IEC 60034-2-2

Edition 1.0 2010-03

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 la CEI 60034-2-1

IEC 60034-2-2:2010

Documents
Document Sharing Hub

Full document details: IEC 60034-2-2 2010

THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2010 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.
If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.
Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub
The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, withdrawn and replaced publications.
- IEC Just Published: www.iec.ch/online_news/justpub
Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.
- Electropedia: www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.
- Customer Service Centre: www.iec.ch/webstore/custserv
If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:
Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

- Catalogue des publications de la CEI: www.iec.ch/searchpub/cur_fut-f.htm
Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,…). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.
- Just Published CEI: www.iec.ch/online_news/justpub
Restez informé sur les nouvelles publications de la CEI. Just Published détaille deux fois par mois les nouvelles publications parues. Disponible en-ligne et aussi par email.
- Electropedia: www.electropedia.org
Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.
- Service Clients: www.iec.ch/webstore/custserv/custserv_entry-f.htm
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:
Email: csc@iec.ch
Tél.: +41 22 919 02 11
Fax: +41 22 919 03 00

Documents
Document Sharing Hub

Full document details: IEC 60034-2-2 2010

IEC 60034-2-2

Edition 1.0 2010-03

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 la CEI 60034-2-1

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX U

ICS 29.160

ISBN 978-2-88910-017-0

® Registered trademark of the International Electrotechnical Commission
Marque déposée de la Commission Electrotechnique Internationale

Documents
Document Sharing Hub

Full document details: IEC 60034-2-2 2010

CONTENTS

FOREWORD ... 3
1 Scope ... 5
2 Normative references ... 5
3 Terms and definitions ... 5
4 Symbols ... 6
4.1 Quantities ... 6
4.2 Subscripts ... 6
5 Basic requirements ... 7
5.1 Direct and indirect efficiency determination ... 7
5.1.1 Direct ... 7
5.1.2 Indirect ... 7
5.2 Uncertainty ... 7
5.3 Preferred methods ... 7
6 Common determinations ... 8
6.1 Efficiency ... 8
6.2 Total loss ... 8
6.3 Load losses ... 9
7 Methods ... 9
7.1 Calibrated machine method ... 10
7.1.1 General ... 10
7.1.2 Machine calibration ... 10
7.1.3 Test procedure ... 10
7.1.4 Determination of performance ... 11
7.2 Retardation method ... 12
7.2.1 Fundamentals ... 12
7.2.2 Test procedure ... 12
7.2.3 Determination of deceleration ... 14
7.2.4 Determination of retardation constant ... 15
7.2.5 Determination of losses ... 16
7.3 Calorimetric method ... 17
7.3.1 General ... 17
7.3.2 Calorimetric instrumentation ... 19
7.3.3 Test procedure ... 22
7.3.4 Determination of losses ... 22

Figure 1 – Method of the chord ... 15
Figure 2 – Reference surface ... 18
Figure 3 – Four coolers connected in parallel, single calorimeter, single coolant ... 20
Figure 4 – Series connected coolers, two coolants ... 20
Figure 5 – Bypass piping ... 21
Figure 6 – Parallel piping ... 21
Figure 7 – Characteristics of pure water as a function of temperature ... 23

Table 1 – Preferred methods for large machines ... 8

Documents
Document Sharing Hub

Full document details: IEC 60034-2-2 2010

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ROTATING ELECTRICAL MACHINES –

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

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

FDIS	Report on voting
2/1585/FDIS	2/1595/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.

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

Documents
Document Sharing Hub

Full document details: IEC 60034-2-2 2010

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 amendment and the base 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.

Documents
Document Sharing Hub

Full document details: IEC 60034-2-2 2010

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 result 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.

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 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.

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

AVA Documents
Document Sharing Hub

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
the state reached when the temperature rises of the several parts of the machine do not vary by more than a gradient of 2 K per hour

[IEV 411-51-08]

4 Symbols

In addition to the symbols in IEC 60034-2-1, the following apply.

4.1 Quantities

A is an area, m^2,

C is the retardation constant, kg m^2 min^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 speed, min^{-1},

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

P_k is the constant loss, W,

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

P_e is the excitation power, W,

P_{Fe} is the iron loss, W,

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

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

P_{mech} is the mechanical power, W,

P_T is the total loss, 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 Subscripts

irs for inside reference surface,

ers for outside reference surface,

E for exciter,

c for the cooling circuit,

Documents
Document Sharing Hub

Full document details: IEC 60034-2-2 2010

N for rated values,

rs for the reference surface,

t for a test procedure,

1 for input or initial condition,

2 for output condition.

