



IEC 60034-1

Edition 14.0 2022-02  
REDLINE VERSION

# INTERNATIONAL STANDARD



**Rotating electrical machines –  
Part 1: Rating and performance**





**THIS PUBLICATION IS COPYRIGHT PROTECTED**  
**Copyright © 2022 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.

IEC Secretariat  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://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 corrigendum or an amendment might have been published.

**IEC publications search - [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)**

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

**IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)**

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

**IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)**

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [sales@iec.ch](mailto:sales@iec.ch).

**IEC Products & Services Portal - [products.iec.ch](http://products.iec.ch)**

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

**Electropedia - [www.electropedia.org](http://www.electropedia.org)**

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.



IEC 60034-1

Edition 14.0 2022-02  
REDLINE VERSION

# INTERNATIONAL STANDARD



---

## Rotating electrical machines – Part 1: Rating and performance

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

ICS 29.160.01

ISBN 978-2-8322-1082-6

**Warning! Make sure that you obtained this publication from an authorized distributor.**

# CONTENTS

|                                                                                                  |    |
|--------------------------------------------------------------------------------------------------|----|
| FOREWORD .....                                                                                   | 7  |
| 1 Scope .....                                                                                    | 10 |
| 2 Normative references .....                                                                     | 10 |
| 3 Terms and definitions .....                                                                    | 12 |
| 4 Duty .....                                                                                     | 18 |
| 4.1 Declaration of duty .....                                                                    | 18 |
| 4.2 Duty types .....                                                                             | 18 |
| 4.2.1 Duty type S1 – Continuous running duty .....                                               | 18 |
| 4.2.2 Duty type S2 – Short-time duty .....                                                       | 19 |
| 4.2.3 Duty type S3 – Intermittent periodic duty .....                                            | 20 |
| 4.2.4 Duty type S4 – Intermittent periodic duty with starting .....                              | 21 |
| 4.2.5 Duty type S5 – Intermittent periodic duty with electric braking .....                      | 22 |
| 4.2.6 Duty type S6 – Continuous operation periodic duty .....                                    | 24 |
| 4.2.7 Duty type S7 – Continuous operation periodic duty with electric braking .....              | 25 |
| 4.2.8 Duty type S8 – Continuous operation periodic duty with related<br>load/speed changes ..... | 26 |
| 4.2.9 Duty type S9 – Duty with non-periodic load and speed variations .....                      | 27 |
| 4.2.10 Duty type S10 – Duty with discrete constant loads and speeds .....                        | 28 |
| 5 Rating .....                                                                                   | 31 |
| 5.1 Assignment of rating .....                                                                   | 31 |
| 5.2 Classes of rating .....                                                                      | 31 |
| 5.2.1 Rating for continuous running duty .....                                                   | 31 |
| 5.2.2 Rating for short-time duty .....                                                           | 31 |
| 5.2.3 Rating for periodic duty .....                                                             | 31 |
| 5.2.4 Rating for non-periodic duty .....                                                         | 31 |
| 5.2.5 Rating for duty with discrete constant loads and speeds .....                              | 32 |
| 5.2.6 Rating for equivalent loading .....                                                        | 32 |
| 5.3 Selection of a class of rating .....                                                         | 32 |
| 5.4 Allocation of outputs to class of rating .....                                               | 32 |
| 5.5 Rated output .....                                                                           | 33 |
| 5.5.1 DC generators .....                                                                        | 33 |
| 5.5.2 AC generators .....                                                                        | 33 |
| 5.5.3 Motors .....                                                                               | 33 |
| 5.5.4 Synchronous <del>condensers</del> compensators .....                                       | 33 |
| 5.6 Rated voltage .....                                                                          | 33 |
| 5.6.1 DC generators .....                                                                        | 33 |
| 5.6.2 AC generators .....                                                                        | 33 |
| 5.6.3 AC motors .....                                                                            | 33 |
| 5.7 <del>Co-ordination</del> Preferred combination of voltages and outputs .....                 | 33 |
| 5.8 Machines with more than one rating .....                                                     | 34 |
| 6 Site conditions .....                                                                          | 34 |
| 6.1 General .....                                                                                | 34 |
| 6.2 Altitude .....                                                                               | 34 |
| 6.3 Maximum ambient air temperature .....                                                        | 34 |
| 6.4 Minimum ambient air temperature .....                                                        | 34 |
| 6.5 Water coolant temperature .....                                                              | 34 |

|        |                                                                                                                                                         |    |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| 6.6    | Standstill, storage and transport .....                                                                                                                 | 35 |
| 6.7    | Purity of hydrogen coolant .....                                                                                                                        | 35 |
| 7      | Electrical operating conditions .....                                                                                                                   | 35 |
| 7.1    | Electrical supply.....                                                                                                                                  | 35 |
| 7.2    | Form and symmetry of voltages and currents .....                                                                                                        | 36 |
| 7.2.1  | AC motors .....                                                                                                                                         | 36 |
| 7.2.2  | AC generators .....                                                                                                                                     | 37 |
| 7.2.3  | Synchronous machines.....                                                                                                                               | 37 |
| 7.2.4  | DC motors supplied from static power converters .....                                                                                                   | 38 |
| 7.3    | Voltage during starting of AC motors.....                                                                                                               | 39 |
| 7.4    | Voltage and frequency variations during operation .....                                                                                                 | 39 |
| 7.5    | Three-phase AC machines operating on unearthed systems .....                                                                                            | 42 |
| 7.6    | Voltage (peak and gradient) withstand levels .....                                                                                                      | 43 |
| 8      | Thermal performance and tests .....                                                                                                                     | 43 |
| 8.1    | Thermal class .....                                                                                                                                     | 43 |
| 8.2    | Reference coolant.....                                                                                                                                  | 43 |
| 8.3    | Conditions for thermal tests .....                                                                                                                      | 44 |
| 8.3.1  | Electrical supply .....                                                                                                                                 | 44 |
| 8.3.2  | Temperature of machine before test .....                                                                                                                | 45 |
| 8.3.3  | Temperature of coolant.....                                                                                                                             | 45 |
| 8.3.4  | Measurement of coolant temperature during test .....                                                                                                    | 45 |
| 8.4    | Temperature rise of a part of a machine.....                                                                                                            | 45 |
| 8.5    | Methods of measurement of temperature .....                                                                                                             | 46 |
| 8.5.1  | General .....                                                                                                                                           | 46 |
| 8.5.2  | Resistance method .....                                                                                                                                 | 46 |
| 8.5.3  | Embedded temperature detector (ETD) method .....                                                                                                        | 46 |
| 8.5.4  | Thermometer method.....                                                                                                                                 | 46 |
| 8.6    | Determination of winding temperature .....                                                                                                              | 46 |
| 8.6.1  | Choice of method .....                                                                                                                                  | 46 |
| 8.6.2  | Determination by resistance method .....                                                                                                                | 47 |
| 8.6.3  | Determination by ETD method.....                                                                                                                        | 49 |
| 8.6.4  | Determination by thermometer method .....                                                                                                               | 49 |
| 8.7    | Duration of thermal tests .....                                                                                                                         | 50 |
| 8.7.1  | Rating for continuous running duty .....                                                                                                                | 50 |
| 8.7.2  | Rating for short-time duty .....                                                                                                                        | 50 |
| 8.7.3  | Rating for periodic duty.....                                                                                                                           | 50 |
| 8.7.4  | Ratings for non-periodic duty and for duty with discrete constant loads .....                                                                           | 50 |
| 8.8    | Determination of the thermal equivalent time constant for machines of duty type S9.....                                                                 | 50 |
| 8.9    | Measurement of bearing temperature.....                                                                                                                 | 50 |
| 8.10   | Limits of temperature and of temperature rise .....                                                                                                     | 51 |
| 8.10.1 | General .....                                                                                                                                           | 51 |
| 8.10.2 | Indirect cooled windings .....                                                                                                                          | 51 |
| 8.10.3 | Direct cooled windings.....                                                                                                                             | 55 |
| 8.10.4 | Adjustments to take account of hydrogen purity on test .....                                                                                            | 56 |
| 8.10.5 | Permanently short-circuited windings, magnetic cores and all structural components (other than bearings) whether or not in contact with insulation..... | 56 |
| 8.10.6 | Commutators and sliprings, open or enclosed and their brushes and brushgear .....                                                                       | 56 |

|        |                                                                                                       |    |
|--------|-------------------------------------------------------------------------------------------------------|----|
| 9      | Other performance and tests .....                                                                     | 58 |
| 9.1    | Routine tests.....                                                                                    | 58 |
| 9.2    | Withstand voltage test.....                                                                           | 60 |
| 9.3    | Occasional excess current .....                                                                       | 64 |
| 9.3.1  | General .....                                                                                         | 64 |
| 9.3.2  | Generators .....                                                                                      | 64 |
| 9.3.3  | Motors (except commutator motors and permanent magnet motors) .....                                   | 64 |
| 9.3.4  | Commutator machines .....                                                                             | 64 |
| 9.4    | Momentary excess torque for motors .....                                                              | 64 |
| 9.4.1  | Polyphase induction motors and DC motors.....                                                         | 64 |
| 9.4.2  | Polyphase synchronous motors .....                                                                    | 65 |
| 9.4.3  | Other motors .....                                                                                    | 65 |
| 9.5    | Pull-up torque and locked-rotor torque for cage induction motors with direct<br>online starting ..... | 65 |
| 9.6    | Safe operating speed of cage induction motors .....                                                   | 65 |
| 9.7    | Overspeed .....                                                                                       | 66 |
| 9.8    | Short-circuit current for synchronous machines.....                                                   | 67 |
| 9.9    | Short-circuit withstand test for synchronous machines .....                                           | 67 |
| 9.10   | Commutation test for commutator machines.....                                                         | 68 |
| 9.11   | Total harmonic distortion ( <i>THD</i> ) for synchronous machines .....                               | 68 |
| 9.11.1 | General .....                                                                                         | 68 |
| 9.11.2 | Limits .....                                                                                          | 68 |
| 9.11.3 | Tests .....                                                                                           | 68 |
| 9.12   | Protective earth test.....                                                                            | 68 |
| 9.13   | Measurement of insulation resistance and polarization index of winding<br>insulation .....            | 69 |
| 9.14   | Shaft-voltage test.....                                                                               | 70 |
| 10     | Information requirements .....                                                                        | 70 |
| 10.1   | General.....                                                                                          | 70 |
| 10.2   | Product documentation .....                                                                           | 70 |
| 10.3   | Rating plate .....                                                                                    | 70 |
| 10.4   | Marking Information content.....                                                                      | 71 |
| 10.4.1 | General .....                                                                                         | 72 |
| 10.4.2 | Minimum information requirements .....                                                                | 72 |
| 10.4.3 | All AC machines .....                                                                                 | 73 |
| 10.4.4 | All DC machines .....                                                                                 | 74 |
| 10.4.5 | Machines over 5 kW (or 5 kVA) rated output.....                                                       | 74 |
| 10.4.6 | Optional information .....                                                                            | 74 |
| 11     | Miscellaneous requirements .....                                                                      | 74 |
| 11.1   | Protective earthing of machines .....                                                                 | 74 |
| 11.2   | Shaft-end key(s) .....                                                                                | 76 |
| 12     | Tolerances .....                                                                                      | 76 |
| 12.1   | General.....                                                                                          | 76 |
| 12.2   | Tolerances on values of quantities.....                                                               | 76 |
| 13     | Electromagnetic compatibility (EMC) .....                                                             | 78 |
| 13.1   | General.....                                                                                          | 78 |
| 13.2   | Immunity.....                                                                                         | 79 |
| 13.2.1 | Machines not incorporating electronic circuits.....                                                   | 79 |
| 13.2.2 | Machines incorporating electronic circuits.....                                                       | 79 |

