SLOVENSKI STANDARD
SIST EN 60034-4:2008

01-december-2008

Nadomeğļ a:
SIST EN 60034-4:1999

Elektriļ ni rotacijski stroji - 4. del: Metode za preskusno ugotavljanje veliļ in sinhronskih strojev (IEC 60034-4:2008)

Rotating electrical machines - Part 4: Methods for determining synchronous machine quantities from tests (IEC 60034-4:2008)

Drehende elektrische Maschinen - Teil 4: Verfahren zur Ermittlung der Kenngrößen von Synchronmaschinen durch Messungen (IEC 60034-4:2008)

Machines électriques tournantes - Partie 4: Méthodes pour la détermination, à partir d'essais, des grandeurs des machines synchrones (CEI 60034-4:2008)

Ta slovenski standard je istoveten z: EN 60034-4:2008

ICS:

29.160.01	Rotacijski stroji na splošno	Rotating machinery in general

SIST EN 60034-4:2008 en,fr

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 60034-4

September 2008

ICS 29.160

Supersedes EN 60034-4:1995

English version

Rotating electrical machines - Part 4: Methods for determining synchronous machine quantities from tests (IEC 60034-4:2008)

Machines électriques tournantes - Partie 4: Méthodes pour la détermination, à partir d'essais, des grandeurs des machines synchrones (CEI 60034-4:2008)

Drehende elektrische Maschinen - Teil 4: Verfahren zur Ermittlung der Kenngrößen von Synchronmaschinen durch Messungen (IEC 60034-4:2008)

This European Standard was approved by CENELEC on 2008-07-01. 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, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the 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 60034-4:2008 E

Foreword

The text of document 2/1488/FDIS, future edition 3 of IEC 60034-4, prepared by IEC TC 2, Rotating machinery, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60034-4 on 2008-07-01.

This European Standard supersedes EN 60034-4:1995.

The main changes with respect to EN 60034-4:1995 are listed below:

– tests described in supplement A of EN 60034-4:1995 were partly removed for lack of relevance in current practice;

– provisions were made for tests on machines with brushless excitation;

– a table of test methods indicates preferred tests, and a test cross-reference is provided;

– the conventional two-axes salient-pole machine model description was added in an annex.

The following dates were 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)	2009-04-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2011-07-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60034-4:2008 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60034-1	2004	Rotating electrical machines - Part 1: Rating and performance	EN 60034-1	2004
IEC 60034-2-1	-[1)]	Rotating electrical machines - Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)	EN 60034-2-1	2007[2)]
IEC 60034-2A	-[1)]	Rotating electrical machines - Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles) – First supplement: Measurement of losses by the calorimetric method	-	-
IEC 60051	Series	Direct acting indicating analogue electrical measuring instruments and their accessories	EN 60051	Series

[1)] Undated reference.

[2)] Valid edition at date of issue.

IEC 60034-4

Edition 3.0 2008-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Rotating electrical machines –
Part 4: Methods for determining synchronous machine quantities from tests

Machines électriques tournantes –
Partie 4: Méthodes pour la détermination, à partir d'essais, des grandeurs des machines synchrones

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX XC

ICS 29.160

ISBN 2-8318-9706-8

CONTENTS

FOREWORD 7
1 Scope 9
2 Normative references 9
3 Terms and definitions 9
4 Symbols and units 14
5 Overview of tests 15
6 Test procedures 18
6.1 General 18
6.1.1 Instrumentation requirements 18
6.1.2 Excitation system requirements 18
6.1.3 Test conditions 18
6.1.4 Per unit base quantities 19
6.1.5 Conventions and assumptions 19
6.1.6 Consideration of magnetic saturation 20
6.2 Direct measurements of excitation current at rated load 21
6.3 Direct-current winding resistance measurements 21
6.4 No-load saturation test 22
6.4.1 Test procedure 22
6.4.2 No-load saturation characteristic determination 23
6.5 Sustained three-phase short-circuit test 23
6.5.1 Test procedure 23
6.5.2 Three-phase sustained short-circuit characteristic 24
6.6 Motor no-load test 24
6.7 Phase shifting test 24
6.8 Over-excitation test at zero power-factor 25
6.9 Negative excitation test 25
6.10 On-load test measuring the load angle 25
6.11 Low slip test 25
6.12 Sudden three-phase short-circuit test 26
6.13 Voltage recovery test 27
6.14 Suddenly applied short-circuit test following disconnection from line 27
6.15 Direct current decay test in the armature winding at standstill test 27
6.16 Suddenly applied excitation test with armature winding open-circuited 28
6.17 Applied voltage test with the rotor in direct and quadrature axis positions 29
6.18 Applied voltage test with the rotor in arbitrary position 29
6.19 Single phase voltage test applied to the three phases 30
6.20 Line-to-line sustained short-circuit test 30
6.21 Sudden line-to-line short-circuit 31
6.22 Line-to-line and to neutral sustained short-circuit test 31
6.23 Negative-phase sequence test 32
6.24 Field current decay test, with the armature winding open-circuited 32
6.24.1 Test at rated speed 32
6.24.2 Test at standstill 32
6.25 Field current decay test at rated speed with the armature-winding short-circuited 32
6.26 Suddenly applied excitation with armature winding short-circuited 33

