IEC 60034-2-2

Edition 2.0 2024-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Rotating electrical machines –
Part 2-2: Specific methods for determining separate losses of large machines from tests – Supplement to IEC 60034-2-1

Machines électriques tournantes –
Partie 2-2: Méthodes spécifiques pour déterminer les pertes séparées des machines de grande taille à partir d'essais – Complément à l'IEC 60034-2-1

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FOREWORD

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

This second edition cancels and replaces the first edition published in 2010. This edition constitutes a technical revision.

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

a) Layout and procedures aligned with IEC 60034-2-1 and IEC 60034-2-3.
b) Annex A added: an informative procedure for the summation of losses for large permanent-magnet excited synchronous machines.

The text of this International Standard is based on the following documents:

Draft	Report on voting
2/2157/FDIS	2/2178/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

ROTATING ELECTRICAL MACHINES –

Part 2-2: Specific methods for determining separate losses of large machines from tests – Supplement to IEC 60034-2-1

1 Scope

This part of IEC 60034 applies to large rotating electrical machines and establishes additional methods of determining separate losses and to define an efficiency supplementing IEC 60034-2-1. These methods apply when full-load testing is not practical and results in a greater uncertainty.

NOTE In situ testing according to the calorimetric method for full-load conditions is recognized.

The specific methods described are:

– Calibrated-machine method.

– Retardation method.

– Calorimetric method.

– Summation of losses for permanent magnet excited synchronous machines.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-2-1, *Rotating electrical machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60034-1 and IEC 60034-2-1 apply, as well as the following.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
calibrated machine
machine whose mechanical power input/output is determined, with low uncertainty, using measured electrical output/input values according to a defined test procedure

3.2
calibrated-machine method
method in which the mechanical input/output to/from an electrical machine under test is determined from the measurement of the electrical input/output of a calibrated machine mechanically coupled to the test machine

3.3
retardation method
method in which the separate losses in a machine under test are deduced from the measurements of the deceleration rate of its rotating components when only these losses are present

3.4
calorimetric method
method in which the losses in a machine are deduced from the measurements of the heat generated by them

3.5
thermal equilibrium
state reached when the temperature rises of the several parts of the machine do not vary by more than rate of change 1 K per half hour

[SOURCE: IEC 60050-411:1996, 411-51-08]

4 Symbols and abbreviated terms

4.1 Symbols

A is an area, m^2,

C is the retardation constant, kg m^2 s^2,

c_p is the specific heat capacity of the cooling medium, J/(kg K),

h is the coefficient of heat transfer, W/(m^2 K),

J is the moment of inertia, kg m^2,

n is the operating speed, s^{-1},

P_1 is the input power, W,

P_{1E} is the excitation power supplied by a separate source, W,

P_2 is the output power, W,

P_a is the I^2R armature-winding losses (interpole, compensation and series field winding loss in case of DC machines), W,

P_b is the brush losses, W,

P_c is the constant losses, W,

P_e is the excitation circuit losses, W,

P_{Ed} is the exciter losses, W,

P_{el} is the electrical power, excluding excitation, W,

P_f is the excitation (field winding) losses, W,

P_{fe} is the iron losses, W,

P_{fw} is the friction and windage losses, W,

P_{sc} is the short-circuit losses, W,

P_{LL} is the additional load losses, W,

P_{mech} is the mechanical power, W,

P_r is the I^2R rotor winding losses, W,

P_s is the stator I^2R winding losses, W,

P_T is the total losses, W,

Q is the volume rate of flow of the cooling medium, m^3/s,

t is the time, s,

v is the exit velocity of cooling medium, m/s,

Δp is the difference between the static pressure in the intake nozzle and ambient pressure, N/m^2,

$\Delta\theta$ is the temperature rise of the cooling medium, or the temperature difference between the machine reference surface and the external ambient temperature, K,

δ is the per unit deviation of rotational speed from rated speed,

ρ is the density of the cooling medium, kg/m^3,

θ is the temperature, °C.