|                                                                                                                                                   |                                                                                                                                                                                                                                                                                  |               |
|---------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| 13.3                                                                                                                                              | Emission .....                                                                                                                                                                                                                                                                   | 79            |
| 13.4                                                                                                                                              | Immunity tests .....                                                                                                                                                                                                                                                             | 79            |
| 13.5                                                                                                                                              | Emission measurements .....                                                                                                                                                                                                                                                      | 79            |
| 14                                                                                                                                                | <b>Safety Application requirements</b> .....                                                                                                                                                                                                                                     | 79            |
| Annex A (informative) Guidance for the application of duty type S10 and for establishing the value of relative thermal life expectancy $TL$ ..... |                                                                                                                                                                                                                                                                                  | 81            |
| Annex B (informative) Electromagnetic compatibility (EMC) limits .....                                                                            |                                                                                                                                                                                                                                                                                  | 82            |
| Bibliography .....                                                                                                                                |                                                                                                                                                                                                                                                                                  | 83            |
|                                                                                                                                                   |                                                                                                                                                                                                                                                                                  |               |
| Figure 1                                                                                                                                          | – Continuous running duty – Duty type S1 .....                                                                                                                                                                                                                                   | 19            |
| Figure 2                                                                                                                                          | – Short-time duty – Duty type S2 .....                                                                                                                                                                                                                                           | 20            |
| Figure 3                                                                                                                                          | – Intermittent periodic duty – Duty type S3 .....                                                                                                                                                                                                                                | 21            |
| Figure 4                                                                                                                                          | – Intermittent periodic duty with starting – Duty type S4 .....                                                                                                                                                                                                                  | 22            |
| Figure 5                                                                                                                                          | – Intermittent periodic duty with electric braking – Duty type S5 .....                                                                                                                                                                                                          | 23            |
| Figure 6                                                                                                                                          | – Continuous operation periodic duty – Duty type S6 .....                                                                                                                                                                                                                        | 24            |
| Figure 7                                                                                                                                          | – Continuous operation periodic duty with electric braking – Duty type S7 .....                                                                                                                                                                                                  | 25            |
| Figure 8                                                                                                                                          | – Continuous operation periodic duty with related load/speed changes – Duty type S8 .....                                                                                                                                                                                        | 27            |
| Figure 9                                                                                                                                          | – Duty with non-periodic load and speed variations – Duty type S9 .....                                                                                                                                                                                                          | 28            |
| Figure 10                                                                                                                                         | – Duty with discrete constant loads – Duty type S10 .....                                                                                                                                                                                                                        | 30            |
| <del>Figure 11 – Voltage and frequency limits for generators .....</del>                                                                          |                                                                                                                                                                                                                                                                                  | <del>31</del> |
| <del>Figure 12 – Voltage and frequency limits for motors .....</del>                                                                              |                                                                                                                                                                                                                                                                                  | <del>32</del> |
| Figure 11                                                                                                                                         | – Voltage and frequency limits for motors and for generators except generators or synchronous compensators within the scope of IEC 60034-3 and hydro generators within the scope of IEC 60034-33 .....                                                                           | 42            |
| Figure 12                                                                                                                                         | – Worst case increase in temperature rise ( $\Delta\theta$ ) and recommended reduction of output power ( $\Delta P$ ) of motors as a function of the combined change of voltage and frequency $ \Delta\phi $ (indicative guideline to users of motors and generators only) ..... | 42            |
| Figure 13                                                                                                                                         | – Factor $K$ for determining $R_{PE,M}$ .....                                                                                                                                                                                                                                    | 69            |
|                                                                                                                                                   |                                                                                                                                                                                                                                                                                  |               |
| Table 1                                                                                                                                           | – Preferred voltage ratings .....                                                                                                                                                                                                                                                | 34            |
| Table 2                                                                                                                                           | – Unbalanced operating conditions for synchronous machines .....                                                                                                                                                                                                                 | 38            |
| Table 3                                                                                                                                           | – CCC symbol designation .....                                                                                                                                                                                                                                                   | 39            |
| Table 4                                                                                                                                           | – Primary functions of machines .....                                                                                                                                                                                                                                            | 41            |
| Table 5                                                                                                                                           | – Reference coolant (see also Table 11) .....                                                                                                                                                                                                                                    | 44            |
| Table 6                                                                                                                                           | – Time interval .....                                                                                                                                                                                                                                                            | 48            |
| Table 7                                                                                                                                           | – Measuring points .....                                                                                                                                                                                                                                                         | 50            |
| Table 8                                                                                                                                           | – Limits of temperature rise of windings indirectly cooled by air .....                                                                                                                                                                                                          | 52            |
| Table 9                                                                                                                                           | – Limits of temperature rise of windings indirectly cooled by hydrogen .....                                                                                                                                                                                                     | 53            |
| Table 10                                                                                                                                          | – Adjustments to limits of temperature rise at the operating site of indirect cooled windings to take account of non-reference operating conditions and ratings .....                                                                                                            | 54            |
| Table 11                                                                                                                                          | – Assumed maximum ambient temperature .....                                                                                                                                                                                                                                      | 55            |
| Table 12                                                                                                                                          | – Adjusted limits of temperature rise at the test site ( $\Delta\theta_T$ ) for windings indirectly cooled by air to take account of test site operating conditions .....                                                                                                        | 56            |
| Table 13                                                                                                                                          | – Limits of temperature of directly cooled windings and their coolants .....                                                                                                                                                                                                     | 57            |

|                                                                                                                                                                                               |    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Table 14 – Adjustments to limits of temperature at the operating site for windings directly cooled by air or hydrogen to take account of non-reference operating conditions and ratings ..... | 57 |
| Table 15 – Adjusted limits of temperature at the test site $\theta_T$ for windings directly cooled by air to take account of test site operating conditions .....                             | 58 |
| Table 16 – Minimum routine tests for machines assembled and tested in the factory of the manufacturer.....                                                                                    | 59 |
| Table 17 – Withstand voltage tests .....                                                                                                                                                      | 62 |
| Table 18 – Test voltage factors for machines with an assigned Impulse Voltage Insulation Class (IVIC) according to IEC 60034-18-41 and IEC 60034-18-42.....                                   | 63 |
| Table 19 – Maximum safe operating speed ( $\text{min}^{-1}$ ) of three-phase single-speed cage induction motors for voltages up to and including 1 000 V.....                                 | 66 |
| Table 20 – Overspeeds .....                                                                                                                                                                   | 67 |
| Table 21 – Cross-sectional areas of earthing conductors .....                                                                                                                                 | 76 |
| Table 22 – Schedule of tolerances on values of quantities .....                                                                                                                               | 77 |
| Table B.1 – Electromagnetic emission limits per CISPR 11 Class B Group 1.....                                                                                                                 | 82 |
| Table B.2 – Electromagnetic emission limits per CISPR 11 Class A Group 1.....                                                                                                                 | 82 |

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## ROTATING ELECTRICAL MACHINES –

## Part 1: Rating and performance

## 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.

**This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 60034-1:2017. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.**

IEC 60034-1 has been prepared by IEC technical committee 2: Rotating machinery. It is an International Standard.

This fourteenth edition cancels and replaces the thirteenth edition published in 2017. This edition constitutes a technical revision.

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

| Clause or subclause | Change                                                                                                                                                                                          |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1                   | Clarification of the scope                                                                                                                                                                      |
| 2                   | General use of dated references                                                                                                                                                                 |
| 3.29                | Clarification on identification of maximum and minimum current                                                                                                                                  |
| 3.34                | Definition of main insulation                                                                                                                                                                   |
| 3.35                | Definition of converter capable machine                                                                                                                                                         |
| 3.36                | Definition of converter duty machine                                                                                                                                                            |
| 3.37                | Definition of shaft voltage                                                                                                                                                                     |
| 4.2                 | Explanation for using duty types S9 and S10 for converter duty machines                                                                                                                         |
| 5.6.3               | New subclause for clarification of the terms range of rated voltages and voltage variations                                                                                                     |
| 6.2                 | Requirement to consider reduced arcing distance in machine design for altitudes >1 000 m                                                                                                        |
| 7.1                 | Clarification on bus transfer or fast reclosing<br>Clarification on the capability to withstand impulse voltages                                                                                |
| 7.3                 | New subclause on voltage deviation during starting                                                                                                                                              |
| 7.4                 | Extended variation of supply frequency<br>Note added on design for operation with extended voltage and frequency<br>Recommended derating added for high variations of voltage and frequency     |
| 7.6                 | Clarification that enamelled wires are no bare living material                                                                                                                                  |
| 8.3.1               | Clarification on electrical supply during thermal tests added                                                                                                                                   |
| 9.1                 | Changes in Table 16, especially inclusion of PM and reluctance synchronous machines                                                                                                             |
| 9.2                 | Requirement on test equipment for withstand voltage test added<br>Test voltage for variable speed AC machines added<br>Clarification to withstand voltage test for machines after stock holding |
| 9.5                 | Extended to requirements on minimum locked rotor torque                                                                                                                                         |
| 9.10                | Note added on criteria for commutation test                                                                                                                                                     |
| 9.11.3              | Clarification added that synchronous motors do not need a THD test                                                                                                                              |
| 9.12                | New subclause on protective earth test                                                                                                                                                          |
| 9.13                | New subclause on measurement of insulation resistance and polarization index                                                                                                                    |
| 9.14                | New subclause on shaft-voltage measurement                                                                                                                                                      |
| 10.                 | Clause has been rearranged completely<br>Clarification on unit symbol for speed added                                                                                                           |
| 11.1                | Clarification on protective earth test after installation added                                                                                                                                 |
| 12.1                | Clarification on the tolerances due to the accuracy of the test equipment<br>Note on measurement uncertainty added                                                                              |

| Clause or subclause | Change                                                                                                                                   |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| 12.2                | Change in the tolerance on efficiency<br>Clarification on the tolerance on locked-rotor current<br>New tolerance on sound pressure level |
| 14                  | Improved title of clause                                                                                                                 |

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

|             |                  |
|-------------|------------------|
| Draft       | Report on voting |
| 2/2084/FDIS | 2/2090/RVD       |

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

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

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/standardsdev/publications](http://www.iec.ch/standardsdev/publications).

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

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

**IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.**

# ROTATING ELECTRICAL MACHINES –

## Part 1: Rating and performance

### 1 Scope

This part of IEC 60034 is applicable to all rotating electrical machines, ~~except those covered by other IEC standards, for example, IEC 60349~~ except rotating electrical machines for rail and road vehicles, which are covered by the IEC 60349 series of standards.

Machines within the scope of this document may also be subject to superseding, modifying or additional requirements in other standards, for example, IEC 60079 and IEC 60092.

NOTE If particular clauses of this document are modified to meet special applications, for example machines subject to radioactivity or machines for aerospace, all other clauses apply insofar as they are compatible.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60027-1:1992, *Letters symbols to be used in electrical technology – Part 1: General*  
IEC 60027-1:1992/AMD1:1997  
IEC 60027-1:1992/AMD2:2005

IEC 60027-4:2006, *Letter symbols to be used in electrical technology – Part 4: Rotating electric machines*

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

IEC 60034-3:2020, *Rotating electrical machines – Part 3: Specific requirements for synchronous generators driven by steam turbines or combustion gas turbines and for synchronous compensators*

IEC 60034-5:2020, *Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification*

IEC 60034-6:1991, *Rotating electrical machines – Part 6: Methods of cooling (IC code)*

IEC 60034-8:2007, *Rotating electrical machines – Part 8: Terminal markings and direction of rotation*  
IEC 60034-8:2007/AMD1:2014

IEC 60034-12:2016, *Rotating electrical machines – Part 12: Starting performance of single-speed three-phase cage induction motors*

IEC 60034-15:2009, *Rotating electrical machines – Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines*

IEC 60034-18 (all parts), *Rotating electrical machines – Part 18: Functional evaluation of insulation systems*

IEC 60034-18-41:2014, *Rotating electrical machines – Part 18-41: Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage converters – Qualification and quality control tests*

IEC 60034-18-41:2014/AMD1:2019

IEC 60034-18-42:2017, *Rotating electrical machines – Part 18-42: Partial discharge resistant electrical insulation systems (Type II) used in rotating electrical machines fed from voltage converters – Qualification tests*

IEC 60034-18-42:2017/AMD1:2020

IEC 60034-19:2014, *Rotating electrical machines – Part 19: Specific test methods for d.c. machines on conventional and rectifier-fed supplies*

IEC TS 60034-25:2014, *Rotating electrical machines – Part 25: AC electrical machines used in power drive systems – Application guide*

IEC 60034-27-4, *Rotating electrical machines – Part 27-4: Measurement of insulation resistance and polarization index of winding insulation of rotating electrical machines*

IEC 60034-29:2008, *Rotating electrical machines – Part 29: Equivalent loading and superposition techniques – Indirect testing to determine temperature rise*

IEC 60034-30-1:2014, *Rotating electrical machines – Part 30-1: Efficiency classes of line operated AC motors (IE-code)*

IEC TS 60034-30-2, *Rotating electrical machines – Part 30-2: Efficiency classes of variable speed AC motors (IE-code)*

IEC 60034-33: *Rotating electrical machines – Part 33: Specific technical requirements for hydro generators*

~~IEC 60038, IEC standard voltages~~

IEC 60050-411:1996, *International Electrotechnical Vocabulary (IEV) – Part 411: Rotating ~~machines~~ machinery*

IEC 60050-411:1996/AMD1:2007

IEC 60050-411:1996/AMD2:2021

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

~~IEC 60072 (all parts), Dimensions and output series for rotating electrical machines~~

IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*

IEC 60204-1:2016, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60204-11:2018, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for ~~HV~~ equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV*

IEC 60335-1:~~2010~~2020, *Household and similar electrical appliances – Safety – Part 1: General requirements*

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60417, *Graphical symbols for use on equipment – 12-month subscription to regularly updated online database comprising all graphical symbols published in IEC 60417*

IEC 60445:2017, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors*

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 61148:2011, *Terminal markings for valve device stacks and assemblies and for power conversion equipment*

IEC TS 61800-8, *Adjustable speed electrical power drive systems – Part 8: Specification of voltage on the power interface*

~~IEC 61293, Marking of electrical equipment with ratings related to electrical supply – Safety requirements~~

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

CISPR 11:2015/AMD1:2016

CISPR 11:2015/AMD2:2019

CISPR 14 (all parts), *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus*

CISPR 16 (all parts), *Specification for radio disturbance and immunity measuring apparatus and methods*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions in IEC 60050-411, ~~some of which are repeated here for convenience,~~ and the following apply.

