



SLOVENSKI STANDARD
oSIST prEN IEC 60034-2-1:2023
01-januar-2023

Električni rotacijski stroji - 2-1. del: Standardne metode za ugotavljanje izgub in izkoristka s preskušanjem (razen strojev za vlečna vozila)

Rotating electrical machines - Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)

Drehende elektrische Maschinen - Teil 2-1: Standardverfahren zur Bestimmung der Verluste und des Wirkungsgrades aus Prüfungen (ausgenommen Maschinen für Schienen- und Straßenfahrzeuge)

Machines électriques tournantes - Partie 2-1: Méthodes normalisées pour la détermination des pertes et du rendement à partir d'essais (à l'exclusion des machines pour véhicules de traction)

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SECRETARY:

Mr Charles Whitlock

OF INTEREST TO THE FOLLOWING COMMITTEES:

PROPOSED HORIZONTAL STANDARD:

Other TC/SCs are requested to indicate their interest, if any, in this CDV to the secretary.

FUNCTIONS CONCERNED:

 EMC ENVIRONMENT QUALITY ASSURANCE SAFETY SUBMITTED FOR CENELEC PARALLEL VOTING NOT SUBMITTED FOR CENELEC PARALLEL VOTING**Attention IEC-CENELEC parallel voting**

The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this Committee Draft for Vote (CDV) is submitted for parallel voting.

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TITLE:

Rotating electrical machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)

PROPOSED STABILITY DATE: 2026

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ROTATING ELECTRICAL MACHINES –

**Part 2-1: Standard methods for determining losses and efficiency
from tests (excluding machines for traction vehicles)**

FOREWORD

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International Standard IEC 60034-2-1 has been prepared by IEC technical committee 2: Rotating machinery.

This third edition cancels and replaces the second edition of IEC 60034-2-1, issued in 2014,. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

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

FDIS	Report on voting

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

NOTE A table of cross-references of all IEC TC 2 publications can be found in the IEC TC 2 dashboard on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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ROTATING ELECTRICAL MACHINES –

Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)

1 Scope

This part of IEC 60034 is intended to establish methods of determining efficiencies from tests, and also to specify methods of obtaining specific losses.

This standard applies to d.c. machines and to a.c. synchronous and induction machines of all sizes within the scope of IEC 60034-1 rated for mains operation.

NOTE These methods may be applied to other types of machines such as rotary converters, a.c. commutator motors and single-phase induction motors.

2 Normative references

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

IEC 60027-1, *Letter symbols to be used in electrical technology – Part 1: General*

IEC 60034-1:2022, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-4-1:2018, *Rotating electrical machines – Part 4-1: Methods for determining synchronous machine quantities from tests*

IEC 60034-19, *Rotating electrical machines – Part 19: Specific test methods for d.c. machines on conventional and rectifier-fed supplies*

IEC 60034-29, *Rotating electrical machines – Part 29: Equivalent loading and superposition techniques – Indirect testing to determine temperature rise*

IEC 60034-30-1, *Rotating electrical machines – Part 30-1: Efficiency classes of line operated AC motors (IE code)*

IEC 60051(all parts), *Direct acting indicating analogue electrical measuring instruments and their accessories*

IEC 60051-1, *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 1: Definitions and general requirements common to all parts*

34 **3 Terms and definitions**

35 For the purposes of this document, the terms and definitions given in IEC 60034-1,
36 IEC 60051-1 and the following apply.

37 **3.1** 38 **efficiency**

39 ratio of output power to input power expressed in the same units and usually given as a
40 percentage

41 **3.2** 42 **direct efficiency determination**

43 method by which the determination of efficiency is made by measuring directly the input
44 power and the output power

45 **3.3** 46 **dual-supply back-to-back test**

47 test in which two identical machines are mechanically coupled together, and the total losses
48 of both machines are calculated from the difference between the electrical input to one
49 machine and the electrical output of the other machine

50 **3.4** 51 **indirect efficiency determination**

52 method by which the determination of efficiency is made by measuring the input power or the
53 output power and determining the total losses. Those losses are added to the output power,
54 thus giving the input power, or subtracted from the input power, thus giving the output power.