5 Basic requirements

5.1 Direct and indirect efficiency determination

Tests can be grouped in the following categories.

5.1.1 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.

5.1.2 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 loss;

– 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 standard 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. This standard uses the following relative uncertainty terms:

– "low" applies to efficiency determinations based solely upon test results;

– "medium" applies to efficiency determinations based upon limited approximations;

– "high" applies to efficiency determinations based upon assumptions.

5.3 Preferred methods

It is difficult to establish specific rules for the determination of efficiency. The choice of test to be made depends on the information required, the accuracy required, the type and size of the machine involved and the available field test equipment (supply, load or driving machine).

Preferred methods for large machines are given in Table 1.

Documents
Document Sharing Hub

Full document details: IEC 60034-2-2 2010

Table 1 – Preferred methods for large machines

Quantity to be determined	Test method	Clause	Uncertainty
Direct efficiency	Calibrated machine	7.1.4.1	medium
Total losses	Calorimetric [1]	7.3.3d)	low/medium
Friction and windage loss	Calibrated machine	7.1.4.2a)	medium
	Retardation	7.2.5.2	medium
	Calorimetric	7.3.3a)	low/medium
Active iron loss, and additional open-circuit losses in d.c. and synchronous machines	Calibrated machine	7.1.4.2b)	medium
	Retardation	7.2.5.3	medium
	Calorimetric	7.3.3b)	low/medium
Winding and additional-load losses	Calibrated machine	7.1.4.2c)	medium
	Retardation	7.2.5.5	medium
	Calorimetric	7.3.3c)	low/medium

6 Common determinations

These determinations are applicable to more than one of the listed methods.

6.1 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 according to 6.2.

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 power P_e of the machine where applicable.

6.2 Total loss

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

For direct current machines:

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

[1] If the relative error in P_{irs} (see 7.3.1) is likely to be greater than 3 %, the calorimetric method is not recommended.

AVA Documents Document Sharing Hub

$$P_e = P_f + P_E$$

$$P_k = P_{fw} + P_{Fe}$$

For induction machines:

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

$$P_k = P_{fw} + P_{Fe}$$

For synchronous machines:

$$P_T = P_k + P_a + P_{LL} + P_e$$

$$P_e = P_f + P_E + P_b$$

$$P_k = P_{fw} + P_{Fe}$$

where:

- P_a is the I^2R armature-winding loss (interpole, compensation and series field winding loss in case of d.c. machines),
- P_b is the brush loss,
- P_E is the exciter loss,
- P_e is the excitation power,
- P_f is the excitation (field winding) loss,
- P_{Fe} is the iron loss,
- P_{fw} is the friction and windage loss,
- P_k is the constant loss,
- P_{LL} is the additional load loss,
- P_r is the I^2R rotor winding loss,
- P_s is the stator I^2R winding loss,
- P_T is the total loss.

6.3 Load losses

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.

7 Methods

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.

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

Documents
Document Sharing Hub

Full document details: IEC 60034-2-2 2010

7.1 Calibrated machine method

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

7.1.1 General

This method is generally applied as a factory test.

This method requires a calibrated machine mechanically coupled to the machine under test and is used when neither a torque meter nor dynamometer is available. The mechanical input of the tested machine is calculated from the electrical input of the calibrated machine.

7.1.2 Machine calibration

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.

NOTE 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.

7.1.3 Test procedure

The tested machine shall be equipped with winding ETDs.

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

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:

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

– for the calibrated machine

  P_1 = 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

Documents
Document Sharing Hub
Full document details: IEC 60034-2-2 2010

U_2 = output voltage

I_2 = armature load current

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

n_2 = speed

– for the unloaded test machine (as a generator)

U_2 = armature voltage (when excited open-circuit)

I_2 = armature current (when excited short-circuit)

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.

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

7.1.4 Determination of performance

From the curve developed in 7.1.2 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.

7.1.4.1 Direct efficiency determination

When tested according to 7.1.3 the test machine efficiency is:

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

where

P_2 is the output power of test generator

P_1 is the calculated input power to the test generator according to 7.1.3.

and:

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

where

P_1 is the input power to test motor

P_2 is the calculated output power from the test motor.

7.1.4.2 Separate losses

Using values of P determined from the calibrated machine curve, it is possible to determine the power dissipated by the test machine for other selected conditions that may be used to determine efficiency according to 6.1.

