SLOVENSKI STANDARD
SIST EN 60034-2:1999

01-april-1999

Rotating electrical machines - Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles) (IEC 60034-2:1972 + IEC 60034-2A:1974)

Rotating electrical machines -- Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)

Drehende elektrische Maschinen -- Teil 2: Verfahren zur Bestimmung der Verluste und des Wirkungsgrades von drehenden elektrischen Maschinen aus Prüfungen (ausgenommen Maschinen für Schienen- und Straßenfahrzeuge)

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

Ta slovenski standard je istoveten z: **EN 60034-2:1996**

ICS:

29.160.01	Rotacijski stroji na splošno	Rotating machinery in general

SIST EN 60034-2:1999 **en**

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 60034-2

November 1996

UDC 621.313.017.2/.6.017.8.083.001.4
ICS 29.160.00

Supersedes HD 53.2 S1:1974

Descriptors: Rotating electrical machines, power losses, efficiency, determination, tests, power measurements

English version

Rotating electrical machines
Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)
(IEC 34-2:1972 + IEC 34-2A:1974)

Machines électriques tournantes
Partie 2: Méthodes pour la détermination des pertes et du rendement des machines électriques tournantes à partir d'essais (à l'exclusion des machines pour véhicules de traction)
(CEI 34-2:1972 + IEC 34-2A:1974)

Drehende elektrische Maschinen
Teil 2: Verfahren zur Bestimmung der Verluste und des Wirkungsgrades von drehenden elektrischen Maschinen aus Prüfungen (ausgenommen Maschinen für Schienen- und Straßenfahrzeuge)
(IEC 34-2:1972 + IEC 34-2A:1974)

This European Standard was approved by CENELEC on 1996-07-02. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 60034-2:1996 E

Foreword

The text of the International Standard IEC 34-2:1972 + IEC 34-2A:1974, prepared by SC 2G, Test methods and procedures, of IEC TC 2, Rotating machinery, was approved by CENELEC as HD 53.2 S1 on 1974-12-11.

This Harmonization Document was submitted to the formal vote for conversion into a European Standard and was approved by CENELEC as EN 60034-2 on 1996-07-02.

The following date was fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1997-06-01

Endorsement notice

The text of the International Standard IEC 34-2:1972 + IEC 34-2A:1974 was approved by CENELEC as a European Standard without any modification.

C.D.U./U.D.C. 621.313.017.2/.6.017.8 083.001.1

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

(affiliée à l'Organisation Internationale de Normalisation — ISO)

RECOMMANDATION DE LA CEI

INTERNATIONAL ELECTROTECHNICAL COMMISSION

(affiliated to the International Organization for Standardization — ISO)

IEC RECOMMENDATION

Publication 34-2

Troisième édition — Third edition

1972

Machines électriques tournantes

Deuxième partie: Méthodes pour la détermination des pertes et du rendement des machines électriques tournantes à partir d'essais (à l'exclusion des machines pour véhicules de traction)

Rotating electrical machines

Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)

Bureau Central de la Commission Electrotechnique Internationale

1, rue de Varembé

Genève, Suisse

Prix Fr. s.
Price S. Fr. 48.—

CONTENTS

	Page
FOREWORD	5
PREFACE	5

Clause

SECTION ONE — GENERAL

1. Scope	7
2. Object	7
3. General	7
3.1 List of symbols	9
4. Definitions	9
4.1 Efficiency	9
4.2 Total loss	9
4.3 Breaking test	9
4.4 Calibrated driving machine test	11
4.5 Mechanical back-to-back test	11
4.6 Electrical back-to-back test	11
4.7 Retardation test	11
4.8 Calorimetric test	11
4.9 No-load test	11
4.10 Open-circuit test	11
4.11 Sustained short-circuit test	11
4.12 Zero power factor-test	11
5. Reference temperature	13