55 **3.5** 56 **single-supply back-to-back test**

57 test in which two identical machines are mechanically coupled together and are both
58 connected electrically to the same power system. The total losses of both machines are taken
59 as the input power drawn from the system.

60 **3.6** 61 **no-load test**

62 test in which a machine is run as a motor providing no useful mechanical output from the
63 shaft, or if run as a generator with its terminals open-circuited

64 **3.7** 65 **zero power factor test (synchronous machines)**

66 no-load test on a synchronous machine, which is over-excited and operates at a power factor
67 very close to zero

68 **3.8** 69 **equivalent circuit method (induction machines)**

70 test in which the losses are determined by help of an equivalent circuit model

71 **3.9** 72 **test with rotor removed and reverse rotation test (induction machines)**

73 combined test in which the additional load losses are determined from a test with rotor
74 removed and a test with the rotor running in reverse direction to the rotating magnetic field of
75 the stator

76 **3.10** 77 **short-circuit test (synchronous machines)**

78 test in which a machine is run as a generator with its terminals short-circuited

79 **3.11**80 **locked rotor test**

81 test in which the rotor is locked to prevent rotation

82 **3.12**83 **Eh-star test**

84 test in which the motor is run in star connection on unbalanced voltage

85 **3.13 Losses**86 **3.13.1**87 **total losses**88 P_T 89 difference between the input power and the output power, equivalent to the sum of the
90 constant losses (see 3.15.2), the load losses (see 3.15.4), the additional load losses (see
91 3.15.5) and the excitation circuit losses (see 3.15.3)92 **3.13.2**93 **constant losses**94 losses incorporating the sum of windage, friction and iron losses. Although these losses
95 change with voltage and load, they are historically called “constant” losses and the name is
96 retained in this standard.97 **3.13.2.1**98 **constant losses**99 P_c

100 sum of the iron losses and the friction and windage losses

101 **3.13.2.2**102 **iron losses**103 P_{fe}

104 losses in active iron and additional no-load losses in other metal parts

105 **3.13.2.3 Friction and windage losses P_{fw}** 106 **3.13.2.3.1**107 **friction losses**108 losses due to friction (bearings and brushes, if not lifted at rated conditions) not including any
109 losses in a separate lubricating system110 **3.13.2.3.2**111 **windage losses**112 total losses due to aerodynamic friction in all parts of the machine, including power absorbed
113 in shaft mounted fans, and in auxiliary machines forming an integral part of the machine

114 Note 1 Losses in a separate ventilating system should be listed separately.

115 Note 2 For machines indirectly or directly cooled by hydrogen, see IEC 60034-1.

116 **3.13.3 Excitation circuit losses**117 **3.13.3.1**118 **excitation circuit losses**119 P_e 120 sum of the excitation winding losses (see 3.15.3.2), the exciter losses (see 3.15.3.3) and, for
121 synchronous machines, electrical brush loss (see 3.15.3.5), if any

122 **3.13.3.2**123 **excitation winding losses**124 P_f 125 excitation (field) winding losses are equal to the product of the exciting current I_e and the
126 excitation voltage U_e 127 **3.13.3.3**128 **exciter losses**129 P_{Ed}

130 the exciter losses for the different excitation systems (see Annex B) are defined as follows:

131 a) Shaft driven exciter

132 The exciter losses are the power absorbed by the exciter at its shaft (reduced by friction
133 and windage losses) plus the power P_{1E} drawn from a separate source at its excitation
134 winding terminals, minus the useful power which the exciter provides at its terminals. The
135 useful power at the terminals of the exciter is equal to the excitation winding losses as per
136 3.15.3.2 plus (in the case of a synchronous machine) the electrical brush losses as per
137 3.15.3.5.138 Note 1 If the exciter can be decoupled and tested separately its losses can be determined according to
139 7.1.3.2.1.140 Whenever the exciter makes use of separate auxiliary supplies, their consumptions are to be included in the
141 exciter losses unless they are considered together with the main machine auxiliaries consumption.