AVA Documents Document Sharing Hub

Full document details: IEC 60034-2-2 2010

a) Friction and windage loss at rated speed (when the test machine is not electrically connected);

b) Active iron loss, and additional open-circuit losses in d.c. and synchronous machines, (when tested at no-load, open-circuit, excited at rated voltage, minus the windage and friction loss). Field losses from a separate source;

c) Armature-winding loss and additional-load loss in synchronous machines, (when tested under short-circuit conditions, excited at rated armature current, minus the windage and friction loss). Field losses from a separate source.

7.2 Retardation method

The retardation method can be used in determining the separate losses of rotating electrical machines having an appreciable rotational inertia.

The retardation method is used to determine:

– sum of the friction loss and windage loss ("mechanical losses") in machines of all types;

– sum of losses in active iron and additional open-circuit losses in d.c. and synchronous machines;

– sum of I^2R losses in an operating winding and additional-load losses ("short-circuit losses") in synchronous machines.

7.2.1 Fundamentals

The recorded test loss P_t which retards the machine is proportional to the product of the speed at which this loss corresponds and the deceleration at that speed:

$$P_t = -Cn\frac{dn}{dt}$$

where:

P_t is the loss being measured, W;

C is the retardation constant according to 7.2.4;

n is the speed, min^{-1};

dn/dt is the deceleration from 7.2.3.

NOTE The accuracy of the retardation method is directly related to the accuracy of the retardation constant C which depends solely on the moment of inertia J (see 7.2.4).

7.2.2 Test procedure

7.2.2.1 Assembly of test machine

The test machine shall be assembled, with all essential components, as for normal operation, but uncoupled from other rotating parts. A suitable speed sensor shall be attached to the rotating element.

NOTE When the machine cannot be uncoupled, all possible steps should be taken to reduce the mechanical losses in other rotating parts, e.g. by partial dismantling or in the case of a water turbine, by preventing water in the runner chamber. Rotation of the runner in air produces a windage loss which should be determined either experimentally or from calculations.

7.2.2.2 Machine preparation for test

Electrically connect the test machine as a motor (on no-load) fed from a separate power source having a wide range of variable frequency. Any excitation shall be obtained from a separate source with a rapid and precise voltage control.

AVA Documents Document Sharing Hub

Full document details: IEC 60034-2-2 2010

NOTE 1 The test machine may be driven by its normal prime mover, e.g. by Pelton turbine when the water supply to the runner can be cut off instantly.

NOTE 2 Excitation from a mechanically-coupled exciter is not recommended, but may be permitted when the value of the deviation of speed δ does not exceed 0,05. Losses in exciters coupled to the shaft of the test machine are to be taken into account.

The bearing temperatures shall be adjusted to the normal temperature at which the bearings operate with rated load, by adjusting the coolant flow.

The air temperature shall be adjusted, whenever possible, to the normal temperature at which the windage loss measurement is required by throttling the air coolant flow.

7.2.2.3 Testing preparation

Retardation tests shall be conducted as a series without interruption, whenever possible. It is recommended that the series start and finish with retardation tests of the test machine unexcited.

All tests shall be repeated several times at the preset rated values of open-circuit voltage or short-circuit current. The arithmetic mean value obtained from each series of measurements shall be assumed to be the appropriate loss value of that category of loss.

Select a value of δ (the per unit deviation of rotational speed from rated speed) which shall not be greater than 0,1 and may have to be less than this, depending on the characteristics of the machine.

7.2.2.4 Tests

Rapidly accelerate the test machine to a speed above n_N (1 + δ). Disconnect the machine from its supply source. Sufficient time delay shall separate the switching off of the supply and starting the measurements to allow electromagnetic transients to decay.

During deceleration to n_N (1 – δ) place the test machine in the required condition, according to the following tests:

When moment of inertia is known.

a) running unexcited;

b) running open-circuited, excited at rated voltage;

c) running with the armature terminals short-circuited, and the excitation set to give the rated armature current.

NOTE As an alternate, tests may be carried out at various values within limits of the order of 95 % to 105 % of either the rated voltage or rated short-circuit current.

Additional tests, when the moment of inertia is unknown, shall be conducted at the same values as determined in b) and c) according to either d) e) or f).

d) with the field suppressed, connect the test machine to a transformer previously set under no-load condition and excited to the preset values of current or open-circuit voltage;

e) with the field suppressed, connect the test machine to a transformer previously set under short-circuit;

f) with the field suppressed, simultaneously load the exciter or the auxiliary generator with a ballast resistance at a predetermined load.

Each retardation test shall be repeated at least twice.

Documents
Document Sharing Hub
Full document details: IEC 60034-2-2 2010

7.2.2.5 Measurements

Measurements of voltage and current shall be taken at the instant when the test machine passes through rated speed, except in the case of an unexcited retardation test.