SECTION TWO — D.C. MACHINES

6. Losses to be included	13
6.1 Excitation circuit losses	13
6.2 Constant losses	13
6.3 Load losses	15
6.4 Additional load losses	15
7. Determination of efficiency	15
7.1 Summation of losses	15
7.2 Total loss measurement	23

SECTION THREE — POLYPHASE INDUCTION MACHINES

8. Losses to be included	25
8.1 Constant losses	25
8.2 Load losses	25
8.3 Additional load losses	27
9. Determination of efficiency	27
9.1 Summation of losses	27
9.2 Total loss measurement	31

SECTION FOUR — SYNCHRONOUS MACHINES

10. Losses to be included	33
10.1 Constant losses	33
10.2 Load losses	35
10.3 Excitation circuit losses	35
10.4 Additional load losses	35
11. Determination of efficiency	37
11.1 Summation of losses	37
11.2 Total loss measurement	43

SECTION FIVE — METHODS OF TEST

12. General	45
13. Calibrated machine test	47
14. Zero power factor test	47
15. Retardation method	47
16. Electrical back-to-back test	51
17. Calorimetric test	53
18. Schedule of preferred tests	53
18.1 D.C. machines	53
18.2 Polyphase induction machines	53
18.3 Synchronous machines	53
FIGURES	54

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ROTATING ELECTRICAL MACHINES

Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote this international unification, the IEC expresses the wish that all National Committees having as yet no national rules, when preparing such rules, should use the IEC recommendations as the fundamental basis for these rules in so far as national conditions will permit.

4) The desirability is recognized of extending international agreement on these matters through an endeavour to harmonize national standardization rules with these recommendations in so far as national conditions will permit. The National Committees pledge their influence towards that end.

PREFACE

This Recommendation has been prepared by Sub-Committee 2D, Losses and Efficiency, of IEC Technical Committee No. 2, Rotating Machinery. It supersedes the second edition published in 1960.

It constitutes part of a series of recommendations dealing with rotating electrical machinery, other parts being:
Part 1, Rating and Performance (IEC Publication 34-1).
Part 3, Ratings and Characteristics of Three-phase, 50 Hz Turbine-type Machines (IEC Publication 34-3).
Part 4, Methods for Determining Synchronous Machine Quantities from Tests (IEC Publication 34-4).
Part 5, Degrees of Protection by Enclosures for Rotating Machinery (IEC Publication 34-5).
Part 6, Methods of Cooling Rotating Machinery (IEC Publication 34-6).

Work on the revision started at the meeting held in Tokyo in 1965, and a further draft was discussed at the meeting held in London in 1968. As a result of this latter meeting, a final draft was submitted to the National Committees for approval under the Six Months' Rule in November 1969.

The following countries voted explicitly in favour of publication:

Australia
Austria
Belgium
Denmark
Finland
France
Germany
Hungary
Israel
Italy
Japan
Korea (Democratic People's Republic of)
Netherlands
Norway
Poland
South Africa
Sweden
Switzerland
Turkey
Union of Soviet Socialist Republics
United Kingdom
United States of America

ROTATING ELECTRICAL MACHINES

Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)

SECTION ONE — GENERAL

1. Scope

This Recommendation applies to d.c. machines and to a.c. synchronous and induction machines of all sizes within the scope of IEC Publication 34-1. The principles can, however, be applied to other types of machines such as rotary convertors, a.c. commutator motors and single-phase induction motors for which other methods of determining losses are generally used.

2. Object

This Recommendation is intended to establish methods of determining efficiencies from tests, and also to specify methods of obtaining particular losses when these are required for other purposes.

3. General

Tests shall be conducted on a completely sound machine with all covers fitted in the manner required for normal service, with any devices for automatic voltage regulation not a composite part of the machine itself being made inoperative, unless otherwise agreed.

Measuring instruments and their accessories, such as measuring transformers, shunts and bridges used during the tests, unless otherwise specified, shall have an accuracy class not above 1.0 (IEC Publication 51, Recommendations for Indicating Electrical Measuring Instruments and their Accessories). Instruments for determining d.c. resistance shall be to accuracy class not above 0.5.

