	Test	What do we test ?
1.	**Visual inspection of the overhang and the slot exit**	Contamination, PD traces, Status of field grading tape at the slot exit, corrosion
2.	**Winding resistance and Inductance**	Balance between phases, connection issues
3.	**Insulation resistance** and **Polarization index**	Groundwall insulation, contamination
4.	**Step Voltage Test**	Groundwall insulation at higher stress
5.	**Surge test**	Turn to Turn and Phase to Phase insulation
6.	**Partial Discharge and Tan delta testing**	Groundwall insulation deterioration in early stage with identification of failure mechanism; aging of insulation

Baker ADX

ICMflex

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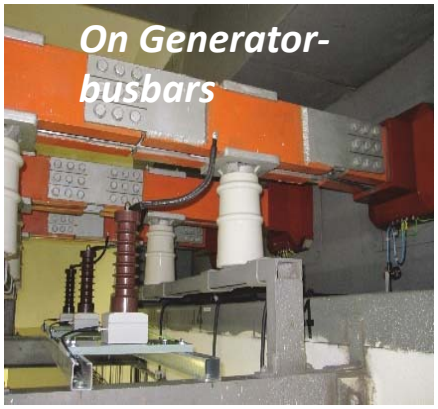
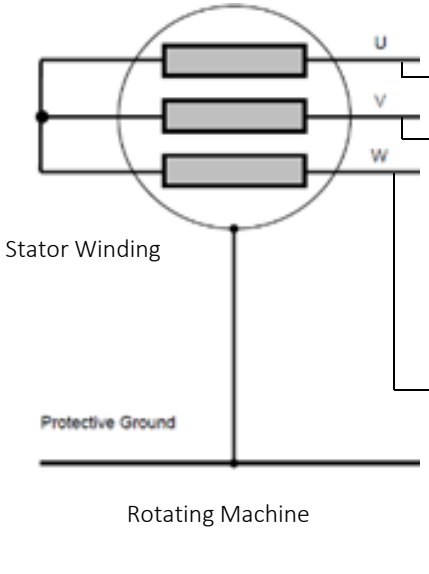
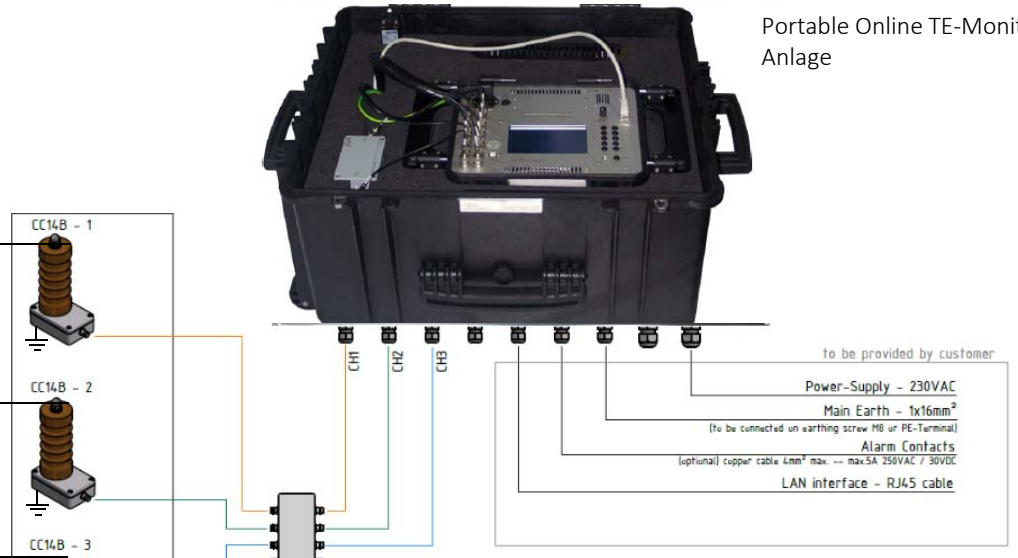
Level 2 (in combination with Level 1)

Online PD spot testing/ temporary monitoring on preinstalled coupling capacitors, e.g. every 6 months, combined with a full offline inspection every 4 – 5 years.



