IEC 60034-2-1

Edition 1.0 2007-09

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

**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)**

IEC 60034-2-1:2007

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ROTATING ELECTRICAL MACHINES –

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FOREWORD

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

This standard cancels and replaces IEC 60034-2 (1972), its amendment 1 (1995) and its amendment 2 (1996). IEC 60034-2A (1974) is retained for the time being.

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

FDIS	Report on voting
2/1443/FDIS	2/1460/RVD

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

A list of all parts of IEC 60034 series, under the general title *Rotating electrical machines,* can be found on the IEC website.

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

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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- withdrawn,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.

INTRODUCTION

During the revision phase for IEC 60034-2: 1972 and its amendments IEC 60034-2 A1: 1995 (defining IEC 60034-2A: 1974 as Clause 17) and IEC 60034-2 A2: 1996, WG 28 proposed and TC 2 agreed to separate the revised standard into three sections:

– the first part (IEC 60034-2-1) to cover machines within the scope of IEC 60034-1, which are normally tested under load;
– the second part (IEC 60034-2-2) to cover tests applicable mainly for large machines where the facility cost for other methods is not economical (especially the calibrated-machine test, the retardation test and the calorimetric method);
– the third part (IEC 60034-2-3) for tests on machines for converter supply..

To retain in IEC 60034-2-1 as normative the test methods that will eventually become IEC 60034-2-2, a temporary Annex D has been added. This annex contains elements from IEC 60034-2:1972 and its amendment 1:1995. It also makes reference to IEC 60034-2A:1974. Both will be incorporated in the future IEC 60034-2-2.

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.

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 referenced documents are indispensable for the application of this document. 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, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-2A, *Rotating electrical machines – Part 2: Methods for determining losses and efficiency of rotating electrical machinery form tests (excluding machines for traction vehicles) – First supplement: Measurement of losses by the calorimetric method*

IEC 60034-4, *Rotating electrical machines – Part 4: 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 60044 (all parts), *Instrument transformers*

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

IEC 61986, *Rotating electrical machines – Equivalent loading and super-position techniques – Indirect testing to determine temperature rise*

NOTE A revision of IEC 61986 is under consideration; it will be published under reference IEC 60034-29.

3 Terms and definitions

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

3.1
efficiency
ratio of output power to input power expressed in the same units and usually given as a percentage

3.2 Tests for direct efficiency determination

3.2.1
general
method by which the direct determination of efficiency is made by measuring directly the input power and the output power

3.2.2
torque meter test
test in which the mechanical power output of a machine acting as a motor is determined by measurement of the shaft torque by means of a torque meter together with the rotational speed. Alternatively, a test performed on a machine acting as a generator, by means of a torque meter to determine the mechanical power input

3.2.3
dynamometer test
test in accordance with 3.2.2 but measuring the shaft torque by means of a dynamometer

3.2.4
dual-supply back-to-back test
test in which two identical machines are mechanically coupled together, and the total losses of both machines are calculated from the difference between the electrical input to one machine and the electrical output of the other machine

3.3 Tests for indirect efficiency determination

3.3.1
general
test in which the indirect determination of efficiency is made by measuring the input power or the output power and determining the total losses. Those losses are added to the output power, thus giving the input power, or subtracted from the input power, thus giving the output power

3.3.2
single-supply back-to-back test
test in which two identical machines are mechanically coupled together, and are both connected electrically to the same power system. The total losses of both machines are taken as the input power drawn from the system

3.3.3
no-load test
test in which a machine run as a motor provides no useful mechanical output from the shaft, or when run as a generator with its terminals open-circuited

3.3.4
zero power factor test (synchronous machines)
no-load test on a synchronous machine, which is over-excited and operates at a power factor very close to zero

3.3.5
equivalent circuit method (induction machines)
test in which the losses are determined by help of an equivalent circuit model

3.3.6
test with rotor removed and reverse rotation test (induction machines)
combined test in which the additional load losses are determined from a test with rotor removed and a test with the rotor running in reverse direction to the rotating magnetic field

3.3.7
short-circuit test (synchronous machines)
test in which a machine is run as a generator with its terminals short-circuited

3.3.8
locked rotor test
test in which the rotor is locked to prevent rotation

3.3.9
eh-star test
test in which the motor is run in star connection on unbalanced voltage.

3.4 Losses

3.4.1
total losses P_T
difference between the input power and the output power, equivalent to the sum of the constant losses (see 3.4.2), the load losses (see 3.4.4), the addititional load losses (see 3.4.5) and the excitation circuit losses (see 3.4.3)

3.4.2 Constant losses

3.4.2.1
constant losses P_k
sum of the iron losses and the friction and windage losses

3.4.2.2
iron losses P_{fe}
losses in active iron and additional no-load losses in other metal parts

3.4.2.3 Friction and windage losses P_{fw}

3.4.2.3.1
friction losses
losses due to friction (bearings and brushes, if not lifted at rated conditions) not including any losses in a separate lubricating system. Losses in common bearings should be stated separately, whether or not such bearings are supplied with the machine. The bearing losses are based on the operating temperatures of the bearings, the type of oil and oil temperature.

NOTE 1 When the losses in a separate lubricating system are required these should be listed separately.

For vertical machines, the losses in thrust bearings shall be determined excluding any external thrust.

NOTE 2 Additional losses due to external thrust may be stated separately by agreement, which should then include thrust load, temperature of the bearings, type of oil and also oil temperature.

NOTE 3 Friction losses due to thrust load may be included by agreement.