4.2 Additional subscripts

c for the cooling circuit,

E for exciter,

ers for outside reference surface,

i for inner voltage,

irs for inside reference surface,

rs for the reference surface,

RR for test with rotor removed,

t test,

0 no-load,

1 input,

2 output.

5 Basic requirements

5.1 Direct and indirect efficiency determination

5.1.1 General

Tests can be grouped in the following categories.

5.1.2 Direct

Input-output measurements on a single machine are considered to be direct. This involves the measurement of electrical or mechanical power into, and mechanical or electrical power out of a machine.

5.1.3 Indirect

Measurements of the separate losses in a machine under a particular condition are considered to be indirect. This is not usually the total loss but comprises certain loss components. The method may, however, be used to calculate the total loss or to calculate a loss component.

The determination of total loss shall be carried out by one of the following methods:

– direct measurement of total losses;
– summation of separate losses.

NOTE The methods for determining the efficiency of machines are based on a number of assumptions. Therefore, it is not possible to make a comparison between the values of efficiency obtained by different methods.

5.2 Uncertainty

Uncertainty as used in this document is the uncertainty of determining a true efficiency. It reflects variations in the test procedure and the test equipment.

Although uncertainty should be expressed as a numerical value, such a requirement needs sufficient testing to determine representative and comparative values.

6 Additional test methods for the determination of the efficiency of large machines

6.1 General

6.1.1 Overview

For the determination of performance when machine load and/or size exceed test capabilities (described in IEC 60034-2-1), the following test methods may be used. See Table 1.

Table 1 – Additional methods for large machines

Reference	Method	Description	Subclause	Application	Required facility
2-2-A	**Calibrated machine**	Loss measurement via calibrated machine	6.2	All types of machines	Calibrated machine
2-2-B	**Retardation method**	Loss measurement by retardation	6.3	Applicable for factory and on-site measurements	
2-2-C	**Calorimetric method**	Loss measurement in the primary and secondary coolant	6.4	Applicable for factory and on-site measurements	

NOTE These methods are generally applicable to large machines where the facility cost for other methods is not economical.

Losses relative to machine load (with lowest uncertainty) are best determined from actual measurements. For example: measurements of current, resistance, etc., under full-load operation.

When this is not possible, these values shall be obtained from calculation of the parameters during the design stage.

Determination of losses not itemized in this part may be found in IEC 60034-2-1.

6.1.2 Efficiency

Efficiency is:

$$\eta = \frac{P_1 + P_{1E} - P_T}{P_1 + P_{1E}} = \frac{P_2}{P_2 + P_T}$$

where

P_1 is the input power excluding excitation power from a separate source;

P_2 is the output power;

P_{1E} is the excitation power supplied by a separate source;

P_T is the total loss.

NOTE 1 Input power P_1 and output power P_2 are as follows:

in motor operation: $P_1 = P_{el}$; $P_2 = P_{mech}$;

in generator operation: $P_1 = P_{mech}$; $P_2 = P_{el}$.

NOTE 2 P_T includes the excitation circuit losses P_e of the machine where applicable.

6.1.3 Total loss

When the total loss is determined as the sum of the separate losses the following formulae apply:

For direct current machines:

$$P_T = P_c + P_a + P_b + P_{LL} + P_e$$

$$P_e = P_f + P_{Ed}$$

$$P_c = P_{fw} + P_{fe}$$

For induction machines:

$$P_T = P_c + P_s + P_r + P_{LL}$$

$$P_c = P_{fw} + P_{fe}$$

For synchronous machines:

$$P_T = P_c + P_s + P_{LL} + P_e$$

$$P_e = P_f + P_{Ed} + P_b$$

$$P_c = P_{fw} + P_{fe}$$

6.2 Method 2-2-A – Calibrated machine

6.2.1 General

The calibrated machine method may be used to determine the test machine efficiency either directly or by separate losses.

For an overview, Figure 1 provides a flowchart for efficiency determination by this test method.