Instruments shall be selected to give readings over the effective range such that a fraction of a division is a small percentage of the actual reading and can be easily estimated.

On machines with adjustable brushes, the brushes shall be placed in the position corresponding to the specified rating. For measurements on no-load, the brushes may be placed on the neutral axis.

Speed of rotation may be measured by a stroboscopic method, digital counter or tachometer. When measuring slip, the synchronous speed should be determined from the supply frequency during the test.

When the over-all efficiency or the absorbed power is measured for a group of machines comprising two electrical machines, or a machine and a transformer, or a generator and its driving machine, or a motor and its driven machine, there is no need to indicate the individual efficiencies. If, however, these are given separately, they should be regarded as approximate.

3.1 *List of symbols*

A list of symbols used in the draft, with the general meanings attributed to each one, is given below:

I = current
I_1 = load current at rated voltage
I_{1r} = main primary current at reduced voltage
I_o = no-load current at rated voltage
I_{or} = no-load current at reduced voltage
J = moment of inertia
n = rated speed, in revolutions per minute
P_1 = power absorbed at rated voltage
P_{1r} = power absorbed by main primary winding at reduced voltage
s = slip
U = excitation voltage across terminals of main rheostat
U_e total excitation voltage
U_n = rated voltage
U_r = reduced voltage for load test
φ = load phase angle at rated voltage
φ_r = load phase angle at reduced voltage
φ_o = no-load phase angle at rated voltage
φ_{or} = no-load phase angle at reduced voltage

4. **Definitions**

For definitions of general terms used in this Recommendation, reference should be made to the International Electrotechnical Vocabulary [IEC Publication 50].

For the purpose of this Recommendation, the following definitions apply:

4.1 *Efficiency*

The ratio of output to input expressed in the same units and usually given as a percentage.

4.2 *Total loss*

The difference between the input and the output.

4.3 *Braking test*

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

4.4 *Calibrated driving machine test*

A test in which the mechanical input or output of an electrical machine is calculated from the electrical output or input of a calibrated machine mechanically coupled to the machine on test.

4.5 *Mechanical back-to-back test*

A 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 (see Figure 1, page 54).

4.6 *Electrical back-to-back test*

A test in which two identical machines are mechanically coupled together, and they are both connected electrically to a power system. The total losses of both machines are taken as the power input drawn from the system (see Figure 2, page 54).

4.7 *Retardation test*

A test in which the losses in a machine are deduced from the rate of deceleration of the machine when only these losses are present.

4.8 *Calorimetric test*

A test in which the losses in a machine are deduced from the heat produced by them. The losses are calculated from the product of the amount of coolant and its temperature rise, and the heat dissipated in the surrounding media.

4.9 *No-load test*

A test in which the machine is run as a motor providing no useful mechanical output from the shaft.

4.10 *Open-circuit test*

A test in which a machine is run as a generator with its terminals open-circuited.

4.11 *Sustained short-circuit test*

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

4.12 *Zero power factor test*

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

5. **Reference temperature**

Unless otherwise specified, all I^2R losses shall be corrected to one of the temperatures given below:

Classes A, E and B: 75 °C
Classes F and H: 115 °C

Note. — The reference temperature need not necessarily correspond with the limits of temperature rise permitted for the actual class of insulation used for a particular part of the machine.

SECTION TWO — D.C. MACHINES

6. **Losses to be included**

The total losses may be taken as the sum of the following component losses:

6.1 *Excitation circuit losses*

a) I^2R losses in shunt or separately excited windings and in the excitation rheostats.

b) Exciter losses.

All the losses in an exciter mechanically driven from the main shaft, which forms part of the complete unit and is used solely for exciting the machine, together with losses in the rheostat in the excitation circuit of such an exciter, but with the exception of friction and windage losses.

In the case of a separate excitation supply such as battery, rectifier or motor generator set, no allowance is made for the losses in the excitation source or in the connections between the source and the brushes.