Examples of coupling capacitors installations





Coupling Capacitors

Portable Online TE-Monitoring Anlage

Degradation of main insulation in early stage, including fault mechanism identification.
Trending: Qp, NQS, PRPD

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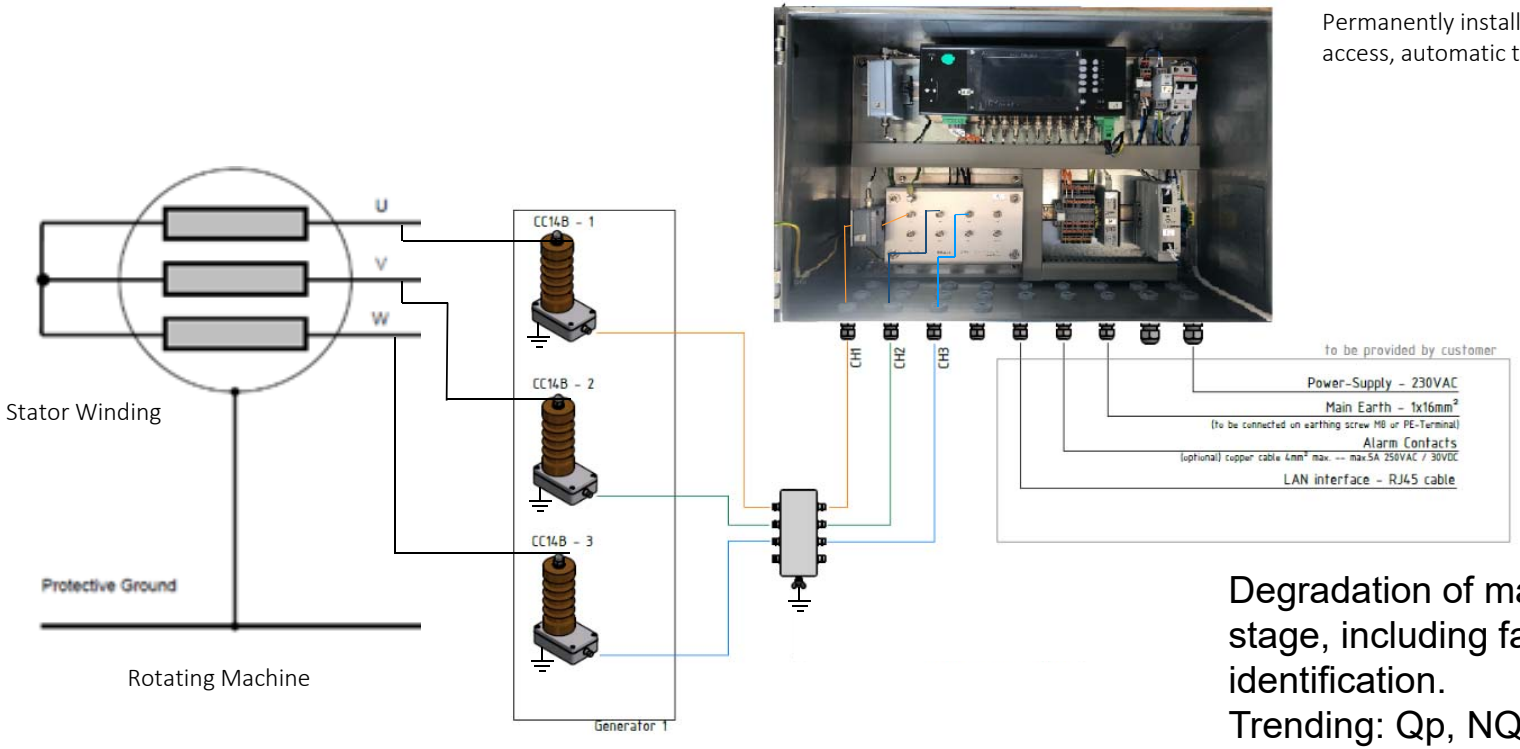
Level 3 (in combination with Level 1, instead of Level 2)

Permanent Online PD Monitoring on preinstalled coupling capacitors
combined with a full offline inspection every 4 – 5 years.



Permanently installed PD monitoring system with remote access, automatic trending and alarming.

