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TITLE:

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

PROPOSED STABILITY DATE: 2025

NOTE FROM TC/SC OFFICERS:

This project was changed from TS into an IS, IEC 60034-27-2 ED1, as per documents 2/2086/Q and 2/2093/RQ.

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## ROTATING ELECTRICAL MACHINES –

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

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC/IS 60034-27-2, which is an international standard, has been prepared by IEC technical committee 2: Rotating machinery.



The text of this international standard is based on the following documents:

Enquiry draft	Report on voting
2/1636/DTS	2/1649/RVC

Full information on the voting for the approval of this international standard can be found in the report on voting indicated in the above table.

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## INTRODUCTION

2 Partial Discharge (PD) on-line measurement of rotating electrical machines has gained wide-  
3 spread acceptance as it could reveal the presence of localized weak points of the stator insu-  
4 lation system and also various arcing and sparking phenomena. Nevertheless, it has emerged  
5 from several studies that not only are there many different methods of measurement in exist-  
6 ence but also the criteria and methods of analysing and finally assessing the measured data  
7 are often very different and not really comparable. Consequently, there is a need to have an  
8 International Standard (IS) to give defined guidelines to the users of on-line PD measurements  
9 to assess the condition of their insulation systems.

10 On-line PD measurements are recorded with the rotating electrical machine experiencing all of  
11 the operating stresses; thermal, electrical, environmental and mechanical. Due to the realistic  
12 stress impact on the winding during measurement and due to the fact that the measurement is  
13 performed during all kinds of normal operation like base load and peak load, PD on-line testing  
14 could identify changes of the winding insulation system at a premature stage and enables real-  
15 time condition assessment as part of predictive maintenance strategies.

16 PD trend evaluation and comparisons with machines of similar design and similar insulation  
17 system measured under similar conditions, using the same measuring equipment, are recom-  
18 mended to ensure reliable assessment of the condition of the stator winding insulation. The  
19 trending information provides a good measure for early indication of a change in insulation  
20 condition. This gives time for planning further standstill examination in terms of visual inspection  
21 and off-line testing during next inspection outage.

22 This IS does not deal with on-line PD measurements on converter driven electrical machines  
23 because different measuring techniques are needed to distinguish between noise from the con-  
24 verter and PD from the winding.

### 25 Limitations

26 PD on-line tests on stator windings produce comparative, rather than absolute measurements.  
27 This creates a fundamental limitation for the interpretation of PD data. Therefore, acceptance  
28 criteria with simple limits for new or rewound stator windings cannot be established as the  
29 following reasons demonstrate:

- 30 ▪ There are many types of PD sensors as well as recording and analysing instruments. Gen-  
31 erally, they are incompatible and will produce different results for the same PD activity.
- 32 ▪ Even with the same measuring system, the high frequency partial discharge pulses will  
33 interact with the winding capacitance and inductance on their way from point of origin to the  
34 measuring point, e.g. at the winding terminals. Thus, PD measurements taken at machines  
35 with different winding design and rating produce different PD results, even though the actual  
36 type of PD source is the same.
- 37 ▪ Different types of winding defects produce different PD magnitudes and have different im-  
38 pact on insulation destruction. There is no strong correlation between high PD and high risk  
39 of insulation failure.
- 40 ▪ PD activity may occur close or far from the PD sensor. In general, if the PD source is inside  
41 the winding coils far away from the PD sensor, it will produce a smaller response at the PD  
42 sensor at the terminals compared to a PD source at the phase connections nearby due to  
43 pulse attenuation.

44 Users should also be aware that there is no evidence that the time to failure of the stator winding  
45 insulation can be estimated using any PD quantity, alone or even in combination. In order to  
46 more comprehensively describe the condition of the stator insulation, PD measurements are  
47 required to be supplemented by other electrical tests. Also, determining the root cause of an  
48 insulation deterioration process using PD pattern recognition, especially if more than one pro-  
49 cess is occurring, is still somewhat subjective, although the digital analysing technology is  
50 evolving rapidly.