NOTE 1 For definitions concerning cooling and coolants, other than those in 3.17 to 3.22, see IEC 60034-6.

NOTE 2 For the purposes of this document, the term ‘agreement’ means ‘agreement between the manufacturer and purchaser’.

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

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

#### 3.1

##### rated value

quantity value assigned, generally by a manufacturer, for a specified operating condition of a machine

Note 1 to entry: The rated voltage or voltage range is the rated voltage or voltage range between lines at the terminals.

[SOURCE: IEC 60050-411:1996, 411-51-23]

### 3.2

#### **rating**

set of rated values and operating conditions

[SOURCE: IEC 60050-411:1996, 411-51-24]

### 3.3

#### **rated output**

value of the output included in the rating

### 3.4

#### **load**

all the values of the, *in case of a generator*, electrical and, *in case of a motor*, mechanical quantities that signify the demand made on a rotating machine by an electrical circuit or a mechanism at a given instant

[SOURCE: IEC 60050-411:1996, 411-51-01, modified: modification indicated in italics.]

### 3.5

#### **no-load (operation)**

state of a machine rotating with zero output power (*but under otherwise normal operating conditions*)

[SOURCE: IEC 60050-411:1996, 411-51-02, modified: modification indicated in italics.]

### 3.6

#### **full load**

load which causes a machine to operate at its rating

[SOURCE: IEC 60050-411:1996, 411-51-10]

### 3.7

#### **full load value**

quantity value for a machine operating at full load

Note 1 to entry: This concept applies to power, torque, current, speed, etc.

[SOURCE: IEC 60050-411:1996, 411-51-11]

### 3.8

#### **rest and de-energized**

complete absence of all movement and of all electrical supply or mechanical drive

[SOURCE: IEC 60050-411:1996, 411-51-03]

### 3.9

#### **duty**

statement of the load(s) to which the machine is subjected, including, if applicable, starting, electric braking, no-load and rest and de-energized periods, and including their durations and sequence in time

[SOURCE: IEC 60050-411:1996, 411-51-06]

### 3.10

#### **duty type**

continuous, short-time or periodic duty, comprising one or more loads remaining constant for the duration specified, or a non-periodic duty in which generally load and speed vary within the permissible operating range

[SOURCE: IEC 60050-411:1996, 411-51-13]

### 3.11

#### **cyclic duration factor**

ratio between the period of loading, including starting and electric braking, and the duration of the duty cycle, expressed as a percentage

[SOURCE: IEC 60050-411:1996, 411-51-09]

### 3.12

#### **locked-rotor torque**

~~smallest~~ minimum measured torque the motor develops at its shaft and with the rotor locked, over all its angular positions, at rated voltage and frequency

[SOURCE: IEC 60050-411:1996, 411-48-06]

### 3.13

#### **locked-rotor current**

greatest steady-state r.m.s. current taken from the line with the ~~motor held at rest~~ rotor locked, over all angular positions of its rotor, at rated voltage and frequency

[SOURCE: IEC 60050-411:1996, 411-48-16]

### 3.14

#### **pull-up torque <of an AC motor>**

~~smallest~~ minimum steady-state asynchronous torque which the motor develops between zero speed and the speed which corresponds to the breakdown torque, when the motor is supplied at the rated voltage and frequency

Note 1 to entry: This definition does not apply to those asynchronous motors of which the torque continually decreases with increase in speed.

Note 2 to entry: In addition to the steady-state asynchronous torques, harmonic synchronous torques, which are a function of rotor load angle, will be present at specific speeds.

At such speeds, the accelerating torque may be negative for some rotor load angles.

Experience and calculation show this to be an unstable operating condition, and therefore, harmonic synchronous torques do not prevent motor acceleration, and are excluded from this definition.

### 3.15

#### **breakdown torque <of an AC motor>**

maximum steady-state asynchronous torque which the motor develops without an abrupt drop in speed, when the motor is supplied at the rated voltage and frequency

Note 1 to entry: This definition does not apply to motors with torques that continually decrease with increase in speed.

### 3.16

#### **pull-out torque <of a synchronous motor>**

maximum torque which the synchronous motor develops at synchronous speed with rated voltage, frequency and field current

**3.17****cooling**

procedure by means of which heat resulting from losses occurring in a machine is given up to a primary coolant, which may be continuously replaced or may itself be cooled by a secondary coolant in a heat exchanger

[SOURCE: IEC 60050-411:1996, 411-44-01]

**3.18****coolant**

medium, liquid or gas, by means of which heat is transferred

[SOURCE: IEC 60050-411:1996, 411-44-02]

**3.19****primary coolant**

medium, liquid or gas, which, being at a lower temperature than a part of a machine and in contact with it, removes heat from that part

[SOURCE: IEC 60050-411:1996, 411-44-03]

**3.20****secondary coolant**

medium, liquid or gas, which, being at a lower temperature than the primary coolant, removes the heat given up by this primary coolant by means of a heat exchanger or through the external surface of the machine

[SOURCE: IEC 60050-411:1996, 411-44-04]

**3.21****direct cooled winding****inner cooled winding**

winding mainly cooled by coolant flowing in direct contact with the cooled part through hollow conductors, tubes, ducts or channels which, regardless of their orientation, form an integral part of the winding inside the main insulation

Note 1 to entry: In all cases when 'indirect' or 'direct' is not stated, an indirect cooled winding is implied.

[SOURCE: IEC 60050-411:1996, 411-44-08]

**3.22****indirect cooled winding**

any winding other than a direct cooled winding

Note 1 to entry: In all cases when 'indirect' or 'direct' is not stated, an indirect cooled winding is implied.

[SOURCE: IEC 60050-411:1996, 411-44-09]

**3.23****supplementary insulation**

independent insulation applied in addition to the main insulation in order to ensure protection against electric shock in the event of failure of the main insulation

**3.24****moment of inertia**

sum (integral) of the products of the mass elements of a body and the squares of their distances (radii) from a given axis

**3.25****thermal equilibrium**

state reached when the temperature rises of the several parts of the machine do not vary by more than a gradient of *1 K per half hour*

Note 1 to entry: Thermal equilibrium may be determined from the time-temperature rise plot when the straight lines between points at the beginning and end of two successive intervals of half hour each have a gradient of 1 K or less per half hour or 2 K or less per hour.

[SOURCE: IEC 60050-411:1996, 411-51-08, modified: modification indicated in italics.]

**3.26****thermal equivalent time constant**

time constant, replacing several individual time constants, which determines approximately the temperature course in a winding after a step-wise current change

**3.27****encapsulated winding**

winding which is completely enclosed or sealed by moulded insulation

[SOURCE: IEC 60050-411:1996, 411-39-06]

**3.28****rated form factor of direct current supplied to a DC motor armature from a static power converter**

ratio of the r.m.s. maximum permissible value of the current  $I_{\text{rms,maxN}}$  to its average value  $I_{\text{avN}}$  (mean value integrated over one period) at rated conditions:

$$k_{\text{fN}} = \frac{I_{\text{rms,maxN}}}{I_{\text{avN}}}$$

**3.29****current ripple factor**

ratio of the difference between the maximum value  $I_{\text{max}}$  and the minimum value  $I_{\text{min}}$  of an undulating current to two times the average value  $I_{\text{av}}$  (mean value integrated over one period):

$$q_i = \frac{I_{\text{max}} - I_{\text{min}}}{2 \times I_{\text{av}}}$$

Note 1 to entry: For small values of current ripple, the ripple factor may be approximated by the following formula:

$$q_i = \frac{I_{\text{max}} - I_{\text{min}}}{I_{\text{max}} + I_{\text{min}}}$$

Note 2 to entry: The above formula may be used as an approximation if the resulting calculated value of  $q_i$  is equal to or less than 0,4.

The basis for determining this variation should be by oscillograph measurement (or a comparable device) and not by ammeter readings. A line should be drawn on the oscillogram through the consecutive peaks of the current wave. This line is the envelope of the current wave. The variation is the difference between the maximum ( $I_{\text{max}}$ ) and minimum ( $I_{\text{min}}$ ) ordinates of this envelope.

**3.30****tolerance**

permitted deviation between the declared value of a quantity and the measured value

**3.31****type test**

test of one or more machines made to a certain design to show that the design meets certain specifications

Note 1 to entry: The type test may also be considered valid if it is made on a machine which has minor deviations of rating or other characteristics. These deviations should be subject to agreement.

[SOURCE: IEC 60050-411:1996, 411-53-01]

**3.32****routine test**

test to which each individual machine is subjected during or after manufacture to ascertain whether it complies with certain criteria

[SOURCE: IEC 60050-411:1996, 411-53-02]

**3.33****runaway speed**

maximum speed attained by the ~~engine/motor~~-generator set after removal of the full load of the generator if the speed regulator does not function

Note 1 to entry: The motor can be also a turbine or an internal combustion engine.

Note 2 to entry: For motors, the maximum overspeed at loss of supply is meant that a motor might reach driven by the coupled equipment

[SOURCE: IEC 60050-411:1996, ~~811~~411-17-23]

**3.34****main insulation**

basic insulation (see IEC 60664-1) of a rotating electrical machine

**3.35****converter capable machine**

electrical machine designed for direct online start and suitable for operation on a power electronic frequency converter without special filtering

Note 1 to entry: Such motors include but are not limited to IEC Design N, NE, H, or HE, or NEMA Design A, B, or C which may be subject to energy efficiency regulation in the EU, North America or other locations.

Note 2 to entry: The intent of the converter capable motor is to run within the thermal class of the insulation system; but as the harmonic content of the converter output voltage varies between different drive topologies, coordination with the manufacturer may be required by the end user.

Note 3 to entry: See IEC TS 60034-25 for performance variations of all characteristics such as efficiency and acoustic noise when operating a converter capable motor on a frequency converter.

**3.36****converter duty machine**

electrical machine designed specifically for operation fed by a power electronic frequency converter with a temperature rise within the specified insulation thermal class or thermal class.

Note 1 to entry: Such motors have no IEC Design or NEMA Design letter and may be exempted from energy efficiency regulation in the EU, North America and other locations.

**3.37****shaft voltage**

voltage of mainly supply frequency measured between the shaft ends of an electrical machine, which may occur due to magnetic asymmetries

Note 1 to entry: For more information on the root cause of the shaft voltage, see IEC TS 60034-24:2008, 5.5 and Clause 6.

Note 2 to entry: The shaft voltage of (mainly) supply frequency should not be mixed-up with the HF shaft voltage which can be caused in converter-fed machines by a high frequency (HF) common mode current impulse.

## 4 Duty

### 4.1 Declaration of duty

It is the responsibility of the purchaser to declare the duty. The purchaser may describe the duty by one of the following:

- a) numerically, where the load does not vary or where it varies in a known manner;
- b) as a time sequence graph of the variable quantities;
- c) by selecting one of the duty types S1 to S10 that is no less onerous than the expected duty.

The duty type shall be designated by the appropriate abbreviation, specified in 4.2, written after the value of the load.

An expression for the cyclic duration factor is given in the relevant duty type figure.