142 b) Brushless exciter

143 exciter losses are the power absorbed by the exciter at its shaft, reduced by friction and
144 windage losses (when the relevant test is performed on the set of main machine and
145 exciter), plus the electrical power P_{1E} from a separate source (if any) absorbed by its field
146 winding or its stator winding (in the case of an induction exciter), minus the useful power
147 which the exciter provides at the rotating power converter terminals.148 Note 2 Whenever the exciter makes use of separate auxiliary supplies their consumptions are to be included in
149 the exciter losses unless they are considered together with the main machine auxiliaries consumption.

150 If the exciter can be decoupled and tested separately, its losses can be determined according to 7.1.3.2.1.

151 c) Separate rotating exciter

152 exciter losses are the difference between the power absorbed by the driving motor, plus
153 the power absorbed by separate auxiliary supplies, of both driving and driven machines,
154 including the power supplied by separate source to their excitation winding terminals, and
155 the excitation power supplied as per 3.15.3.2 and 3.15.3.4. The exciter losses may be
156 determined according to 7.1.3.2.1.

157 d) Static excitation system (static exciter)

158 excitation system losses are the difference between the electrical power drawn from its
159 power source, plus the power absorbed by separate auxiliary supplies, and the excitation
160 supplied as per 3.15.3.2 and 3.15.3.4.161 Note 3 In the case of systems fed by transformers, the transformer losses shall be included in the exciter
162 losses.

163 e) Excitation from auxiliary winding (auxiliary winding exciter)

164 exciter losses are the copper losses in the auxiliary (secondary) winding and the additional
165 iron losses produced by increased flux harmonics. The additional iron losses are the
166 difference between the losses which occur when the auxiliary winding is loaded and when
167 it is unloaded.168 Note 4: Because separation of the excitation component of losses is difficult, it is recommended to consider
169 these losses as an integral part of the stator losses when determining overall losses.170 In the cases c) and d) no allowance is made for the losses in the excitation source (if any) or
171 in the connections between the source and the brushes (synchronous machine) or between
172 the source and the excitation winding terminals (d.c. machine).

173 If the excitation is supplied by a system having components as described in b) to e) the
 174 exciter losses shall include the relevant losses of the components pertaining to the categories
 175 listed in Annex B as applicable.

176 **3.13.3.4**

177 **separately supplied excitation power**

178 P_{1E}

179 excitation power P_{1E} supplied from a separate power source is:

- 180 – for exciter types a) and b) the exciter excitation power (d.c. or synchronous exciter) or
 181 stator winding input power (induction exciter). It covers a part of the exciter losses P_{Ed}
 182 (and further losses in induction exciters) while a larger part of P_e is supplied via the shaft;
- 183 – for exciter types c) and d) equal to the excitation circuit losses, $P_{1E} = P_e$;
- 184 – for exciter type e) $P_{1E} = 0$, the excitation power being delivered entirely by the shaft. Also,
 185 $P_{1E} = 0$ for machines with permanent magnet excitation.

186 Exciter types shall be in accordance with 3.15.3.3.

187 **3.13.3.5**

188 **brush losses (excitation circuit)**

189 P_b

190 electrical brush loss (including contact loss) of separately excited synchronous machines

191 **3.13.4 Load losses**

192 **3.13.4.1**

193 **load losses**

194 P_L

195 sum of the winding (I^2R) losses (see 3.15.4.2) and the electrical brush losses (see 3.15.4.3), if
 196 any

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197 **3.13.4.2**

198 **winding losses**

199 winding losses are I^2R losses:

- 200 – in the armature circuit of d.c. machines;
- 201 – in the stator and rotor windings of induction machines;
- 202 – in the armature and field windings of synchronous machines

203 **3.13.4.3**

204 **brush losses (load circuits)**

205 P_b

206 electrical brush loss (including contact loss) in the armature circuit of d.c. machines and in
 207 wound-rotor induction machines

208 **3.13.5**

209 **additional load losses (stray-load losses)**

210 P_{LL}

211 losses produced in active iron and other metal parts by alternating stray fluxes when the
 212 machine is loaded; eddy current losses in winding conductors caused by load current-
 213 dependent flux pulsations and additional brush losses caused by commutation