51 Noise and disturbance from electrical environment have a great impact to on-line PD measure-  
52 ment. Cross-coupling of PD and noise between different phases can make objective interpreta-  
53 tion of the test results difficult. Therefore, different analogue and digital noise suppression tech-  
54 niques are used to improve PD measuring sensitivity and PD analysing tools.

55 Users of PD measurement should be aware that, due to the principles of the method, not all  
56 insulation-related problems in stator windings can be detected by measuring on-line PD activity,  
57 e.g. insulation failures involving continuous leakage currents due to conductive paths between  
58 different electrical potential of the insulation system or fine main insulation cracks with too small  
59 PD activity compared to normal delamination PD or pulse-less discharge phenomena.

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## ROTATING ELECTRICAL MACHINES –

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

#### 68 **1 Scope**

69 This part of IEC 60034-27 series deals with on-line PD measurements and provides a common  
70 basis with standardized procedures if possible for

- 71 – measuring techniques and instruments;
- 72 – the arrangement of the installation;
- 73 – normalization and sensitivity assessment;
- 74 – measuring procedures;
- 75 – noise reduction;
- 76 – the documentation of results;
- 77 – the interpretation of results;

78 with respect to partial discharge on-line measurements on the stator winding insulation of non-  
79 converter driven rotating electrical machines with rated voltage of 3 kV and up. This interna-  
80 tional standard covers PD measuring systems and methods detecting electrical PD signals. The  
81 same measuring devices and procedures can also be used to detect electrical sparking and  
82 arcing phenomena.

#### 83 **2 Normative references**

84 The following documents, in whole or in part, are normatively referenced in this document and  
85 are indispensable for its application. For dated references, only the edition cited applies. For  
86 undated references, the latest edition of the referenced document (including any amendments)  
87 applies.

88 IEC 60270:2000, *High-voltage test techniques – Partial discharge measurements*

89 IEC 60034-27-1, *Rotating electrical machines – Part 27-1: Off-line partial discharge measure-*  
90 *ments on the stator winding insulation*

91 IEC TS 62478, *High voltage test techniques-Measurement of partial discharges by electromag-*  
92 *netic and acoustic methods, 2016-08*

#### 93 **3 Terms and definitions**

94 For the purposes of this document the general terms and definitions for partial discharge meas-  
95 urements given in IEC 60270 apply, together with the following.

##### 96 **3.1** 97 **Partial discharge** 98 **PD**

99 **localized** electrical discharge that only partially bridges the insulation between conductors and  
100 which can or cannot occur adjacent to a conductor

- 101 **3.2**  
 102 **on-line measurement**  
 103 measurement taken with the rotating electrical machine in operation
- 104 **3.3**  
 105 **off-line measurement**  
 106 measurement taken with the rotating electrical machine at standstill, the machine being disconnected from the power system  
 107
- 108 Note 1 to entry: The necessary test voltage is applied to the winding from a separate voltage source.
- 109 **3.4 conductive slot coating**  
 110 conductive paint or tape layer in intimate contact with the groundwall insulation in the slot portion of the coil side, often called 'semiconductive' coating  
 111
- 112 Note 1 to entry: This coating together with adequate slot design provides electrical contact to the stator core, without shorting the core laminations.  
 113
- 114 **3.5**  
 115 **stress control coating**  
 116 paint or tape on the surface of the groundwall insulation that extends beyond the conductive slot portion coating in high-voltage stator bars and coils  
 117
- 118 Note 1 to entry: The stress control coating reduces the electric field stress along the winding overhang to below a critical value that would initiate PD on the surface. The stress control coating overlaps the conductive slot portion coating to provide electrical contact between them.  
 119  
 120
- 121 **3.6**  
 122 **corona discharge**  
 123 **visible partial discharge adjacent to the surface of a bare conductor or the surface of an insulation of a conductor**  
 124
- 125 **3.7**  
 126 **slot discharges**  
 127 discharges that occur between the outer surface of the slot portion of a coil or bar and the earthed core laminations due to high electrical field strength  
 128
- 129 **3.8**  
 130 **vibration sparking**  
 131 interrupted surface currents between the outer surface of the slot portion of a bar and the earthed core laminations due to axially induced voltages on the conductive slot coating combined with bar vibrations  
 132  
 133
- 134 **3.9**  
 135 **internal discharges**  
 136 discharges that occur within the **mainwall** insulation
- 137 **3.10**  
 138 **surface discharges**  
 139 discharges that occur on the surface of the insulation or on the surface of winding components in the winding overhang or the active part of the machine winding  
 140
- 141 **3.11**  
 142 **pulse magnitude distribution**  
 143 number of pulses within a series of equally-spaced windows of pulse magnitude during a predefined measuring time  
 144
- 145 **3.12**  
 146 **pulse phase distribution**  
 147 number of pulses within a series of equally-spaced windows of phase during a predefined measuring time  
 148
- 149 **3.13**  
 150 **phase resolved partial discharge pattern (PRPD)**  
 151 PD distribution map of PD magnitude and number of PD pulses vs. a.c. cycle phase position, for visualization of the PD behaviour during a predefined measuring time  
 152