The purchaser normally cannot provide values for the moment of inertia of the machine ( $J_M$ ) or the relative thermal life expectancy ( $TL$ ), see Annex A. These values are provided by the manufacturer.

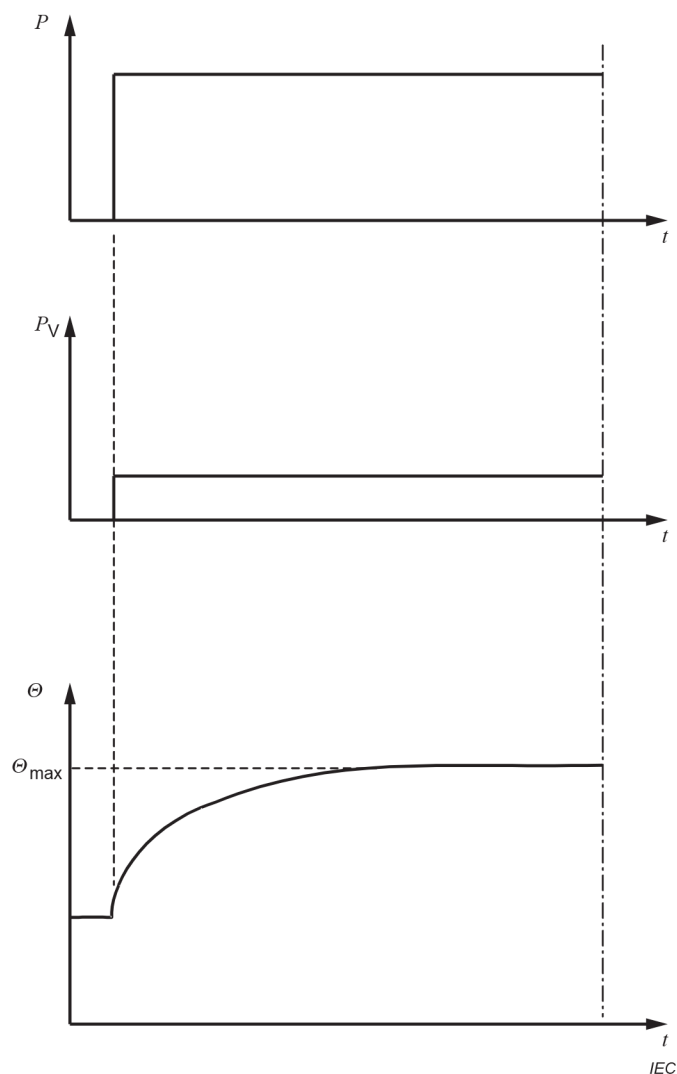
Where the purchaser does not declare a duty, the manufacturer shall assume that duty type S1 (continuous running duty) applies.

### 4.2 Duty types

#### 4.2.1 Duty type S1 – Continuous running duty

Operation at a constant load maintained for sufficient time to allow the machine to reach thermal equilibrium, see Figure 1.

The appropriate abbreviation is S1.

**Key**

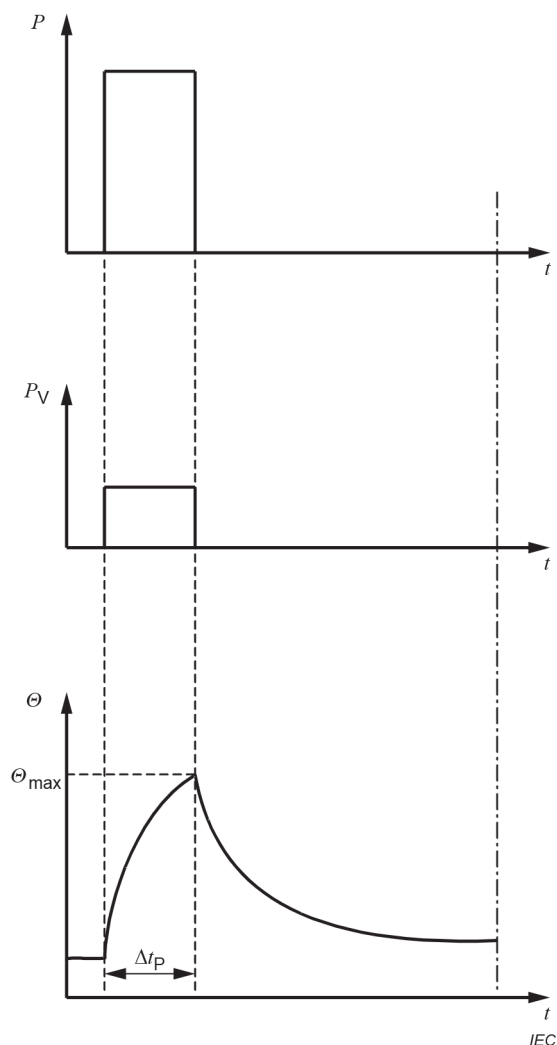
|                 |                              |
|-----------------|------------------------------|
| $P$             | load                         |
| $P_V$           | electrical losses            |
| $\Theta$        | temperature                  |
| $\Theta_{\max}$ | maximum temperature attained |
| $t$             | time                         |

**Figure 1 – Continuous running duty – Duty type S1****4.2.2 Duty type S2 – Short-time duty**

Operation at constant load for a given time, less than that required to reach thermal equilibrium, followed by a time at rest and de-energized of sufficient duration to re-establish machine temperatures within 2 K of the coolant temperature, see Figure 2.

The appropriate abbreviation is S2, followed by an indication of the duration of the duty.

Example: S2 60 min.



#### Key

|                 |                                                                               |
|-----------------|-------------------------------------------------------------------------------|
| $P$             | load                                                                          |
| $P_V$           | electrical losses                                                             |
| $\Theta$        | temperature                                                                   |
| $\Theta_{\max}$ | maximum temperature attained                                                  |
| $t$             | time                                                                          |
| $\Delta t_P$    | operation time at constant load,<br>e. g. $\Delta t_P = 60$ min for S2 60 min |

**Figure 2 – Short-time duty – Duty type S2**

#### 4.2.3 Duty type S3 – Intermittent periodic duty

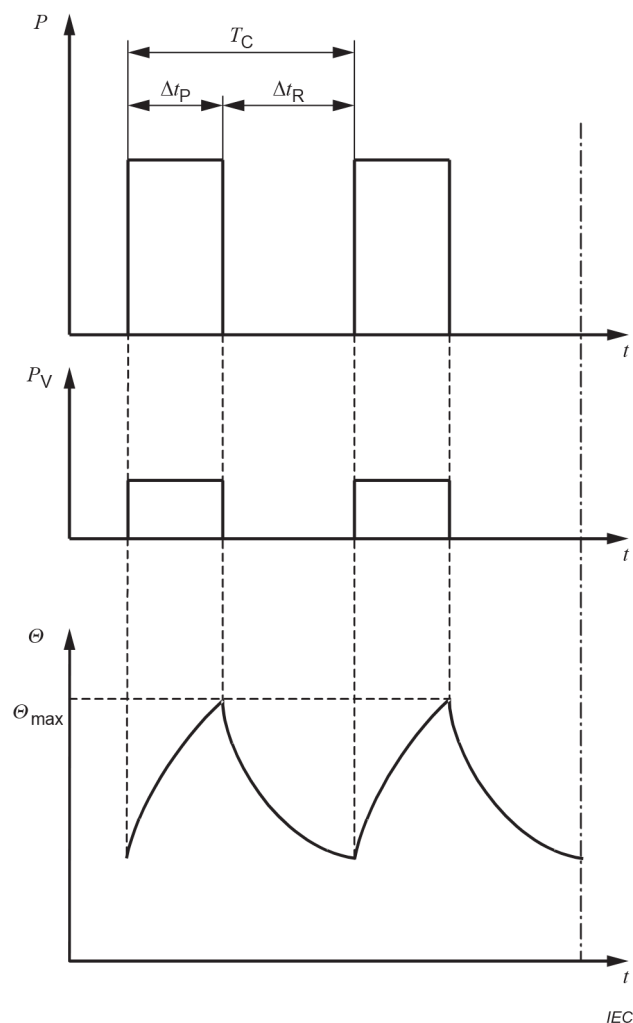
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

NOTE 2 For duty cycles with a time of one load cycle  $T_C$  other than 10 min, see 5.2.3.

A sequence of identical duty cycles, each including a time of operation at constant load and a time at rest and de-energized, see Figure 3. In this duty, the cycle is such that the starting current does not significantly affect the temperature rise.

The appropriate abbreviation is S3, followed by the cyclic duration factor.

Example: S3 25 %.

**Key**

|                                             |                                 |
|---------------------------------------------|---------------------------------|
| $P$                                         | load                            |
| $P_V$                                       | electrical losses               |
| $\Theta$                                    | temperature                     |
| $\Theta_{\max}$                             | maximum temperature attained    |
| $t$                                         | time                            |
| $T_C$                                       | time of one load cycle          |
| $\Delta t_P$                                | operation time at constant load |
| $\Delta t_R$                                | time at rest and de-energized   |
| Cyclic duration factor = $\Delta t_P / T_C$ |                                 |

**Figure 3 – Intermittent periodic duty – Duty type S3****4.2.4 Duty type S4 – Intermittent periodic duty with starting**

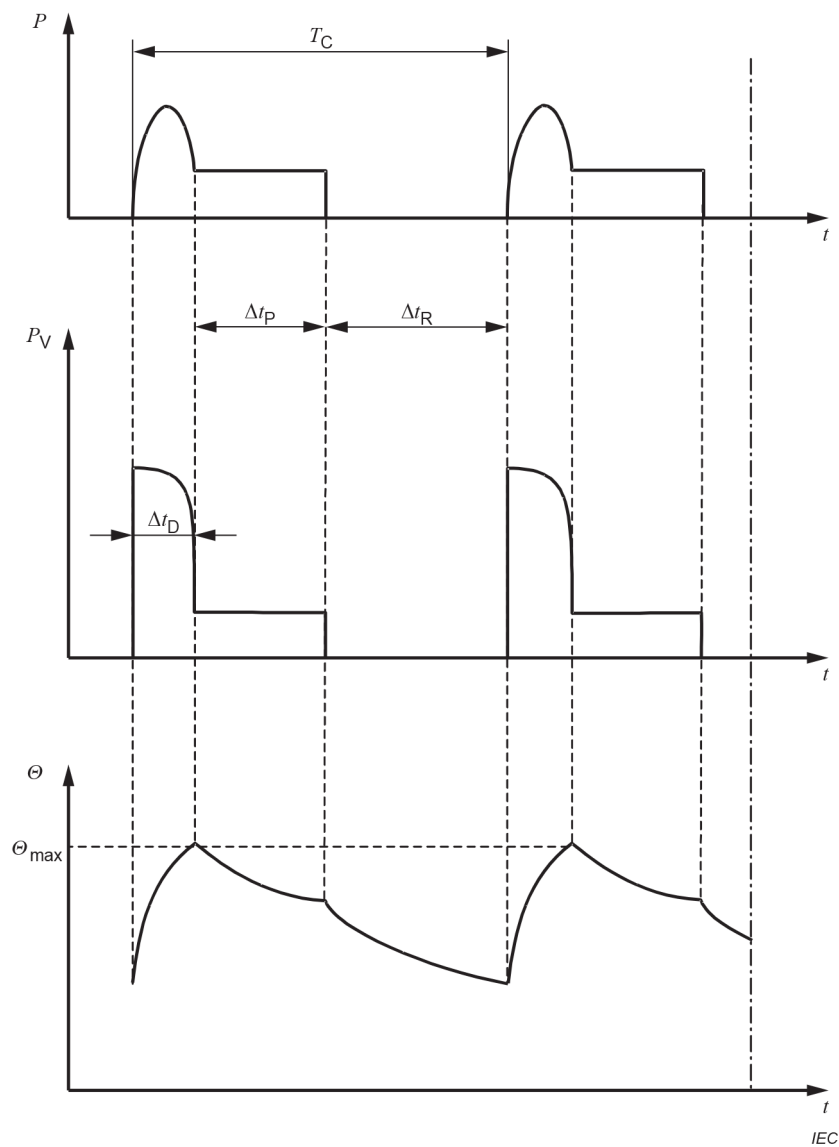
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

NOTE 2 For duty cycles with a time of one load cycle  $T_C$  other than 10 min, see 5.2.3.

A sequence of identical duty cycles, each cycle including a significant starting time, a time of operation at constant load and a time at rest and de-energized, see Figure 4.