214 NOTE These losses do not include the additional no-load losses of 3.15.2.2.

215 **3.13.6**
 216 **short-circuit losses**
 217 P_{sc}
 218 current-dependent losses in a synchronous machine and in a d.c. machine when the armature
 219 winding is short-circuited

220 **3.14 Test quantities (polyphase a.c. machines)**

221 **3.14.1**
 222 **terminal voltage**
 223 for polyphase a.c. machines, the arithmetic average of line voltages

224 **3.14.2**
 225 **line current**
 226 for polyphase a.c. machines, the arithmetic average of line currents

227 **3.14.3**
 228 **line-to-line resistance**
 229 for polyphase a.c. machines, the arithmetic average of resistances measured between each
 230 pair of terminals

231 Note 1 For Y-connected three-phase machines, the phase-resistance is 0,5 times the line-to-line resistance. For
 232 Δ -connected machines, the phase-resistance is 1,5 times the line-to-line resistance.

233 Note 2 In Clauses 6 and 7 explanations and formulae given are for three-phase machines, unless otherwise
 234 indicated.

235 **3.14.4**
 236 **temperature rise**
 237 is the machine temperature minus the cooling medium (coolant) temperature as defined by
 238 IEC 60034-1

239 **4 Symbols and abbreviations**

240 **4.1 Symbols**

241 $\cos \varphi$ is the power factor¹
 242 f is the supply frequency, Hz
 243 I is the average line current, A
 244 k_{θ} is the temperature correction factor
 245 n is the operating speed, s⁻¹
 246 p is the number of pole pairs
 247 P is the power, W
 248 P_0 is the input power at no-load, W
 249 P_1 is the input power, excluding excitation², W
 250 P_2 is the output power, W
 251 P_b is the brush loss, W
 252 P_e is the excitation circuit losses, W

¹ This definition assumes sinusoidal voltage and current.

² Unless otherwise indicated, the tests in this standard are described for motor operation, where P_1 and P_2 are electrical input and mechanical output power, respectively.

253	P_{1E}	is the excitation power supplied by a separate source, W
254	P_{Ed}	is the exciter losses, W
255	P_{el}	is the electrical power, excluding excitation, W
256	P_f	is the excitation (field) winding losses, W
257	P_{fe}	is the iron losses, W
258	P_{fw}	is the friction and windage losses, W
259	P_c	is the constant losses, W
260	P_L	is the load losses, W
261	P_{Lr}	is the residual losses, W
262	P_{LL}	is the additional-load losses, W
263	P_{sc}	is the short-circuit losses, W
264	P_{mech}	is the mechanical power, W
265	P_T	is the total losses, W
266	P_w	is the winding losses, W, where subscript w is generally replaced by a, f, e, s or r
267		(see 4.2)
268	R	is a winding resistance, Ω
269	R_{eh}	is the actual value of the auxiliary resistor for the Eh-star test (see 6.2.5), Ω
270	R'_{eh}	is the typical value of the auxiliary resistor, Ω
271	R_f	is the field winding resistance, Ω
272	R_{ll}	is the average line-to-line-resistance, Ω
273	R_{ph}	is the average phase-resistance, Ω
274	s	is the slip, in per unit value of synchronous speed
275	T	is the machine torque, N·m
276	T_d	is the reading of the torque measuring device, N·m
277	U	is the average terminal voltage, V
278	U_0	is the terminal voltage at no-load, V
279	U_N	is the rated terminal voltage, V
280	X	is the reactance, Ω
281	$\underline{Z} = R + j \times X$	is the notation for a complex quantity (impedance as example)
282	$Z = \underline{Z} = \sqrt{R^2 + X^2}$	is the absolute value of a complex quantity (impedance as example)
283	Z	is the impedance, Ω
284	η	is the efficiency
285	θ_0	is the initial winding temperature, $^{\circ}\text{C}$
286	θ_a	is the ambient temperature, $^{\circ}\text{C}$
287	θ_c	primary coolant inlet temperature, $^{\circ}\text{C}$
288	θ_w	is the winding temperature, $^{\circ}\text{C}$
289	τ	is a time constant, s

290 4.2 Additional subscripts

291 The following subscripts may be added to symbols to clarify the machine function and to
292 differentiate values.