153 **3.14**  
 154 **PD sensor**  
 155 general type of transducer, which can be used to detect PD signals from the machine winding

156 Note 1 to entry: A PD sensor typically consists of a high voltage coupling capacitor of low inductance design and a  
 157 low voltage coupling device in series.

158 **3.15**  
 159 **coupling device**  
 160 usually an active or passive four-terminal network that converts the input currents to output  
 161 voltage signals

162 Note 1 to entry: These signals are transmitted to the measuring device by a transmission system. The frequency  
 163 response of the coupling device is normally chosen at least so as to efficiently prevent the test voltage frequency  
 164 and its harmonics from reaching the measuring device.

165 **3.16**  
 166 **resistance temperature detector**  
 167 **RTD**  
 168 temperature detector inserted into the stator winding, usually between the top and bottom bar  
 169 or between embedded coil sides in a given slot

170 **3.17**  
 171 **PD magnitude Q**  
 172 **magnitude** associated with a PD pulse recorded by a measuring system

173 Note 1 to entry: In this document, the symbol Q will be used as a placeholder for both definitions of charge,  $Q_m$  and  
 174  $Q_{IEC}$  as given in IEC 60034-27-1. This magnitude is usually derived from a stream of individual PD pulses.

## 175 **4 Cause and effects of on-line PD**

176 Generally, partial discharges (PD) can develop at locations where the dielectric properties of  
 177 insulating materials are inhomogeneous. At such locations, the local electrical field strength  
 178 may be enhanced. Due to local electrical over-stressing this may lead to a local, partial break-  
 179 down. This breakdown only partially bridges the insulation material. PD in general requires a  
 180 gas volume or void volume to develop, e.g. cavities embedded in the insulation adjacent to  
 181 conductors or at insulation interfaces.

182 A partial discharge can occur when the local field strength exceeds the dielectric strength of  
 183 the material. This process may result in numerous PD pulses during one cycle of the applied  
 184 voltage.

185 The amount of charge transferred in the discharge is closely related to the specific properties  
 186 of the inhomogeneity such as the dimensions, the actual breakdown voltage and the specific  
 187 dielectric properties of the materials involved, e.g. surface properties, kind of gas, gas pressure,  
 188 etc.

189 Stator winding insulation systems for high voltage machines will normally have some PD activity  
 190 but are inherently resistant to partial discharges due to their inorganic mica components. How-  
 191 ever, significant PD in these machines is usually more a symptom of insulation deficiencies,  
 192 like manufacturing problems or in-service deterioration, rather than being a direct cause of fail-  
 193 ure. Nevertheless, depending on the individual processes, PD in machines may also directly  
 194 attack the insulation and thus influence the ageing process. The time to failure or failure prob-  
 195 ability may not always correlate with PD levels, but depends significantly on other factors, for  
 196 example operating temperature, wedging conditions, bar vibrations, degree of contamination,  
 197 etc.