The appropriate abbreviation is S4, followed by the cyclic duration factor, the moment of inertia of the motor ( $J_M$ ) and the moment of inertia of the load ( $J_{\text{ext}}$ ), both referred to the motor shaft.

Example: S4 25 %  $J_M = 0,15 \text{ kg} \times \text{m}^2$   $J_{\text{ext}} = 0,7 \text{ kg} \times \text{m}^2$ .



**Key**

|                       |                              |              |                                 |
|-----------------------|------------------------------|--------------|---------------------------------|
| $P$                   | load                         | $t$          | time                            |
| $P_V$                 | electrical losses            | $T_C$        | time of one load cycle          |
| $\Theta$              | temperature                  | $\Delta t_D$ | starting/accelerating time      |
| $\Theta_{\text{max}}$ | maximum temperature attained | $\Delta t_P$ | operation time at constant load |
|                       |                              | $\Delta t_R$ | time at rest and de-energized   |

Cyclic duration factor =  $(\Delta t_D + \Delta t_P)/T_C$

**Figure 4 – Intermittent periodic duty with starting – Duty type S4**

**4.2.5 Duty type S5 – Intermittent periodic duty with electric braking**

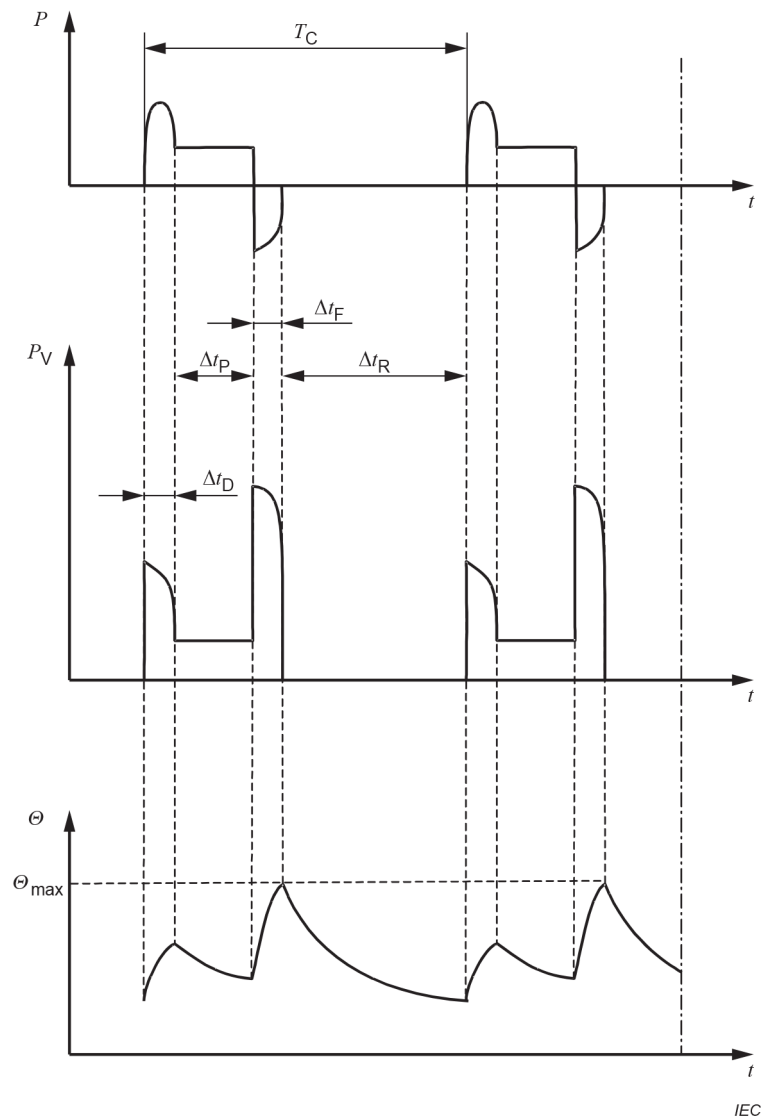
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

NOTE 2 For duty cycles with a time of one load cycle  $T_C$  other than 10 min, see 5.2.3.

A sequence of identical duty cycles, each cycle consisting of a starting time, a time of operation at constant load, a time of electric braking and a time at rest and de-energized, see Figure 5.

The appropriate abbreviation is S5, followed by the cyclic duration factor, the moment of inertia of the motor ( $J_M$ ) and the moment of inertia of the load ( $J_{ext}$ ), both referred to the motor shaft.

Example: S5 25 %  $J_M = 0,15 \text{ kg} \times \text{m}^2$   $J_{ext} = 0,7 \text{ kg} \times \text{m}^2$ .



**Key**

|                |                              |              |                                 |
|----------------|------------------------------|--------------|---------------------------------|
| $P$            | load                         | $T_C$        | time of one load cycle          |
| $P_V$          | electrical losses            | $\Delta t_D$ | starting/accelerating time      |
| $\Theta$       | temperature                  | $\Delta t_P$ | operation time at constant load |
| $\Theta_{max}$ | maximum temperature attained | $\Delta t_F$ | time of electric braking        |
| $t$            | time                         | $\Delta t_R$ | time at rest and de-energized   |

Cyclic duration factor =  $(\Delta t_D + \Delta t_P + \Delta t_F)/T_C$

**Figure 5 – Intermittent periodic duty with electric braking – Duty type S5**

4.2.6 Duty type S6 – Continuous operation periodic duty

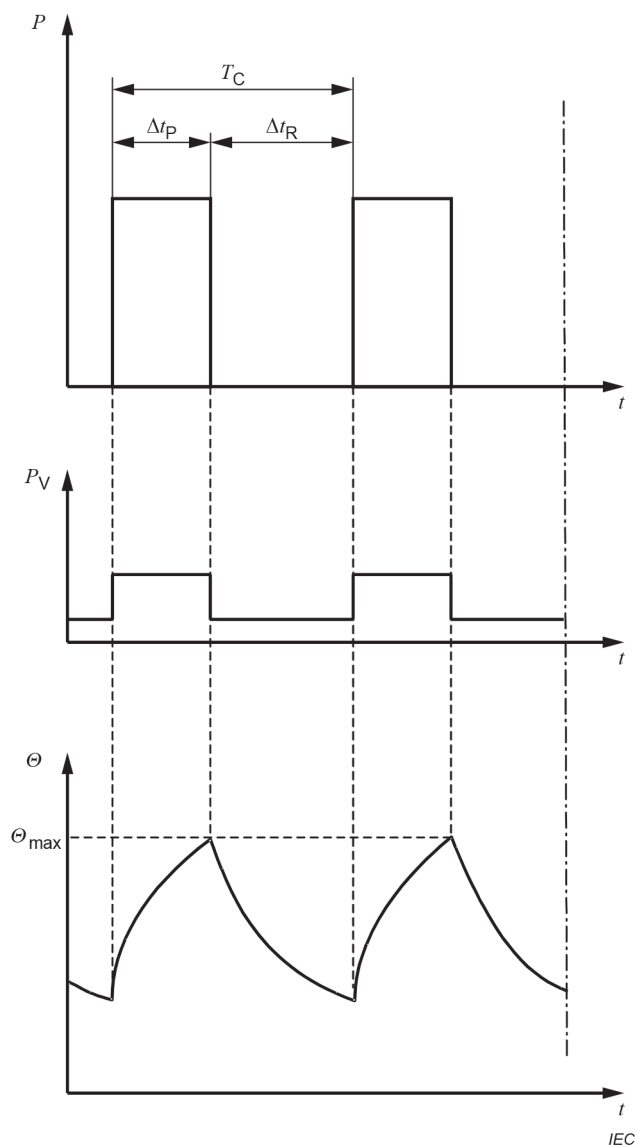
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

NOTE 2 For duty cycles with a time of one load cycle  $T_C$  other than 10 min, see 5.2.3.

A sequence of identical duty cycles, each cycle consisting of a time of operation at constant load and a time of operation at no-load. There is no time at rest and de-energized, see Figure 6.

The appropriate abbreviation is S6, followed by the cyclic duration factor.

Example: S6 40 %.



Key

|                                           |                              |              |                                 |
|-------------------------------------------|------------------------------|--------------|---------------------------------|
| $P$                                       | load                         | $t$          | time                            |
| $P_V$                                     | electrical losses            | $T_C$        | time of one load cycle          |
| $\Theta$                                  | temperature                  | $\Delta t_P$ | operation time at constant load |
| $\Theta_{\max}$                           | maximum temperature attained | $\Delta t_V$ | operation time at no-load       |
| Cyclic duration factor = $\Delta t_P/T_C$ |                              |              |                                 |

Figure 6 – Continuous operation periodic duty – Duty type S6

4.2.7 Duty type S7 – Continuous operation periodic duty with electric braking

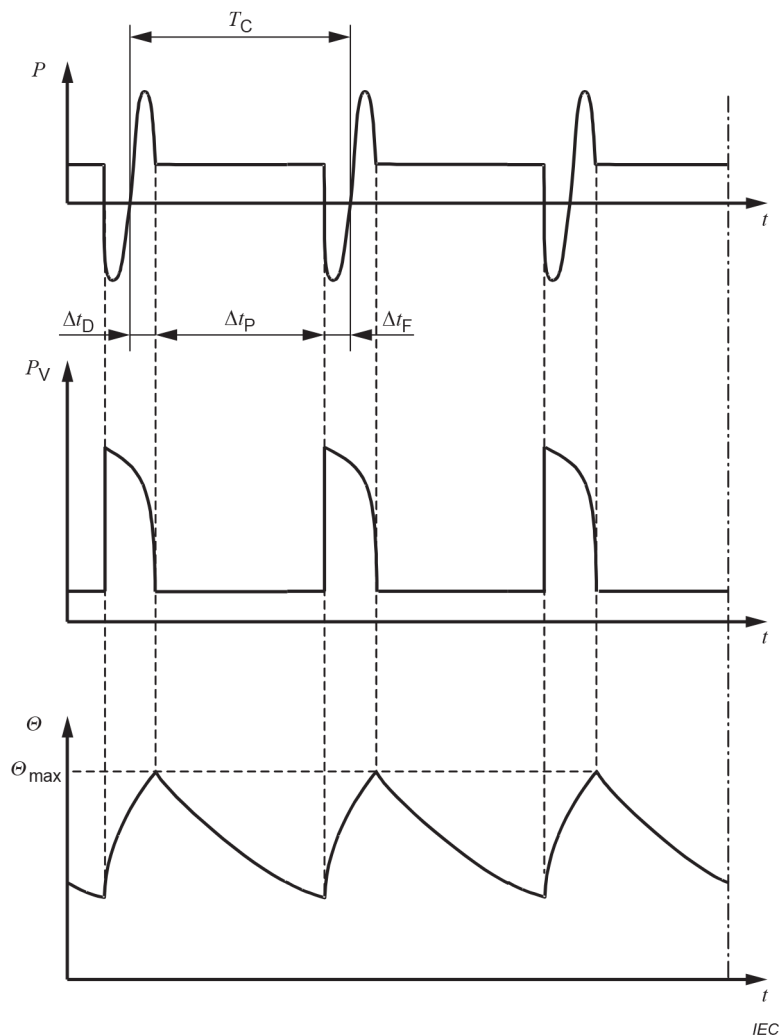
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

NOTE 2 For duty cycles with a time of one load cycle  $T_C$  other than 10 min, see 5.2.3.

A sequence of identical duty cycles, each cycle consisting of a starting time, a time of operation at constant load and a time of electric braking. There is no time at rest and de-energized, see Figure 7.

The appropriate abbreviation is S7, followed by the moment of inertia of the motor ( $J_M$ ) and the moment of inertia of the load ( $J_{ext}$ ), both referred to the motor shaft.