Degradation of main insulation in early stage, including fault mechanism identification.
Trending: Qp, NQS, PRPD

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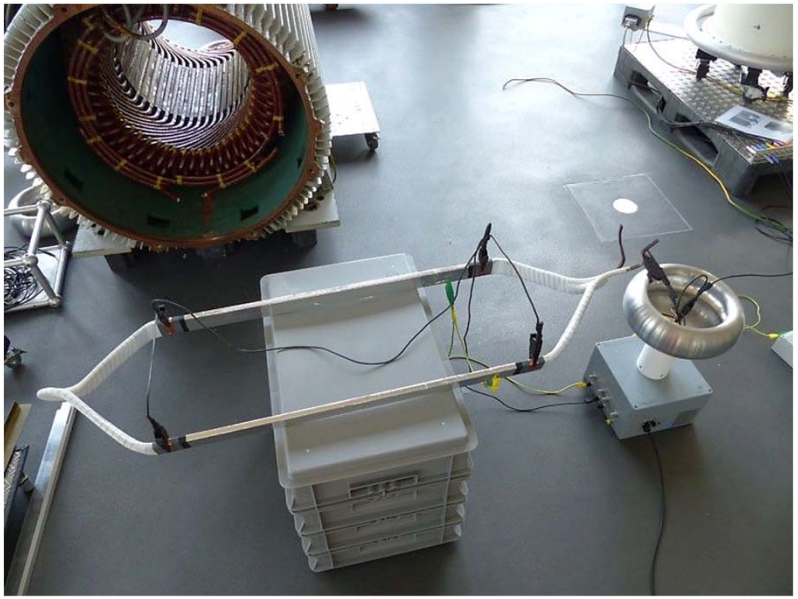
Main products for rotating machines testing

ICM*flex*

Offline PD and tan delta
test set



ICM*flexGRC*

Offline PD and tan delta test set
with Guard Ring Control for stator winding and
coil tesing according to IEC 60034-27-3

Main products for rotating machines testing

ICM*system*

Multichannel PD test system for FAT,
onsite offline testing and online spot testing (on preinstalled coupling capacitors)

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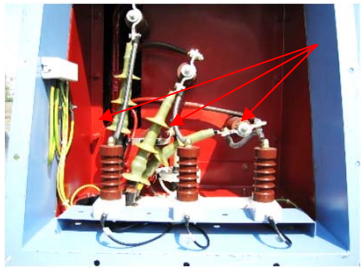
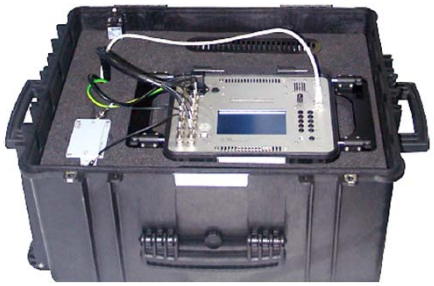
Main products for rotating machines testing

- Temporary (periodical) online monitoring with portable monitoring device and preinstalled coupling capacitors (CC)

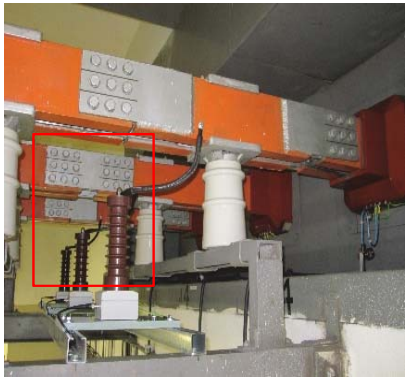


Example of preinstalled CC on motor terminals



ICM*monitor portable*

- Permanently installed monitoring system with remote access and alarming



Example of preinstalled CC on generator busbar

ICM*monitor*

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Normative references for testing of rotating machines

IEC 60270

Edition 3.1 2015-11
CONSOLIDATED VERSION

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Abstract

IEC 60270:2000+A1:2015 Applies to the measurement of localizedelectrical discharges in insulating media, restricted to only a part of the dielectric under test and only partially bridging the insulation between conductors. The contents of the corrigendum of October 2001 have been included in this copy. **This consolidated version consists of the third edition (2000) and its amendment 1 (2015). Therefore, no need to order amendment in addition to this publication.**

High-voltage test techniques – Partial discharge measurements

Techniques des essais à haute tension – Mesures des décharges partielles

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Normative references

Abstract

IEC 60034-27-1:2017 provides a common basis for:
- measuring techniques and instruments;
- the arrangement of test circuits;
- normalization and testing procedures;
- noise reduction;
- the documentation of test results;
- the interpretation of test results,

with respect to partial discharge off-line measurements on the winding insulation of rotating electrical machines.
This International Standard cancels and replaces IEC TS 60034-27 (2006). It constitutes a technical revision and reflects numerous improvements and corrections with respect to the previous publication.