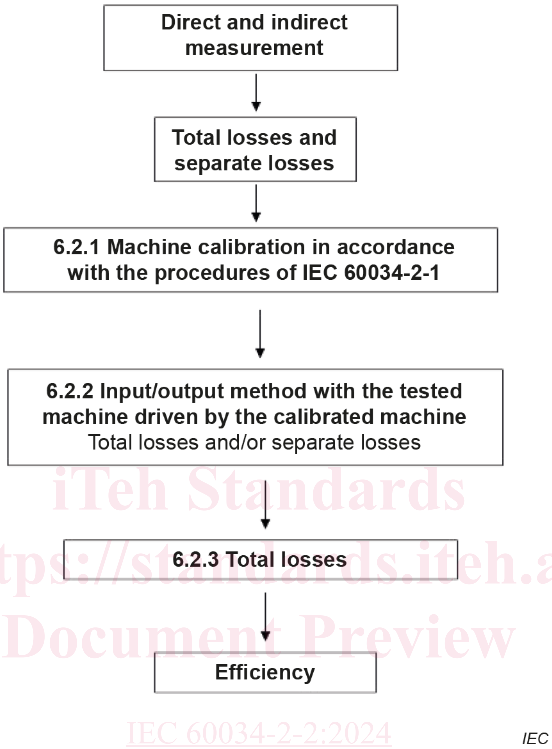

Figure 1 – Efficiency determination according to method 2-2-A

This method is generally applied as a factory test.

The tested machine shall be equipped with winding ETDs.

The tested machine shall be completely assembled with essential components as for normal operation.

This method requires a calibrated machine mechanically coupled to the machine under test and is used when a torque meter is not available. The mechanical input of the tested machine is calculated from the electrical input of the calibrated machine.

When a gear-box is directly connected to the machine it shall be considered as part of the calibrated machine.

Calibrate an electric machine, preferably a direct-current machine, according to one of the procedures in IEC 60034-2-1 at a sufficient number of thermally stable loads (including no-load) to determine an accurate relationship of output power as a function of input power adjusted for the temperature of the cooling air/medium at inlet. This is generally developed in the form of a curve.

It is generally advisable to take several readings of all instruments at each load-point during short periods of time and average the results to obtain a more accurate test value.

6.2.2 Test procedure

Before starting the test, record the winding resistances and the ambient temperature.

The machine for which the performance is to be determined shall be mechanically coupled to the calibrated machine and be operated at a speed equivalent to its synchronous/rated speed.

Operate the calibrated machine with the test machine at either rated-load, partial-load; no-load not excited, with or without brushes; no-load excited at rated voltage; or short-circuited, which enables specific categories of losses to be determined.

When the test machine is operated at each specified test condition and has reached thermal stability, record:

- for the calibrated machine

  P_1 = input power

  U_1 = input voltage

  I_1 = current

  θ_{1c} = temperature of inlet cooling air

  θ_{1w} = winding temperature (by variation of resistance if possible)

  n_1 = speed

- for the test machine (direct determination as a generator)

  P_2 = output power

  U_2 = output voltage or armature voltage (when excited open-circuit)

  I_2 = armature load current

  θ_{2w} = windings temperature (either directly by ETDs or by resistance variation)

  n_2 = speed.

Upon completion of each test, stop the machines and record in the given order:

- test machine winding resistance;
- calibrated machine winding resistance.

NOTE The example represents testing with a motor as the calibrated machine.

Finally operate the calibrated machine without electrical connection to the test machine and record as specified above.

From the curve developed in 6.2.1 and using the calibrated machine input values, select the appropriate output power to the test machine.

Adjust the output power for the standardized coolant temperature.

Determination of excitation power shall be in accordance with IEC 60034-2-1.

6.2.3 Direct efficiency determination

When the test machine is operated with rated conditions, the test machine efficiency is:

$\eta = \frac{P_2}{P_1}$ test machine working as a generator, calibrated machine working as a motor