Example: S7  $J_M = 0,4 \text{ kg} \times \text{m}^2$   $J_{ext} = 7,5 \text{ kg} \times \text{m}^2$



Key

|                            |                              |              |                                 |
|----------------------------|------------------------------|--------------|---------------------------------|
| $P$                        | load                         | $t$          | time                            |
| $P_V$                      | electrical losses            | $T_C$        | time of one load cycle          |
| $\Theta$                   | temperature                  | $\Delta t_D$ | starting/accelerating time      |
| $\Theta_{max}$             | maximum temperature attained | $\Delta t_P$ | operation time at constant load |
| Cyclic duration factor = 1 |                              | $\Delta t_F$ | time of electric braking        |

Figure 7 – Continuous operation periodic duty with electric braking – Duty type S7

#### 4.2.8 Duty type S8 – Continuous operation periodic duty with related load/speed changes

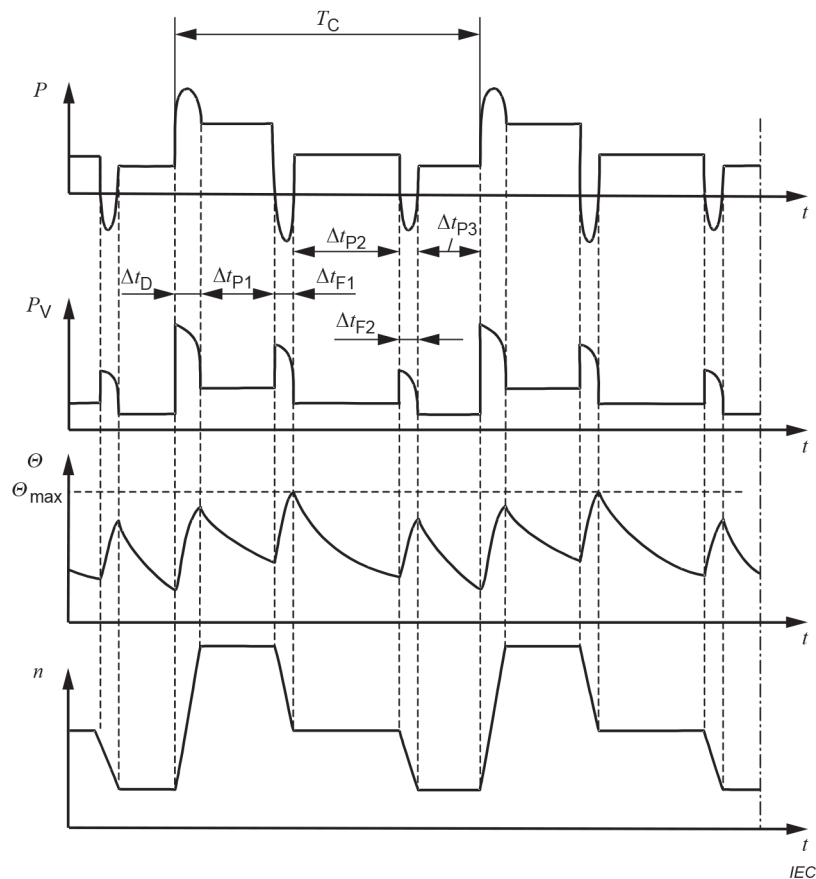
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

NOTE 2 For duty cycles with a time of one load cycle  $T_C$  other than 10 min, see 5.2.3.

A sequence of identical duty cycles, each cycle consisting of a time of operation at constant load corresponding to a predetermined speed of rotation, followed by one or more times of operation at other constant loads corresponding to different speeds of rotation (carried out, for example, by means of a change in the number of poles in the case of induction motors). There is no time at rest and de-energized (see Figure 8).

The appropriate abbreviation is S8, followed by the moment of inertia of the motor ( $J_M$ ) and the moment of inertia of the load ( $J_{ext}$ ), both referred to the motor shaft, together with the load, speed and cyclic duration factor for each speed condition.

|          |                                             |                                            |       |                         |       |
|----------|---------------------------------------------|--------------------------------------------|-------|-------------------------|-------|
| Example: | S8 $J_M = 0,5 \text{ kg} \times \text{m}^2$ | $J_{ext} = 6 \text{ kg} \times \text{m}^2$ | 16 kW | 740 min <sup>-1</sup>   | 30 %  |
|          |                                             |                                            | 40 kW | 1 460 min <sup>-1</sup> | 30 %  |
|          |                                             |                                            | 25 kW | 980 min <sup>-1</sup>   | 40 %. |



**Key**

|                 |                              |              |                                              |
|-----------------|------------------------------|--------------|----------------------------------------------|
| $P$             | load                         | $t$          | time                                         |
| $P_V$           | electrical losses            | $T_C$        | time of one load cycle                       |
| $\Theta$        | temperature                  | $\Delta t_D$ | starting/accelerating time                   |
| $\Theta_{\max}$ | maximum temperature attained | $\Delta t_P$ | operation time at constant load (P1, P2, P3) |
| $n$             | speed                        | $\Delta t_F$ | time of electric braking (F1, F2)            |

Cyclic duration factor =  $(\Delta t_D + \Delta t_{P1})/T_C$ ;  $(\Delta t_{F1} + \Delta t_{P2})/T_C$ ;  $(\Delta t_{F2} + \Delta t_{P3})/T_C$

**Figure 8 – Continuous operation periodic duty with related load/speed changes – Duty type S8**

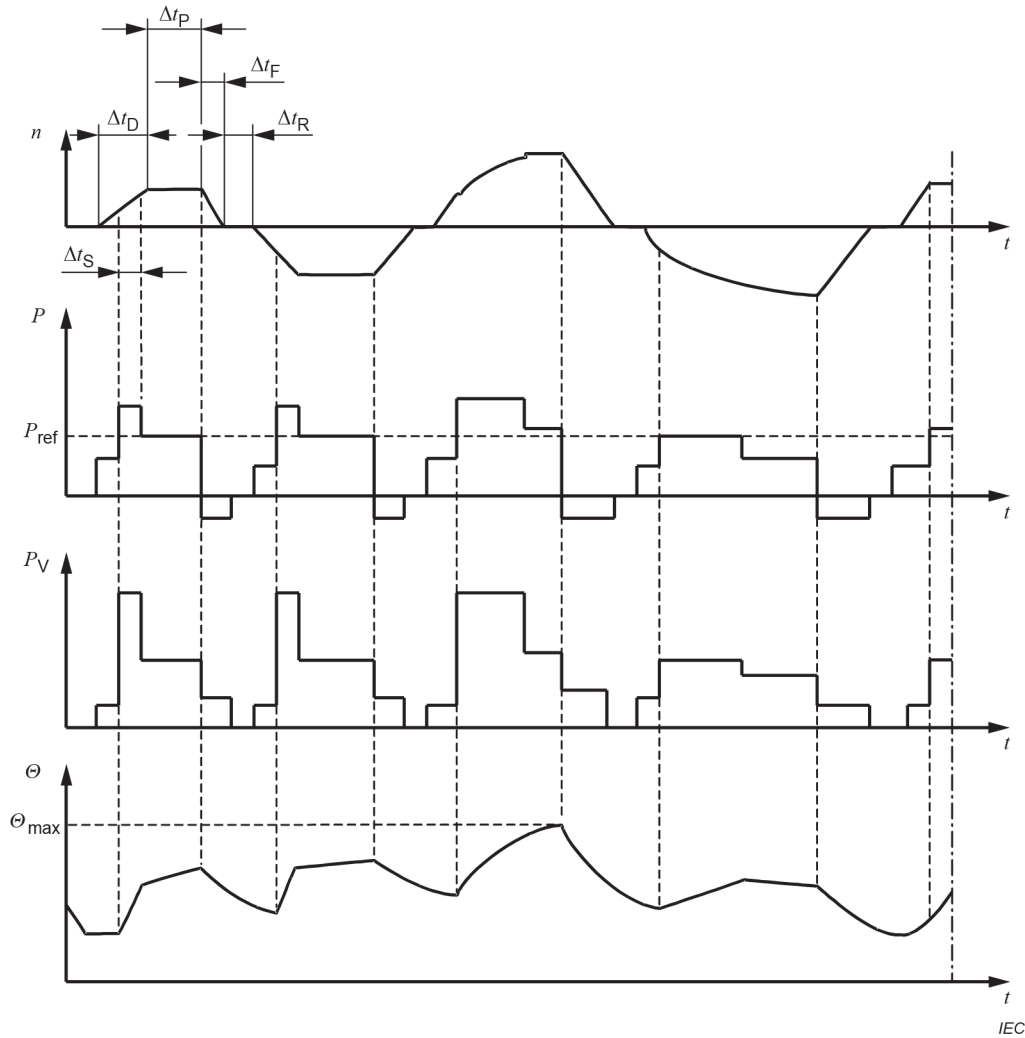
**4.2.9 Duty type S9 – Duty with non-periodic load and speed variations**

A duty in which generally load and speed vary non-periodically within the permissible operating range. This duty includes frequently applied overloads that may greatly exceed the reference load (see Figure 9).

The appropriate abbreviation is S9.

For this duty type, a constant load appropriately selected and based on duty type S1 is taken as the reference value ( $P_{\text{ref}}$  in Figure 9) for the overload concept.

Converter duty can also be determined under duty type S9 when operated on dynamic non-periodic load and speed variations. Subclause 4.2 of IEC TS 60034-25:2014 can be considered as reference in determining converter duty.



**Key**

|                |                              |              |                                 |
|----------------|------------------------------|--------------|---------------------------------|
| $P$            | load                         | $t$          | time                            |
| $P_{ref}$      | reference load               | $\Delta t_D$ | starting/accelerating time      |
| $P_V$          | electrical losses            | $\Delta t_P$ | operation time at constant load |
| $\Theta$       | temperature                  | $\Delta t_F$ | time of electric braking        |
| $\Theta_{max}$ | maximum temperature attained | $\Delta t_R$ | time at rest and de-energized   |
| $n$            | speed                        | $\Delta t_S$ | time under overload             |

**Figure 9 – Duty with non-periodic load and speed variations – Duty type S9**

**4.2.10 Duty type S10 – Duty with discrete constant loads and speeds**

A duty consisting of a specific number of discrete values of load (or equivalent loading) and if applicable, speed, each load/speed combination being maintained for sufficient time to allow the machine to reach thermal equilibrium, see Figure 10. The minimum load within a duty cycle may have the value zero (no-load or at rest and de-energized).

The appropriate abbreviation is S10, followed by the per unit quantities  $p/\Delta t$  for the respective load and its duration and the per unit quantity  $TL$  for the relative thermal life expectancy of the insulation system. The reference value for the thermal life expectancy is the thermal life expectancy at rating for continuous running duty and permissible limits of temperature rise based on duty type S1. For a time at rest and de-energized, the load shall be indicated by the letter  $r$ .

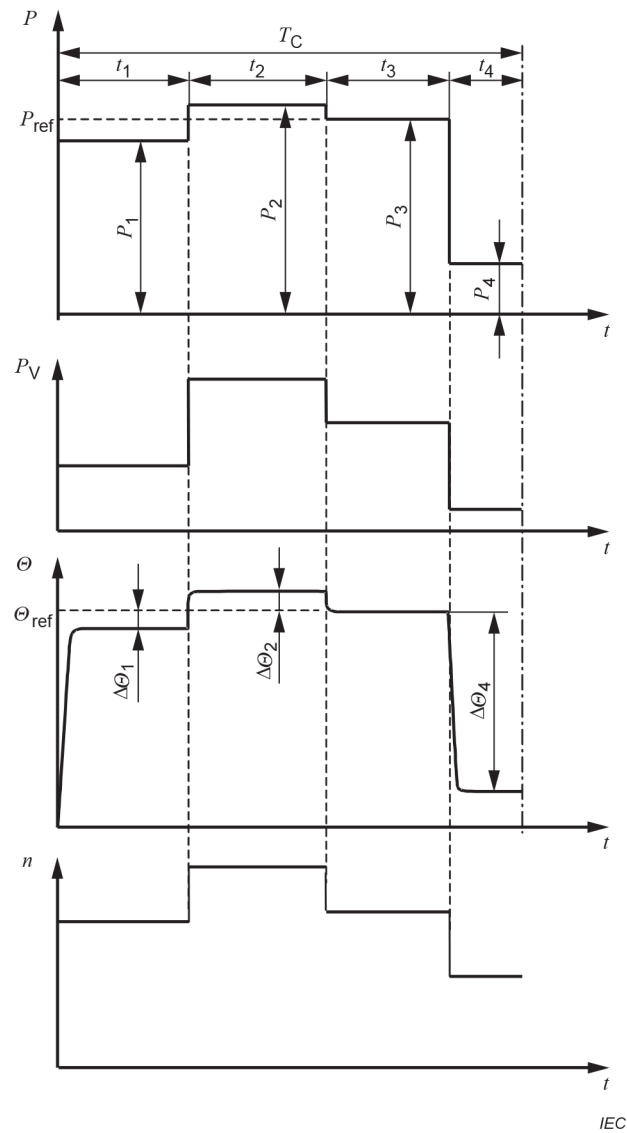
Example: S10  $p/\Delta t = 1,1/0,4; 1/0,3; 0,9/0,2; r/0,1$   $TL = 0,60$ .