Normative references

IEC/TS 60034-27-2

Edition 1.0 2012-03

TECHNICAL SPECIFICATION

colour inside

Rotating electrical machines –
Part 27-2: On-line partial discharge measurements on the stator winding insulation of rotating electrical machines

Abstract

IEC/TS 60034-27-2:2012(E) provides a common basis for:
- measuring techniques and instruments;
- the arrangement of the installation;
- normalization and sensitivity assessment;
- measuring procedures;
- noise reduction;
- the documentation of results;
- the interpretation of results with respect to partial discharge on-line measurements on the stator winding insulation of non-converter driven rotating electrical machines with rated voltage of 3 kV and up. Keywords: rotating electrical machines

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Normative references

IEC 60034-27-3

Edition 1.0 2015-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Rotating electrical machines –
Part 27-3: Dielectric dissipation factor measurement on stator winding insulation of rotating electrical machines

Machines électriques tournantes –
Partie 27-3: Mesure du facteur de dissipation diélectrique sur le système d'isolation des enroulements statoriques des machines électriques tournantes

Abstract

IEC 60034-27-3:2015 provides guidelines for the test procedures and the interpretation of test results for dielectric dissipation factor measurements on the stator winding insulation of rotating electrical machines. These guidelines are valid for rotating electrical machines with conductive slot coatings operating at a rated voltage of 6 kV and higher. This standard applies to individual form-wound stator bars and coils outside a core (uninstalled), individual stator bars and coils installed in a core and complete form-wound stator winding of machines in new or aged condition. This edition includes the following significant technical changes with respect to the previous publication IEC TR 60894:1987:

- inclusion of digital measurement of dissipation factor and capacitance;
- inclusion of limits for dissipation factor values;
- detailed description of measuring techniques; extension of scope to complete windings.

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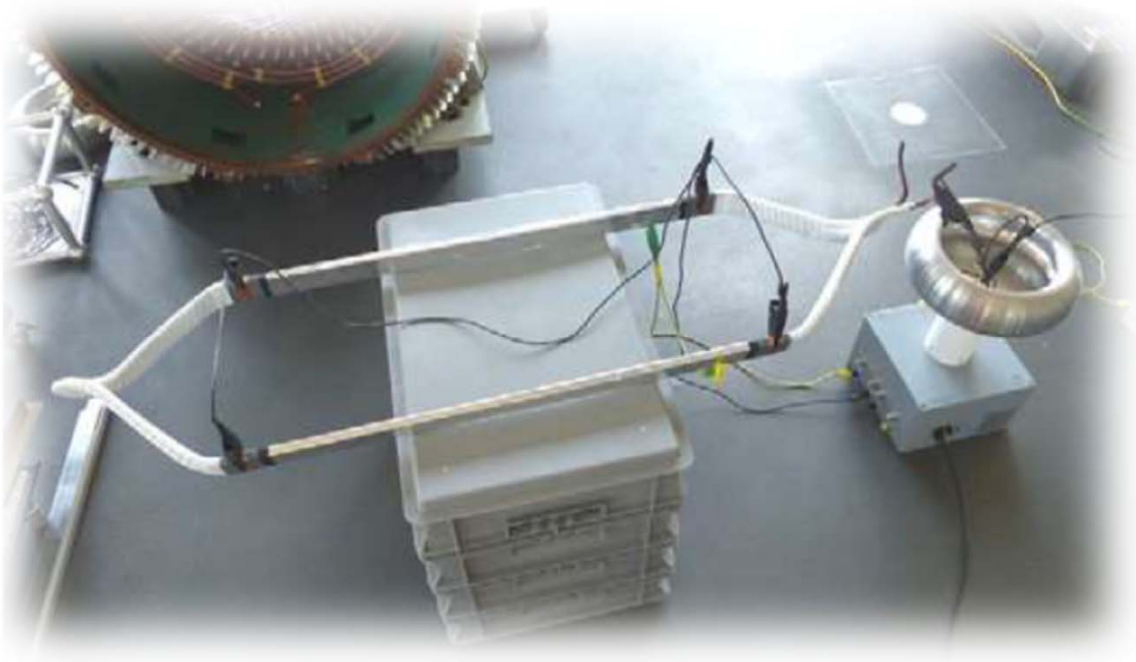
Normative references