If the tested machine uses direct flow cooling of the bearings, these losses are distributed between the tested machine and any other one coupled to it mechanically, such as a turbine, in proportion to the masses of their rotating parts. If there is no direct flow cooling, the distribution of bearing losses shall be determined from empirical formulae by agreement

3.4.2.3.2
windage losses
total losses due to aerodynamic friction in all parts of the machine, including power absorbed in shaft mounted fans, and in auxiliary machines forming an integral part of the machine

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

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

3.4.3 Excitation circuit losses

3.4.3.1
excitation circuit losses P_e
sum of the excitation winding losses (see 3.4.3.2), the exciter losses (see 3.4.3.3) and, for synchronous machines, electrical brush loss (see 3.4.3.5), if any

3.4.3.2
excitation winding losses P_f
the excitation (field) winding losses are equal to the product of the exciting current I_e and the excitation voltage U_e

3.4.3.3
exciter losses P_{Ed}
the exciter losses for the different excitation systems (see Annex C) are defined as follows:

a) Shaft driven exciter

The exciter losses are the power absorbed by the exciter at its shaft (reduced by friction and windage losses) plus the power P_{1E} drawn from a separate source at its excitation winding terminals, minus the useful power which the exciter provides at its terminals. The useful power at the terminals of the exciter is equal to the excitation winding losses as per 3.4.3.2 plus (in the case of a synchronous machine) the electrical brush losses as per 3.4.3.5.

If the exciter can be decoupled and tested separately its losses can be determined according to 5.3.

Whenever the exciter makes use of separate auxiliary supplies, their consumptions are to be included in the exciter losses unless they are considered together with the main machine auxiliaries consumption.

b) Brushless exciter

The exciter losses are the power absorbed by the exciter at its shaft, reduced by friction and windage losses (when the relevant test is performed on the set of main machine and exciter), plus the electrical power P_{1E} from a separate source (if any) absorbed by its field winding or its stator winding (in the case of an induction exciter), minus the useful power which the exciter provides at the rotating power converter terminals.

Whenever the exciter makes use of separate auxiliary supplies their consumptions are to be included in the exciter losses unless they are considered together with the main machine auxiliaries consumption.

If the exciter can be decoupled and tested separately, its losses can be determined according to 5.3.

c) Separate rotating exciter

The exciter losses are the difference between the power absorbed by the driving motor, plus the power absorbed by separate auxiliary supplies, of both driving and driven machines, including the power supplied by separate source to their excitation winding terminals, and the excitation power supplied as per 3.4.3.2 and 3.4.3.4. The exciter losses may be determined according to 5.3.

d) Static excitation system (static exciter)

The excitation system losses are the difference between the electrical power drawn from its power source, plus the power absorbed by separate auxiliary supplies, and the excitation supplied as per 3.4.3.2 and 3.4.3.4.

In the case of systems fed by transformers, the transformer losses shall be included in the exciter losses.

e) Excitation from auxiliary winding (auxiliary winding exciter)

The exciter losses are the copper losses in the auxiliary (secondary) winding and the additional iron losses produced by increased flux harmonics. The additional iron losses are the difference between the losses which occur when the auxiliary winding is loaded and when it is unloaded.

Because separation of the excitation component of losses is difficult, it is recommended to consider these losses as an integral part of the stator losses when determining overall losses.

In the cases c) and d) no allowance is made for the losses in the excitation source (if any) or in the connections between the source and the brushes (synchronous machine) or between the source and the excitation winding terminals (d.c. machine).

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

3.4.3.4
separately supplied excitation power P_{1E}
the excitation power P_{1E} supplied from a separate power source is:

– for exciter types a) and b) the exciter excitation power (d.c. or synchronous exciter) or stator winding input power (induction exciter). It covers a part of the exciter losses P_{Ed} (and further losses in induction exciters) while a larger part of P_e is supplied via the shaft;

– for exciter types c) and d) equal to the excitation circuit losses, $P_{1E} = P_e$;

– for exciter type e) $P_{1E} = 0$, the excitation power being delivered entirely by the shaft. Also, $P_{1E} = 0$ for machines with permanent magnet excitation.

Exciter types shall be in accordance with 3.4.3.3

3.4.3.5
brush losses P_b (excitation circuit)
electrical brush loss (including contact loss) of separately excited synchronous machines

3.4.4 Load losses

3.4.4.1
load losses P_L
the sum of the winding (I^2R) losses (see 3.4.4.2) and the electrical brush losses (see 3.4.4.3), if any

3.4.4.2
winding losses
winding losses are I^2R losses:

– in the armature circuit of d.c. machines;

– in the stator and rotor windings of induction machines;

– in the armature windings of synchronous machines

3.4.4.3
brush losses P_b (load circuits)
electrical brush loss (including contact loss) in the armature circuit of d.c. machines and in wound-rotor induction machines

3.4.5
additional load losses P_{LL} (stray-load losses)
losses produced by the load current in active iron and other metal parts other than conductors; eddy current losses in winding conductors caused by load current-dependent flux pulsations and additional brush losses caused by commutation

NOTE These losses do not include the additional no-load losses of 3.4.2.2.

3.4.6
short-circuit losses P_{sc}
current-dependent losses in a synchronous machine and in a d.c. machine when the armature winding is short-circuited

3.5 Test quantities (polyphase a.c. machines)

3.5.1
terminal voltage
for polyphase a.c. machines the arithmetic average of line voltages

3.5.2
line current
for polyphase a.c. machines the arithmetic average of line currents