

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**

IEC 60034-4:2008

<https://standards.iteh.ai/standards/iec/60034-4-2008>



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2008 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 Varembe
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 It also gives information on projects, withdrawn and replaced publications.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

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**

IEC 60034-4:2008

<https://standards.iteh.ai/standards/iec/6c866a57-9eea-40b2-9f6c-8fa2800f2373/iec-60034-4-2008>

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX

XC

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

Witholdrawn

iTen Standards
(<https://standards.iteh.ai>)
Document Preview

IEC 60034-4:2008

<https://standards.iteh.ai/standards/iec/60034-4/60034-4-2008>

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.

iTech Standards
(<https://standards.itih.ai>)
Document Preview

IEC 60034-4:2008

<https://standards.itih.ai/standards/iec/60034-4-2008>

WITHDRAWN

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

3.2

direct-axis synchronous reactance

the quotient of the sustained value of that fundamental a.c. component of armature voltage, which is produced by the total direct-axis primary flux due to direct-axis armature current, and the value of the fundamental a.c. component of this current, the machine running at rated speed

[IEV 411-50-07]

3.3

direct-axis transient reactance

the quotient of the initial value of a sudden change in that fundamental a.c. component of armature voltage, which is produced by the total direct-axis primary flux, and the value of the simultaneous change in fundamental a.c. component of direct-axis armature current, the machine running at rated speed and the high decrement components during the first cycles being excluded

[IEV 411-50-09]

3.4

direct-axis sub-transient reactance

the quotient of the initial value of a sudden change in that fundamental a.c. component of armature voltage, which is produced by the total direct-axis armature flux, and the value of the simultaneous change in fundamental a.c. component of direct-axis armature current, the machine running at rated speed

[IEV 411-50-11]

3.5

quadrature-axis synchronous reactance

the quotient of the sustained value of that fundamental a.c. component of armature voltage, which is produced by the total quadrature-axis primary flux due to quadrature-axis armature current, and the value of the fundamental a.c. component of this current, the machine running at rated speed

[IEV 411-50-08]

3.6

quadrature-axis transient reactance

the quotient of the initial value of a sudden change in that fundamental a.c. component of armature voltage, which is produced by the total quadrature-axis armature winding flux, and the value of the simultaneous change in fundamental a.c. component of quadrature-axis armature current, the machine running at rated speed and the high decrement components during the first cycles being excluded

[IEV 411-50-10]

3.7

quadrature-axis sub-transient reactance

the quotient of the initial value of a sudden change in that fundamental a.c. component of armature voltage, which is produced by the total quadrature-axis primary flux and the value of the simultaneous change in fundamental a.c. component of quadrature-axis armature current, the machine running at rated speed

[IEV 411-50-12]

3.8

positive sequence reactance

the quotient of the reactive fundamental component of the positive sequence armature voltage, due to the sinusoidal positive sequence armature current at rated frequency, by the value of that component of current, the machine running at rated speed

[IEV 411-50-14]

3.9

negative sequence reactance

the quotient of the reactive fundamental component of negative sequence armature voltage, due to the sinusoidal negative sequence armature current at rated frequency, by the value of that component of current, the machine running at rated speed

[IEV 411-50-15]

3.10

zero sequence reactance

the quotient of the reactive fundamental component of zero sequence armature voltage, due to the presence of fundamental zero sequence armature current at rated frequency, by the value of that component of current, the machine running at rated speed

[IEV 411-50-16]

3.11

Potier reactance

a reactance taking into account the leakage of the field winding, on load and in the over-excited region, which is used in place of the armature leakage reactance to calculate the excitation on load by means of the Potier method

[IEV 411-50-13]

3.12

armature-leakage reactance

quotient of the reactive fundamental component of armature voltage due to the leakage flux of armature winding and the fundamental component of armature current, the machine running at rated speed

3.13

armature resistance

resistance measured by direct current between terminals of the armature winding, assigned to a certain winding temperature, expressed as per phase value

3.14

excitation winding resistance

resistance measured by direct current between terminals of the excitation winding, assigned to a certain winding temperature

3.15

positive sequence resistance

the quotient of the in-phase component of positive sequence armature voltage corresponding to losses in the armature winding and stray load losses due to the sinusoidal positive sequence armature current, by the value of that component of current, the machine running at rated speed

[IEV 411-50-18]

3.16

negative sequence resistance

the quotient of the in-phase fundamental component of negative sequence armature voltage, due to the sinusoidal negative sequence armature current at rated frequency, by the value of that component of current, the machine running at rated speed

[IEV 411-50-19]

3.17

zero sequence resistance

the quotient of the in-phase fundamental component of zero sequence armature voltage, due to the fundamental zero sequence armature current of rated frequency, by the value of that component of current, the machine running at rated speed

[IEV 411-50-20]

**3.18
short-circuit ratio**

the ratio of the field current for rated armature voltage on open-circuit to the field current for rated armature current on sustained symmetrical short-circuit, both with the machine running at rated speed

[IEV 411-50-21]

**3.19
direct-axis transient open-circuit time constant**

the time required, following a sudden change in operating conditions, for the slowly changing component of the open-circuit armature voltage, which is due to direct-axis flux, to decrease to $1/e$, that is 0,368 of its initial value, the machine running at rated speed

[IEV 411-48-27]

**3.20
direct-axis transient short-circuit time constant**

the time required, following a sudden change in operating conditions, for the slowly changing component of direct-axis short-circuit armature current to decrease to $1/e$, that is 0,368 of its initial value, the machine running at rated speed

[IEV 411-48-28]

**3.21
direct-axis sub-transient open-circuit time constant**

the time required, following a sudden change in operating conditions, for the rapidly changing component present during the first few cycles of the open-circuit armature winding voltage which is due to direct-axis flux, to decrease to $1/e$, that is 0,368 of its initial value, the machine running at rated speed

[IEV 411-48-29]

**3.22
direct-axis sub-transient short-circuit time constant**

the time required, following a sudden change in operating conditions, for the rapidly changing component, present during the first few cycles in the direct-axis short-circuit armature current, to decrease to $1/e$, that is 0,368 of its initial value, the machine running at rated speed

[IEV 411-48-30]

**3.23
quadrature-axis transient open-circuit time constant**

the time required, following a sudden change in operating conditions, for the slowly changing component of the open-circuit armature winding voltage which is due to quadrature-axis flux, to decrease to $1/e$, that is 0,368 of its initial value, the machine running at rated speed

[IEV 411-48-32]

**3.24
quadrature-axis transient short-circuit time constant**

the time required, following a sudden change in operating conditions, for the slowly changing component of quadrature-axis short-circuit armature winding current, to decrease to $1/e$, that is 0,368 of its initial value, the machine running at rated speed

[IEV 411-48-33]