IEC 60034-27-3

Edition 1.0 2015-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Rotating electrical machines –
Part 27-3: Dielectric dissipation factor measurement on stator winding insulation of rotating electrical machines

Machines électriques tournantes –
Partie 27-3: Mesure du facteur de dissipation diélectrique sur le système d'isolation des enroulements statoriques des machines électriques tournantes

Table 1 – Maximum values of dielectric dissipation factor of single bars and coils in new condition with guard ring electrodes up to a rated voltage of U_N = 21 kV

	Characteristic values measured at room temperature	
1	initial value of tan delta at $0{,}2U_N$ – $\tan \delta_{0,2}$	20×10^{-3}
2	delta tan delta per $0{,}2U_N$ up to U_N – $\Delta \tan \delta / 0{,}2U_N$	5×10^{-3}
3	tan delta tip-up between $0{,}6U_N$ and $0{,}2U_N$ – $(\tan \delta_{0,6} - \tan \delta_{0,2})$	5×10^{-3}

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Normative references

Abstract

IEC 60034-27-4:2018 provides recommended test procedures for the measurement of insulation resistance and polarization index of stator and rotor winding insulation of rotating electrical machines. This document recommends minimum acceptable values of insulation resistance and polarization index of winding insulation valid for fully processed low and high voltage AC and DC rotating electrical machines with a rated power of 750 W or higher.

Normative references

IEC TS 60034-27-5

Edition 1.0 2021-04

TECHNICAL SPECIFICATION

Abstract

IEC TS 60034-27-5:2021 provides an off-line measurement method of the partial discharge inception and extinction voltage on winding insulation under repetitive impulse voltage. This document is relevant to rotating machines supplied by a voltage source converter.

colour inside

Rotating electrical machines –
Part 27-5: Off-line measurement of partial discharge inception voltage on winding insulation under repetitive impulse voltage

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Normative references

1 Scope

This part of IEC 60034 defines criteria for assessing the insulation system of stator/rotor windings which are subjected to voltage-source pulse-width-modulation (PWM) drives. It applies to stator/rotor windings of single or polyphase AC machines with insulation systems for converter operation.

It describes qualification tests and quality control (type and routine) tests on representative samples or on completed machines which verify fitness for operation with voltage source converters.

This standard does not apply to:

- rotating machines which are only started by converters;
- rotating electrical machines with rated voltage ≤ 300 V r.m.s.;
- rotor windings of rotating electrical machines operating at ≤ 200 V (peak).

12 Routine tests

It is good practice to perform a routine test on each winding. For this purpose, it is recommended that the tests described in 11.2 and 11.3 are performed in agreement between the manufacturer and customer.

IEC 60034-18-41

Edition 1.0 2014-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Rotating electrical machines –
Part 18-41: Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage converters – Qualification and quality control tests

Machines électriques tournantes –
Partie 18-41: Systèmes d'isolation électrique sans décharge partielle (Type I) utilisés dans des machines électriques tournantes alimentées par des convertisseurs de tension – Essais de qualification et de contrôle qualité

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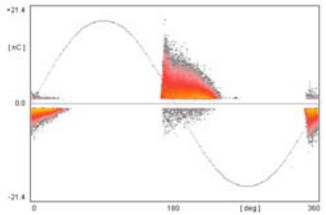
Summary

- Up to 60% of all failures on HV rotating machines are caused by stator winding insulation issues.
- Electrical diagnosis is therefore the most important predictive maintenance measure on HV rotating machines, in combination with vibration analysis (detects appr. 30% of issues) and other complementary methods.
- For critical machines it is recommended to perform the test sequence according to Stage 1 as FAT and also a few months after installation as SAT, which can then serve as base measurements for future comparison and trending.
- The most effective strategy for predictive maintenance of the insulation status of critical machines is a combination of periodical offline testing and online PD monitoring (temporary, or permanent).



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Avoid insulation failures of critical rotating machines by implementing the 3 Stage Predictive Maintenance Strategy

Thanks you for your attention!

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