198 The measurement and the analysis of the specific PD behaviour can be efficiently used for  
 199 quality control of new windings and winding components and for early detection of insulation  
 200 deficiencies caused by thermal, electrical, ambient and mechanical ageing factors in service,  
 201 which might result in an insulation fault.

202 The main differences between on-line measurements and off-line measurements are due to a  
 203 different voltage distribution along the winding and various thermal and mechanical effects re-  
 204 lated to the operation, like vibration, contact arcing or temperature gradients between stator

205 copper and stator iron core. Furthermore, especially for hydrogen-cooled machines the gas and  
206 the gas pressure may be different for off- and on-line PD measurements.

207 Further details on the nature of PD are given in Annex A.

## 208 **5 Noise and disturbances**

### 209 **5.1 General**

210 An important challenge with on-line PD measurement is separating stator-winding PD from elec-  
211 trical noise or disturbances as well as clustering the signal with respect to specific PD sources.  
212 In contrast to properly set-up off-line PD tests, in most on-line tests electrical disturbance pulses  
213 will often be present, and these disturbance pulses may be more frequent and of larger magni-  
214 tude than the stator winding PD pulses, also the signals may be phase-locked to the AC power  
215 frequency voltage. If the disturbances are not adequately suppressed, or the test technician is  
216 not able to adequately identify what is a disturbance and what is **PD from the stator**, there is a  
217 great risk that the disturbance will be **classified** as stator PD. Consequently, the stator may be  
218 identified as having serious insulation problems, when in fact the insulation may be in good  
219 condition. If too many “false positive” indications occur, confidence is lost in the test, and future  
220 testing may not be routinely done, losing the benefit of on-line PD testing.

### 221 **5.2 Noise and disturbance sources**

222 Consistent with IEC 60034-27-1, noise is defined to be non-stator winding signals that clearly  
223 are not pulses. Noise may be due to electronic devices within the PD detection system itself,  
224 for example thermal noise from semiconductive devices. Noise can also be from radio stations,  
225 radio transmitters, mobile telephones, power line carrier signals, etc. This noise is easily sepa-  
226 rated from pulse-like signals either visually on an oscillographic display or with the use of filters.  
227 Thus, it is not considered further in this international standard.

228 Disturbances are electrical pulses of relatively short duration that may have many of the char-  
229 acteristics of stator winding PD pulses – but in fact are not stator winding PD. **Disturbances** can  
230 be differentiated into two groups: In lower frequency range they preferably spread as electrical  
231 signals via metal conductors and in the very high frequency range they mainly distribute wire-  
232 less as electromagnetic waves. Some of these disturbances are synchronized to the AC cycle,  
233 and some are not. Sometimes synchronized disturbance pulses can be suppressed based on  
234 their position with respect to the AC phase angle.

235 Examples of synchronized disturbances are:

- 236 a) Partial discharges caused by e.g. electrostatic precipitators or bushing discharges
- 237 b) Power tool operation such as from arc welding and commutator sparking (may also be un-  
238 synchronized)
- 239 c) Transients caused by power electronics, for example converter fed motors or excitation sys-  
240 tems. This disturbance may also be unsynchronized to the AC cycle
- 241 d) Poor electrical connections (leading to contact sparking) on the bus or cable connecting the  
242 rotating electrical machine to the power system
- 243 e) Poor electrical connections elsewhere in the plant that lead to contact sparking
- 244 f) PD in other apparatus connected to the motor or generator terminals, for example output  
245 bus, power cable, switchgear and/or transformers
- 246 g) Arcing or sparking sources within the motor or generator, such as stator core lamination  
247 sparking

248 Examples of non-synchronized disturbances are:

- 249 h) Power tool operation (arc welding and commutator sparking)
- 250 i) Transients caused by power electronics, for example converter fed motors or static excita-  
251 tion systems
- 252 j) Slip ring sparking on the machine rotor
- 253 k) Overhead crane power rail sparking