Note. — When the losses in a separate excitation system are required, these should be listed separately and can be taken as the difference between the excitation power divided by the efficiency of the excitation system, and the excitation power.

6.2 *Constant losses*

a) Losses in active iron, and additional no-load losses in other metal parts.

b) Losses due to friction (bearings and brushes) not including any losses in a separate lubricating system. Losses in common bearings shall be stated separately, whether or not such bearings are supplied with the machine.

Note. — When the losses in a separate lubricating system are required, these should be listed separately.

c) The total windage loss in the machine including power absorbed in integral fans and in auxiliary machines, if any, forming an integral part of the machine. The losses in auxiliary machines such as external fans, water and oil pumps not forming an integral part of the machine, but provided exclusively for the machine in question, shall be included only by agreement.

Note. — When the losses in a separate ventilating system are required, they should be listed separately as they are not part of the machine losses.

6.3 *Load losses*

a) I^2R losses in armature, and windings carrying armature current (e.g. commutating, compensating, excitation and series connected windings).

b) Electrical losses in brushes.

6.4 *Additional load losses*

a) Losses introduced by load in active iron, and other metal parts other than the conductors.

b) Eddy current losses in armature conductors caused by current dependent flux pulsation and commutation.

c) Losses in the brushes caused by commutation.

Note. — These losses are sometimes called additional losses, but they do not include the additional no-load losses in Sub-clause 6.2 *a*).

7. Determination of efficiency

7.1 *Summation of losses*

The efficiency can be calculated from the total losses which are assumed to be the summation of the losses obtained in the following manner:

7.1.1 *Excitation losses*

These are:

7.1.1.1 *Excitation winding I^2R losses*

These losses are calculated from the formula I^2R, where R is the resistance of the shunt excitation winding (or separately excited winding), corrected to the reference temperature, and I is the excitation current. Except for case *c)* below, the excitation current shall be that corresponding to rated speed under rated load conditions. For case *c)* below, the excitation current shall be that corresponding to rated speed at no-load.

If the excitation current cannot be measured during a test on load, it should be taken as:

a) For shunt connected or separately excited generators with or without commutation poles; 110% of the excitation current, corresponding to no-load at a voltage equal to the rated voltage plus ohmic drop in the armature circuit (armature, brushes and commutating windings if any, see also Sub-clause 7.1.3.2) at rated load current.

b) For compensated shunt or separately excited generators: the excitation current corresponding to no-load at a voltage equal to the rated voltage plus the ohmic drop in the armature circuit (armature, brushes, commutating windings and compensating windings, see also Sub-clause 7.1.3.2) at rated load current.

c) For level-compounded generators: the excitation current for the rated no-load voltage.

d) For over-compounded and under-compounded generators, and special types of generator not covered by items *a)* to *c)*: as agreed between manufacturer and purchaser.

e) For shunt wound motors: equal to no-load excitation current corresponding to the rated voltage.

7.1.1.2 *Main rheostat losses*

These losses are calculated from the formula I^2R, where R is the resistance of the part of the rheostat in circuit for the rating considered, and I is the value of the excitation current defined as in Sub-clause 7.1.1.1 above. They are also equal to the product, IU, of the excitation current multiplied by U, the excitation voltage which must be absorbed in the rheostat.

The sum of the losses, Sub-clauses 7.1.1.1 and 7.1.1.2, is also equal to the product IU_e of the excitation current I and the total excitation voltage U_e.

Note. — Where a resistance is permanently connected in series in the excitation circuit it should be dealt with in the same way as the main rheostat.

7.1.1.3 *Exciter losses*

Note. — This applies only to the case where the exciter is mechanically driven from the main shaft and is used solely for exciting the main machine.

These losses include the difference between the power absorbed at the shaft by the exciter and the useful power which it provides at its terminals,* as well as the excitation losses in the exciter if this is excited from a separate source.

If the exciter can be uncoupled from the main machine and tested separately, the power which it absorbs may be measured by using the calibrated-machine method.