6.27 Field current decay test at standstill with two phases of armature winding short-circuited 33
6.28 Applied voltage test with rotor removed 33
6.29 No-load retardation test 34
6.30 Suspended rotor oscillation test 34
6.31 Locked rotor test 35
6.32 Over-excitation test at zero power factor and variable armature voltage 35
6.33 Asynchronous operation during the low-voltage test 35
6.34 Applied variable frequency voltage test at standstill 36
7 Determination of quantities 38
7.1 Graphic procedures and analysis of oscillographic records 38
7.1.1 No-load saturation and three-phase, sustained short-circuit curves 38
7.1.2 Sudden three-phase short-circuit test 38
7.1.3 Voltage recovery test 41
7.1.4 Direct current decay in the armature winding at standstill 41
7.1.5 Suddenly applied excitation test with armature winding open-circuited 43
7.2 Direct-axis synchronous reactance 44
7.2.1 From no-load saturation and three-phase sustained short-circuit test 44
7.2.2 From motor no-load test 44
7.2.3 From phase shifting test 44
7.2.4 From on-load test measuring the load angle 44
7.3 Direct-axis transient reactance 45
7.3.1 From sudden three-phase short-circuit test 45
7.3.2 From voltage recovery test 45
7.3.3 From d.c. decay test in the armature winding at standstill 45
7.3.4 Calculation from test values 45
7.4 Direct-axis sub-transient reactance 45
7.4.1 From sudden three-phase short-circuit test 45
7.4.2 From voltage recovery test 46
7.4.3 From applied voltage test with the rotor in direct and quadrature axis 46
7.4.4 From applied voltage test with the rotor in arbitrary position 46
7.5 Quadrature-axis synchronous reactance 47
7.5.1 From negative excitation test 47
7.5.2 From low slip test 47
7.5.3 From phase shifting test 48
7.5.4 From on-load test measuring the load angle 49
7.6 Quadrature-axis transient reactance 49
7.6.1 From direct current decay test in the armature winding at standstill 49
7.6.2 Calculation from test values 49
7.7 Quadrature-axis sub-transient reactance 49
7.7.1 From applied voltage test with the rotor in direct and quadrature position 49
7.7.2 From applied voltage test with the rotor in arbitrary position 50
7.8 Zero-sequence reactance 50
7.8.1 From single-phase voltage application to the three phases 50
7.8.2 From line-to-line and to neutral sustained short-circuit test 50
7.9 Negative-sequence reactance 51
7.9.1 From line-to-line sustained short-circuit test 51
7.9.2 From negative-phase sequence test 51

7.9.3 Calculation from test values 52
7.9.4 From sudden line-to-line short-circuit test 52
7.9.5 From direct-current decay test at standstill 52
7.10 Armature leakage reactance 52
7.11 Potier reactance 53
7.12 Zero-sequence resistance 54
7.12.1 From single-phase voltage test applied to the three phases 54
7.12.2 From line-to-line and to neutral sustained short-circuit test 54
7.13 Positive-sequence armature winding resistance 54
7.14 Negative-sequence resistance 54
7.14.1 From line-to-line sustained short-circuit test 54
7.14.2 From negative-phase sequence test 55
7.15 Armature and excitation winding resistance 55
7.16 Direct-axis transient short-circuit time constant 56
7.16.1 From sudden three-phase short-circuit test 56
7.16.2 From field current decay at rated speed with armature winding short-circuited 56
7.16.3 From direct current decay test at standstill 56
7.16.4 From suddenly applied excitation with armature winding short-circuited 56
7.16.5 From field current decay test at standstill with two phases of armature winding short-circuited 56
7.17 Direct-axis transient open-circuit time constant 56
7.17.1 From field current decay at rated speed with armature winding open 56
7.17.2 From field current decay test at standstill with armature winding open 56
7.17.3 From voltage recovery test 56
7.17.4 From direct-current decay test at standstill 57
7.17.5 From suddenly applied excitation with armature winding open-circuited 57
7.18 Direct-axis sub-transient short-circuit time constant 57
7.19 Direct-axis sub-transient open-circuit time constant 57
7.19.1 From voltage recovery test 57
7.19.2 From direct-current decay test at standstill 57
7.20 Quadrature-axis transient short-circuit time constant 57
7.20.1 Calculation from test values 57
7.20.2 From direct-current decay test at standstill 57
7.21 Quadrature-axis transient open-circuit time constant 57
7.21.1 Determination from direct-current decay test at standstill 57
7.22 Quadrature-axis sub-transient short-circuit time constant 57
7.22.1 Calculation from test values 57
7.22.2 Determination from direct- current decay test at standstill 58
7.23 Quadrature-axis sub-transient open-circuit time constant 58
7.23.1 From direct-current decay test at standstill 58
7.24 Armature short-circuit time constant 58
7.24.1 From sudden three-phase short-circuit test 58
7.24.2 Calculation from test values 58
7.25 Rated acceleration time and stored energy constant 58
7.25.1 From suspended rotor oscillation test 58
7.25.2 From no-load retardation test 59