The value of  $TL$  should be rounded off to the nearest multiple of 0,05. Advice concerning the significance of this parameter and the derivation of its value is given in Annex A.

For this duty type a constant load appropriately selected and based on duty type S1 shall be taken as the reference value ( $P_{ref}$  in Figure 10) for the discrete loads.

The discrete values of load will usually be equivalent loading based on integration over a period of time. It is not necessary that each load cycle be exactly the same, only that each load within a cycle be maintained for sufficient time for thermal equilibrium to be reached, and that each load cycle be capable of being integrated to give the same relative thermal life expectancy.

Converter duty can also be determined under duty type S10 when operated on discrete, i. e. non-dynamic, non-periodic load and speed variations. Subclause 4.2 of IEC TS 60034-25:2014 can be considered as reference in determining converter duty.



**Key**

|                |                                                     |                  |                                                                                                                                                                          |
|----------------|-----------------------------------------------------|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $P$            | load                                                | $t$              | time                                                                                                                                                                     |
| $P_i$          | constant load within a load cycle                   | $t_i$            | time of a constant load within a cycle                                                                                                                                   |
| $P_{ref}$      | reference load based on duty type S1                | $T_C$            | time of one load cycle                                                                                                                                                   |
| $P_V$          | electrical losses                                   | $\Delta\Theta_i$ | difference between the temperature rise of the winding at each of the various loads within one cycle and the temperature rise based on duty cycle S1 with reference load |
| $\Theta$       | temperature                                         | $n$              | speed                                                                                                                                                                    |
| $\Theta_{ref}$ | temperature at reference load based on duty type S1 |                  |                                                                                                                                                                          |

**Figure 10 – Duty with discrete constant loads – Duty type S10**

## 5 Rating

### 5.1 Assignment of rating

The rating, as defined in 3.2, shall be assigned by the manufacturer. In assigning the rating the manufacturer shall select one of the classes of rating defined in 5.2.1 to 5.2.6. The designation of the class of rating shall be written after the rated output. If no designation is stated, rating for continuous running duty applies.

When accessory components (such as reactors, capacitors, etc.) are connected by the manufacturer as part of the machine, the rated values shall refer to the supply terminals of the whole arrangement.

NOTE This does not apply to power transformers connected between the machine and the supply.

Special considerations are required when assigning ratings to machines fed from or supplying static converters. IEC TS 60034-25 gives guidance on this.

### 5.2 Classes of rating

#### 5.2.1 Rating for continuous running duty

A rating at which the machine may be operated for an unlimited period, while complying with the requirements of this document.

This class of rating corresponds to duty type S1 and is designated as for the duty type S1.

#### 5.2.2 Rating for short-time duty

A rating at which the machine may be operated for a limited period, starting at ambient temperature, while complying with the requirements of this document.

This class of rating corresponds to duty type S2 and is designated as for the duty type S2.

#### 5.2.3 Rating for periodic duty

A rating at which the machine may be operated on duty cycles, while complying with the requirements of this document.

This class of rating corresponds to one of the periodic duty types S3 to S8 and is designated as for the corresponding duty type.

Unless otherwise specified, the duration of a duty cycle shall be 10 min and the cyclic duration factor shall be one of the following values:

15 %, 25 %, 40 %, 60 %.

#### 5.2.4 Rating for non-periodic duty

A rating at which the machine may be operated non-periodically while complying with the requirements of this document.

This class of rating corresponds to the non-periodic duty type S9 and is designated as for the duty type S9.

### 5.2.5 Rating for duty with discrete constant loads and speeds

A rating at which the machine may be operated with the associated loads and speeds of duty type S10 for an unlimited period of time while complying with the requirements of this document. The maximum permissible load within one cycle shall take into consideration all parts of the machine, for example, the insulation system regarding the validity of the exponential law for the relative thermal life expectancy, bearings with respect to temperature, other parts with respect to thermal expansion. Unless specified in other relevant IEC standards, the maximum load shall not exceed 1,15 times the value of the load based on duty type S1. The minimum load may have the value zero, the machine operating at no-load or being at rest and de-energized. Considerations for the application of this class of rating are given in Annex A.

This class of rating corresponds to the duty type S10 and is designated as for the duty type S10.

NOTE Other relevant IEC standards may specify the maximum load in terms of limiting winding temperature (or temperature rise) instead of per unit load based on duty type S1.

### 5.2.6 Rating for equivalent loading

A rating, for test purposes, at which the machine may be operated at constant load until thermal equilibrium is reached and which results in the same stator winding temperature rise as the average temperature rise during one load cycle of the specified duty type.

The determination of an equivalent rating should take account of the varying load, speed and cooling of the duty cycle.

This class of rating, if applied, is designated 'equ'.

## 5.3 Selection of a class of rating

A machine manufactured for general purpose shall have a rating for continuous running duty and be capable of performing duty type S1.

If the duty has not been specified by the purchaser, duty type S1 applies and the rating assigned shall be a rating for continuous running duty.

When a machine is intended to have a rating for short-time duty, the rating shall be based on duty type S2, see 4.2.2.

When a machine is intended to supply varying loads or loads including a time of no-load or times where the machine will be in a state of at rest and de-energized, the rating shall be a rating for periodic duty based on a duty type selected from duty types S3 to S8, see 4.2.3 to 4.2.8.

When a machine is intended to supply non-periodically variable loads at variable speeds, including overloads, the rating shall be a rating for non-periodic duty based on duty type S9, see 4.2.9.

When a machine is intended to supply discrete constant loads including times of overload or times of no-load (or at rest and de-energized), the rating shall be a rating with discrete constant loads based on duty type S10, see 4.2.10.

## 5.4 Allocation of outputs to class of rating

In the determination of the rating:

For duty types S1 to S8, the specified value(s) of the constant load(s) shall be the rated output(s), see 4.2.1 to 4.2.8.

For duty types S9 and S10, the reference value of the load based on duty type S1 shall be taken as the rated output, see 4.2.9 and 4.2.10.

## 5.5 Rated output

### 5.5.1 DC generators

The rated output is the output at the terminals and shall be expressed in watts (W).

### 5.5.2 AC generators

The rated output is the apparent power at the terminals and shall be expressed in volt-amperes (VA) together with the power factor.

The rated power factor for synchronous generators shall be 0,8 lagging (over-excited), unless otherwise specified by the purchaser.

NOTE A P-Q capability diagram (power chart) indicating the limits of operation, provides more detailed information on generator's performance.

### 5.5.3 Motors

The rated output is the mechanical power available at the shaft and shall be expressed in watts (W).

NOTE It is the practice in some countries for the mechanical power available at the shafts of motors to be expressed in horsepower (1 h.p. is equivalent to 745,7 W; 1 ch (cheval or metric horsepower) is equivalent to 736 W).

### 5.5.4 Synchronous ~~condensers~~ compensators

The rated output is the reactive power at the terminals and shall be expressed in volt-amperes ~~reactive (var)~~ (VA) in leading (under-excited) and lagging (over-excited) conditions.

## 5.6 Rated voltage

### 5.6.1 DC generators

For DC generators intended to operate over a relatively small range of voltage, the rated output and current shall apply at the highest voltage of the range, unless otherwise specified, see also 7.3.

### 5.6.2 AC generators

For AC generators intended to operate over a relatively small range of voltage, the rated output and power factor shall apply at any voltage within the range, unless otherwise specified, see also 7.3.

### 5.6.3 AC motors

AC motors may have two or more different rated voltages or a rated voltage range, as indicated on the rating plate (see 10.4.2). In all these cases, voltage (and frequency) variations according to 7.4 are valid in addition and do not need be indicated separately.

## 5.7 ~~Co-ordination~~ Preferred combinations of voltages and outputs

It is not practical to build machines of all ratings for all rated voltages. In general, for AC machines, based on design and manufacturing considerations, preferred voltage ratings above 1 kV in terms of rated output are as shown in Table 1.

**Table 1 – Preferred voltage ratings**

| <b>Rated voltage</b><br>kV | <b>Minimum rated output</b><br>kW (or kVA) |
|----------------------------|--------------------------------------------|
| $1,0 < U_N \leq 3,0$       | 100                                        |
| $3,0 < U_N \leq 6,0$       | 150                                        |
| $6,0 < U_N \leq 11,0$      | 800                                        |
| $11,0 < U_N \leq 15,0$     | 2 500                                      |

### 5.8 Machines with more than one rating

For machines with more than one rating, the machine shall comply with this document in all respects at each rating.

For multi-speed machines, a rating shall be assigned for each speed.

When a rated quantity (output, voltage, speed, etc.) may assume several values or vary continuously within two limits, the rating shall be stated at these values or limits. This provision does not apply to voltage and frequency variations during operation as defined in 7.3 or to star-delta connections intended for starting.

## 6 Site conditions

### 6.1 General

Unless otherwise specified, machines shall be suitable for the following site conditions outside the casing during operation, for standstill, storage and transportation. The cold coolant inlet temperatures for different types of cooling are specified in Table 5. For site operating conditions deviating from those values, corrections are given in Clause 8.

Machines operating outside the range of the standard site conditions shall require special consideration.

### 6.2 Altitude

The altitude shall not exceed 1 000 m above sea level. For higher altitudes, it shall be considered in the design of the machine that the arcing distance will decrease with the decreasing air-pressure.

### 6.3 Maximum ambient air temperature

The ambient air temperature shall not exceed 40 °C.

### 6.4 Minimum ambient air temperature

Unless otherwise agreed between manufacturer and customer, the ambient air temperature shall not be less than –15 °C for all machines except machines with any of the following, for which the ambient temperature shall be not less than 0 °C:

- a) rated output greater than 3 300 kW (or kVA) per 1 000 min<sup>-1</sup>;
- b) rated output less than 600 W (or VA);
- c) a commutator;
- d) a sleeve bearing;

e) water as a primary or secondary coolant.

### 6.5 Water coolant temperature

For the reference water coolant temperature, see Table 5. For other water coolant temperatures, see Table 10. The water coolant temperature shall not be less than +5 °C.

### 6.6 Standstill, storage and transport

When temperatures lower than specified in 6.4 are expected during transportation, storage, or after installation at standstill, the purchaser shall inform the manufacturer and specify the expected minimum temperature.

**NOTE**—Special measures may be needed before energizing the machine after longer periods of standstill, storage and transportation. Special measures may also be needed during the un-operational periods. See manufacturer's instructions.

### 6.7 Purity of hydrogen coolant

Hydrogen cooled machines shall be capable of operating at rated output under rated conditions with a coolant containing not less than 95 % hydrogen by volume.

**NOTE**—For safety reasons, the hydrogen content should at all times be maintained at 90 % or more, it being assumed that the other gas in the mixture is air.

For calculating efficiency in accordance with IEC 60034-2 (all parts), the standard composition of the gaseous mixture shall be 98 % hydrogen and 2 % air by volume, at the specified values of pressure and temperature of the re-cooled gas, unless otherwise agreed. Windage losses shall be calculated at the corresponding density.

## 7 Electrical operating conditions

### 7.1 Electrical supply

For three-phase AC machines, 50 Hz or 60 Hz, intended to be directly connected to distribution or utilisation systems, the rated voltages shall be derived from the nominal voltages given in IEC 60038.

**NOTE** For large high-voltage AC machines, the voltages may be selected for optimum performance.

For AC machines connected to static converters these restrictions on voltage, frequency and waveform do not apply. In this case, the rated voltages shall be selected by agreement.

~~For electrical machines with Type I insulation systems according to IEC 60034-18-41, which are specifically designed for supply by voltage source converters, the manufacturer can assign an impulse voltage insulation class (IVIC) according to IEC 60034-18-41 for the insulation system. In this case, the insulation system should be suitable for IVIC C for phase-to-phase and IVIC B for phase-to-ground or as otherwise agreed to between the user and the manufacturer. The IVIC level shall be given in the documentation and preferably on the nameplate (see 10.2).~~

For converter capable or converter duty electrical machines with Type I or Type II insulation systems according to IEC 60034-18-41 or IEC 60034-18-42, the manufacturer can assign an impulse voltage insulation class (IVIC) for the insulation system.

In case of a converter capable or converter duty electrical machine with rated power above 1 kW with a Type I insulation system and an IVIC assigned, the insulation system should be suitable for IVIC C for phase-to-phase and IVIC B for phase-to-ground, or as otherwise agreed to between the user and the manufacturer.