* The useful power at the terminals of the exciter is equal to the sum of the losses, Sub-clauses 7.1.1.1 and 7.1.1.2, of the main machine.

If the exciter cannot be uncoupled from the main machine, the power which it absorbs may be measured either by the method of working the main machine as a motor on no-load, or by the calibrated machine method (Clause 13), or by the retardation method (Clause 15), applied to the whole unit. In these three methods, the power absorbed by the exciter is obtained as the difference between the total losses of the unit measured under identical conditions, first with the exciter on-load and secondly with the exciter non-excited, the excitation being supplied by an independent source.

If none of these methods is applicable, the power absorbed by the exciter is obtained by adding to the power, measured at the terminals, the different separate losses determined as under Clause 6. However, mechanical friction and windage losses which are measured at the same time as those of the main machine need not be taken into account.

7.1.2 *Constant losses*

7.1.2.1 *No-load test at rated voltage*

The constant losses shall be determined by running the machine under no-load conditions as a motor with rated voltage applied and with rated speed achieved by adjustment of the excitation, which shall preferably be derived from a separate source.

The total electric power absorbed, less the I^2R losses in the armature and in the excitation winding or, if necessary, less the power absorbed by the exciter, gives the sum of the constant losses.

7.1.2.2 *Open circuit test*

The constant losses can be determined separately by driving the machine at its rated speed by means of a calibrated machine. The machine on test is excited (preferably from an independent source), so as to work as a generator on no-load at a voltage equal to its rated voltage, the power which it absorbs at its shaft, and which can be obtained from the electric power absorbed by the calibrated machine, giving the sum of the constant losses. By removing the excitation, the sum of the friction and windage losses is obtained in the same way. The core losses may be determined separately by subtracting the losses during this test from those measured during the previous no-load test. By lifting the brushes the brush friction loss may be determined separately by subtracting the losses during this test from those measured during the previous, unexcited test.

7.1.2.3 *Retardation test*

In machines with large inertia, the total constant losses, as well as the separate constant losses, can be determined by the retardation method.

7.1.3 *Load losses*

These are:

7.1.3.1 *Armature circuit* I^2R *losses*

These losses are calculated from the current and the measured resistance, corrected to the reference temperature, except that where resistance measurement is impracticable due to very low resistances, calculation is permissible.

Note. — Under this heading are included compensating windings, commutating pole windings and diverters. In the case of diverters in parallel with a series winding, the I^2R losses should be determined using the total current and the resulting resistance.

7.1.3.2 *Electrical losses in brushes*

The sum of these losses shall be taken as the product of the armature current and a fixed voltage drop.

The voltage drop allowed for all brushes of each polarity shall be 1.0 V for carbon or graphite brushes and 0.3 V for metal-carbon brushes, i.e. a total drop of 2.0 V for carbon or graphite brushes, and 0.6 V for metal-carbon brushes.

7.1.4 *Additional load losses*

Unless otherwise specified, it is assumed that these losses vary as the square of the current, and that their total value at maximum rated current is, for:

Uncompensated machines

1% of the rated input for motors;
1% of the rated output for generators.

Compensated machines

0.5% of the rated input for motors;
0.5% of the rated output for generators.

For constant speed machines, the rated output or input as appropriate is taken as the output or input which would be obtained at maximum rated current and maximum rated voltage.

For variable speed motors where the speed change is obtained by applied voltage, the rated input is defined at each speed as being the input when the maximum rated current at any speed is associated with the applied voltage of the particular speed considered.

For variable speed motors where the increase in speed is obtained by weakening the field, the rated input is defined as being the input when the rated voltage is associated with the maximum rated current. For variable speed generators where the voltage is maintained constant by varying the field, the rated output is defined as being the output which is available at the terminals at rated voltage and maximum rated current. The allowances for additional losses at the speed corresponding to the full field shall be as specified above. The allowances for additional losses at other speeds shall be calculated using the appropriate multiplying factors given in Table I, page 23.