NOTE Excitation circuit power should be measured, if excitation is not provided by a separate source.

The measured values of open-circuit voltage or short-circuit current shall not differ from the preset values by more than ± 2 %. The calculated final value of the speed derivative in time for each of the tests shall be adjusted proportionally by the ratio of the square of the preset value to the measured value.

Highly accurate recording instruments shall be used either with continuous or with discrete recording of test values of speed and time.

For each test category, take sufficient measurements to accurately locate the points n_N (1 + δ) and n_N (1 – δ) as a function of time.

7.2.2.5.1 All tests

For all tests, record

n as a function of t (the armature circuit being short-circuited);

θ_w = winding temperatures (either directly or by resistance variation);

θ_a = inlet/outlet temperature of the primary cooling medium.

For the following tests record additionally:

where the numbered subscript denotes the specific test number.

7.2.2.5.2 Test 2

P_2 during initial operation at rated voltage (see 7.2.4.2.1);

U_2 open-circuit rated voltage.

7.2.2.5.3 Test 3 (for synchronous machines)

I_a armature current.

7.2.2.5.4 Test 4

P_4 transformer no-load loss;

U_4 open-circuit rated voltage.

7.2.2.5.5 Test 5

P_5 transformer short-circuit loss;

I_a armature current.

7.2.2.5.6 Test 6

P_6 exciter or auxiliary generator load.

7.2.3 Determination of deceleration

This chord method requires the measurement of the time interval (t_2 – t_1) during which the speed of the tested machine changes from n_N (1 + δ) to n_N (1 – δ), see Figure 1. The ratio of speed interval 2 δ n_N to (t_2 – t_1) is approximately the deceleration at rated speed:

$$\frac{2\delta n_N}{t_2 - t_1} \approx -\left.\frac{dn}{dt}\right|_{n = n_N}$$

Documents
Document Sharing Hub
Full document details: IEC 60034-2-2 2010

where

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

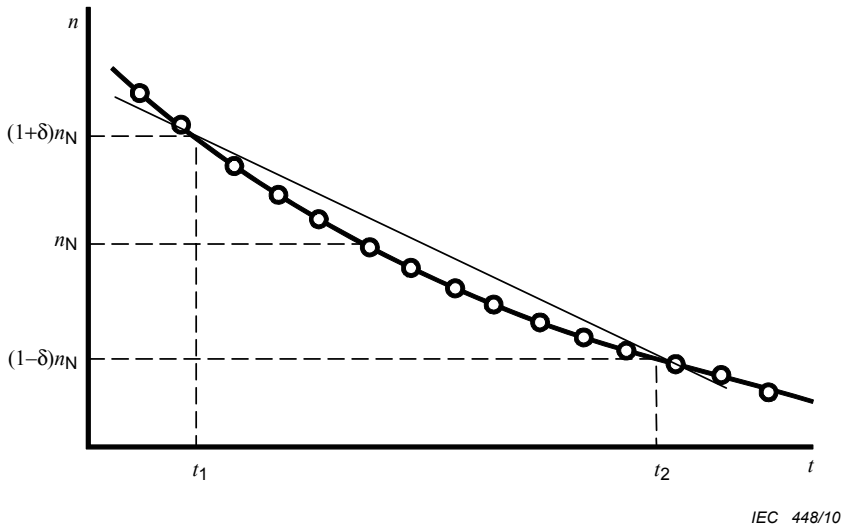

Figure 1 – Method of the chord

Determine the deceleration for the required tests and record as:

$$\left.\frac{dn}{dt}\right|_{\mathrm{t}}$$

Where:

t is the number of the test according to 7.2.2.4.

NOTE According to the definition in 7.2.3 dn/dt is a negative value.

7.2.4 Determination of retardation constant

7.2.4.1 Known moment of inertia

When the moment of inertia of a machine rotating-part has been previously determined by either measurement (preferred) or by design calculation, the retardation constant is calculated from:

$$C = \frac{4\pi^2\ J}{60^2} = 10{,}97 \times 10^{-3} J$$

where:

J is the moment of inertia, in kg·m^2.

7.2.4.2 Unknown moment of inertia

7.2.4.2.1 Operation as an unloaded motor

When the test machine is operated as an unloaded motor, the input power is equal to the sum of the mechanical loss P_{fw} and iron loss P_{Fe} (the armature circuit I^2R loss is ignored), then the retardation constant C is determined from the formula:

Documents
Document Sharing Hub
Full document details: IEC 60034-2-2 2010