7.26 Rated excitation current 59
7.26.1 From direct measurement 59
7.26.2 Potier diagram 60
7.26.3 ASA diagram 61
7.26.4 Swedish diagram 62
7.27 Excitation current referred to rated armature sustained short-circuit current 63
7.27.1 From over-excitation test at zero power factor 63
7.27.2 From sustained three-phase short-circuit test 64
7.28 Frequency response characteristics 64
7.28.1 General 64
7.28.2 From asynchronous operation at reduced voltage 64
7.28.3 From applied variable frequency voltage test at standstill 65
7.28.4 From direct current decay test in the armature winding at standstill 66
7.29 Short-circuit ratio 67
7.30 Rated voltage regulation 67
7.30.1 From direct measurement 67
7.30.2 From no-load saturation characteristic and known field current at rated load 67
7.31 Initial starting impedance of synchronous motors 67
Annex A (informative) Testing cross-reference 69
Annex B (informative) Calculation scheme for frequency response characteristics 72
Annex C (informative) Conventional electrical machine model 74

Figure 1 – Schematic for d.c. decay test at standstill 28
Figure 2 – Circuit diagram for line-to-line short-circuit test 30
Figure 3 – Circuit diagram for line-to-line and to neutral sustained short-circuit test 31
Figure 4 – Search coil installation with rotor removed 34
Figure 5 – Power and current versus slip (example) 36
Figure 6 – Schematic for variable frequency test at standstill 36
Figure 7 – Recorded quantities from variable frequency test at standstill (example) 37
Figure 8 – Combined saturation and short-circuit curves 38
Figure 9 – Transient and sub-transient component of short-circuit current 39
Figure 10 – Determination of transient component of short-circuit current 40
Figure 11 – Graphical determination of aperiodic component 40
Figure 12 – Transient and sub-transient component of recovery voltage 41
Figure 13 – Semi-logarithmic plot of decay currents 42
Figure 14 – Suddenly applied excitation with armature winding open-circuited 43
Figure 15 – No-load e.m.f. and excitation current for one pole-pitch slip 47
Figure 16 – Current envelope from low-slip test 48
Figure 17 – Determination of Potier reactance 53
Figure 18 – Potier's diagram 60
Figure 19 – ASA diagram 61
Figure 20 – Swedish diagram 62
Figure 21 – Excitation current from over-excitation at zero power factor 63
Figure 22 – Frequency response characteristics at low frequencies (example) 65

Figure C.1 – Equivalent circuit model of a salient pole machine 74

Table 1 – Test methods and cross-reference table 16
Table A.1 – Test cross-reference 69

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ROTATING ELECTRICAL MACHINES –

Part 4: Methods for determining synchronous machine quantities from tests

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 provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
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 60034-4 has been prepared by IEC technical committee 2: Rotating machinery.

This third edition cancels and replaces the second edition published in 1985 and its amendment 1 (1995). This edition constitutes a technical revision. The main changes with respect to the previous edition are listed below:

– Tests described in Supplement A of the previous edition were partly removed for lack of relevance in current practise.
– Provisions were made for tests on machines with brushless excitation.
– A table of test methods indicates preferred tests, and a test cross-reference is provided.
– The conventional two-axes salient-pole machine model description was added in an Annex.

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

FDIS	Report on voting
2/1488/FDIS	2/1495/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.

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

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.

ROTATING ELECTRICAL MACHINES –

Part 4: Methods for determining synchronous machine quantities from tests

1 Scope

This part of IEC 60034 applies to three-phase synchronous machines of 1 kVA rating and larger with rated frequency of not greater than 500 Hz and not less than 10 Hz.

Most of the methods are intended to be used for machines having an excitation winding with slip-rings and brushes for their supply. Synchronous machines with brushless excitation require special effort for some of the tests. For machines with permanent magnet excitation, there is a limited applicability of the described tests, and special precautions have to be taken against irreversible demagnetization.

Excluded are axial-field machines and special synchronous machines such as inductor type machines and transversal flux machines.

It is not intended that this standard be interpreted as requiring any or all of the tests described therein on any given machine. The particular tests to be carried out shall be subject to agreement between manufacturer and customer.

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 60034-1:2004, *Rotating electrical machines – Part 1: Rating and performance*

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

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

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
initial starting impedance, synchronous motors
quotient of the applied armature voltage and the sustained average armature current, the machine being at standstill