In case of a converter capable or converter duty electrical machine with rated voltage  $U_N \leq 1$  kV with a Type II insulation system and an IVIC assigned, the insulation system should be suitable for IVIC 5 for phase-to-phase and IVIC 4 for phase-to-ground or as otherwise agreed to between the user and the manufacturer.

In case of a converter capable or converter duty electrical machine with rated voltage  $U_N > 1$  kV with a Type II insulation system, it is the responsibility of the electrical machine manufacturer to specify the impulse voltage withstand ability of the electrical machine winding insulation. Since drive topologies vary greatly, and since these larger motors are converter duty machines mostly custom designed as needed, it is, in case an IVIC is assigned, not practical to define a default IVIC level (see IEC TS 60034-25). If the topology of the frequency converter and the system are known, IEC TS 61800-8 can be used to give an indication of the peak voltage at the motor terminals and therefore the motor's needed IVIC.

In case an IVIC is assigned, the IVIC level shall be given in the documentation and preferably on the rating plate (see Clause 10).

NOTE For more information on special considerations for converter fed machines, see IEC TS 60034-25.

Any bus transfer or fast reclosing of an AC machine, as it might occur, for example, due to the voltage ride through requirements of grid codes, can lead to very high peak currents endangering the stator winding overhang and to a very high peak torque of up to 20 times rated torque endangering the mechanical structure including the coupling and the driven or driving equipment, if the reclosing is done without synchronizing. Bus transfer or fast reclosing is therefore only allowed if specified and accepted by the manufacturers of electric machine and driven equipment.

For induction machines with ratings  $\leq 10$  MW or MVA, slow reclosing exceeding 1,5 times the open circuit time constant is allowed, if specified and accepted by the manufacturers of the electric machine and the driven equipment. For ratings  $> 10$  MW or MVA, the allowed minimum time for slow reclosing should be determined by transient analysis of the complete system by the system integrator and is allowed if accepted by the manufacturers of the electric machine and the driven equipment.

## 7.2 Form and symmetry of voltages and currents

### 7.2.1 AC motors

**7.2.1.1** AC motors rated for use on a power supply of fixed frequency, supplied from an AC generator (whether local or via a supply network) shall be suitable for operation on a supply voltage having a harmonic voltage factor (*HVF*) not exceeding:

- 0,02 for single-phase motors and three-phase motors, including synchronous motors but excluding motors of design N (see IEC 60034-12), unless the manufacturer declares otherwise;
- 0,03 for design N motors.

The *HVF* shall be computed by using the following formula:

$$HVF = \sqrt{\sum_{n=2}^k \frac{u_n^2}{n}}$$

where

$u_n$  is the ratio of the harmonic voltage  $U_n$  to the rated voltage  $U_N$ ;

$n$  is the order of harmonic (not divisible by three in the case of three-phase AC motors);

$k = 13$ .

Three-phase AC motors shall be suitable for operation on a three-phase voltage system having a negative-sequence component not exceeding 1 % of the positive-sequence component over a long period, or 1,5 % for a short period not exceeding a few minutes, and a zero-sequence component not exceeding 1 % of the positive-sequence component.

Should the limiting values of the *HVF* and of the negative-sequence and zero-sequence components occur simultaneously in service at the rated load, this shall not lead to any harmful temperature in the motor, and it is recommended that the resulting excess temperature rise related to the limits specified in this document should be not more than approximately 10 K.

**NOTE**—In the vicinity of large single-phase loads (e.g. induction furnaces), and in rural areas particularly on mixed industrial and domestic systems, supplies may be distorted beyond the limits set out above. Special arrangements will then be necessary.

**7.2.1.2** AC motors supplied from static converters have to tolerate higher harmonic contents of the supply voltage; see IEC TS 60034-25.

**NOTE** When the supply voltage is significantly non-sinusoidal, for example from static converters, the r.m.s. value of the total waveform and of the fundamental are both relevant in determining the performance of an AC machine.

## 7.2.2 AC generators

Three-phase AC generators shall be suitable for supplying circuits which, when supplied by a system of balanced and sinusoidal voltages:

- a) result in currents not exceeding a harmonic current factor (*HCF*) of 0,05, and
- b) result in a system of currents where neither the negative-sequence component nor the zero-sequence component exceed 5 % of the positive-sequence component.

The *HCF* shall be computed by using the following formula:

$$HCF = \sqrt{\sum_{n=2}^k i_n^2}$$

where

$i_n$  is the ratio of the harmonic current  $I_n$  to the rated current  $I_N$ ;

$n$  is the order of harmonic;

$k = 13$ .

Should the limits of deformation and imbalance occur simultaneously in service at the rated load, this shall not lead to any harmful temperature in the generator, and it is recommended that the resulting excess temperature rise related to the limits specified in this document should be not more than approximately 10 K.

## 7.2.3 Synchronous machines

Unless otherwise specified, three-phase synchronous machines shall be capable of operating continuously on an unbalanced system in such a way that, with none of the phase currents exceeding the rated current, the ratio of the negative-sequence component of current ( $I_{(2)}$ ) to the rated current ( $I_N$ ) does not exceed the values in Table 2, and under fault conditions shall be capable of operation with the product of  $(I_{(2)}/I_N)^2$  and time ( $t$ ) not exceeding the values in Table 2.

**Table 2 – Unbalanced operating conditions for synchronous machines**

| Item                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Machine type                                              | Maximum $I_{(2)}/I_N$ value for continuous operation | Maximum $(I_{(2)}/I_N)^2 \times t$ in seconds for operation under fault conditions |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|------------------------------------------------------|------------------------------------------------------------------------------------|
| Salient pole machines and PM excited machines                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                           |                                                      |                                                                                    |
| 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Indirect cooled windings                                  |                                                      |                                                                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | motors                                                    | 0,1                                                  | 20                                                                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | generators                                                | 0,08                                                 | 20                                                                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | synchronous <del>condensers</del><br>compensators         | 0,1                                                  | 20                                                                                 |
| 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Direct cooled (inner cooled) stator and/or field windings |                                                      |                                                                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | motors                                                    | 0,08                                                 | 15                                                                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | generators                                                | 0,05                                                 | 15                                                                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | synchronous <del>condensers</del><br>compensators         | 0,08                                                 | 15                                                                                 |
| Cylindrical rotor synchronous machines                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                           |                                                      |                                                                                    |
| 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Indirect cooled rotor windings                            |                                                      |                                                                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | air-cooled                                                | 0,1                                                  | 15                                                                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | hydrogen-cooled                                           | 0,1                                                  | 10                                                                                 |
| 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Direct cooled (inner cooled) rotor windings               |                                                      |                                                                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | ≤350 MVA                                                  | 0,08                                                 | 8                                                                                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | >350 ≤900 MVA                                             | a                                                    | b                                                                                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | >900 ≤1 250 MVA                                           | a                                                    | 5                                                                                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | >1 250 ≤1 600 MVA                                         | 0,05                                                 | 5                                                                                  |
| <p><sup>a</sup> For these machines, the value of <math>I_{(2)}/I_N</math> is calculated as follows:</p> $\frac{I_2}{I_N} = 0,08 - \frac{S_N - 350}{3 \times 10^4} \quad \frac{I_{(2)}}{I_N} = 0,08 - \frac{S_N - 350}{3 \times 10^4}$ <p><sup>b</sup> For these machines, the value of <math>(I_{(2)}/I_N)^2 \times t</math>, in seconds, is calculated as follows:</p> $(I_{(2)}/I_N)^2 \times t = 8 - 0,005 \, 45 (S_N - 350)$ <p>where in the two footnotes, <math>S_N</math> is the rated apparent power in MVA.</p> |                                                           |                                                      |                                                                                    |

#### 7.2.4 DC motors supplied from static power converters

In the case of a DC motor supplied from a static power converter, the pulsating voltage and current affect the performance of the machine. Losses and temperature rise will increase and the commutation is more difficult compared with a DC motor supplied from a pure DC power source.

It is necessary, therefore, for motors with a rated output exceeding 5 kW, intended for supply from a static power converter, to be designed for operation from a specified supply, and, if considered necessary by the motor manufacturer, for an external inductance to be provided for reducing the undulation.

The static power converter supply shall be characterized by means of an identification code, as follows:

$$[CCC - U_{aN} - f - L]$$

where

*CCC* is the identification code from Table 3, which is based on IEC 61148;

$U_{aN}$  consists of three or four digits indicating the rated alternating voltage at the input terminals of the converter, in V;

$f$  consists of two digits indicating the rated input frequency, in Hz;

$L$  consists of one, two or three digits indicating the series inductance to be added externally to the motor armature circuit, in mH. If this is zero, it is omitted.

**Table 3 – *CCC* symbol designation**

| Identification code<br><i>CCC</i> | 1-pair configuration<br>(configuration name) | Pair number “m”<br>for arms in<br>IEC 61148 | Clause No. and title<br>in IEC 61148 |
|-----------------------------------|----------------------------------------------|---------------------------------------------|--------------------------------------|
| A-Type                            | Thyristor + Thyristor<br>(Full bridge)       | m = 3                                       | 5.1.3.2 Bridge connection            |
| B-Type                            | Thyristor + Diode<br>(Mixed bridge)          | m = 3                                       | Same as above                        |
| C-Type                            | Thyristor + Thyristor<br>(Full bridge)       | m = 2                                       | Same as above                        |
| D-Type                            | Thyristor + Diode<br>(Mixed bridge)          | m = 2                                       | Same as above                        |

Motors with rated output not exceeding 5 kW, instead of being tied to a specific type of static power converter, may be designed for use with any static power converter, with or without external inductance, provided that the rated form factor for which the motor is designed will not be surpassed and that the insulation level of the motor armature circuit is appropriate for the rated alternating voltage at the input terminals of the static power converter.

In all cases, the undulation of the static power converter output current is assumed to be so low as to result in a current ripple factor not higher than 0,1 at rated conditions.

### 7.3 Voltage during starting of AC motors

An AC motor will start only if its starting torque is adequately matched to the counter-torque and the inertia of the load. For three-phase, single-speed AC motors, a motor shall be able to start at 90 % of its rated voltage at a load torque proportional to the speed squared up to 70 % of the rated torque at rated speed and a load inertia up to 50 % of the motor's inertia, as long as no different value has been specified beforehand.

NOTE 1 See IEC TS 60034-25 for information on converter duty machines.

NOTE 2 For starting performance of design N motors, see IEC 60034-12.

### 7.4 Voltage and frequency variations during operation

For AC machines rated for use on a power supply of fixed frequency supplied from an AC generator (whether local or via a supply network), combinations of voltage variation and frequency variation are classified as being either zone A or zone B, in accordance with Figure 11 ~~for generators and synchronous condensers, and Figure 12 for motors~~. For generators or synchronous compensators within the scope of IEC 60034-3 and for hydro generators within the scope of IEC 60034-33, different voltage and frequency limits apply as defined in those standards.

For DC machines, when directly connected to a normally constant DC bus, zones A and B apply only to the voltages.

A machine shall be capable of performing its primary function, as specified in Table 4, continuously within zone A, but need not comply fully with its performance at rated voltage and frequency (see rating point in Figure 11 ~~and 12~~), and may exhibit some deviations. Temperature rises may be higher than at rated voltage and frequency.

A machine shall be capable of performing its primary function within zone B, but may exhibit greater deviations from its performance at rated voltage and frequency than in zone A. Temperature rises may be higher than at rated voltage and frequency and most likely will be higher than those in zone A. Extended operation at the perimeter of zone B is not recommended.

In practical applications and operating conditions, a machine will sometimes be required to operate outside the perimeter of zone A. Such excursions should be limited in value, duration and frequency of occurrence. Corrective measures should be taken, where practical, within a reasonable time, for example, a reduction in output. Such action may avoid a reduction in machine life from temperature effects.

For machines that are designed to operate at the temperature rise limits of their thermal class, the graph in Figure 12 is offered as indicative guidance to machine users for the required reduction of output power as function of the combined variation of voltage and frequency that can limit, but not necessarily completely avoid a reduction in machine life. The combined variation of voltage and frequency is calculated as:

$$|\Delta\phi| = \left| \frac{U-U_N}{U_N} - \frac{f-f_N}{f_N} \right|$$

Operating outside zone A may also have significant effects on the acoustic noise, the vibration and the magnetic pull.

NOTE 1 The temperature-rise limits or temperature limits in accordance with this document apply at the rating point and may be progressively exceeded as the operating point moves away from the rating point. For conditions at the extreme boundaries of zone A, the temperature rises and temperatures typically exceed the limits specified in this document by approximately 10 K; the hot-spot temperature might even increase significantly more.

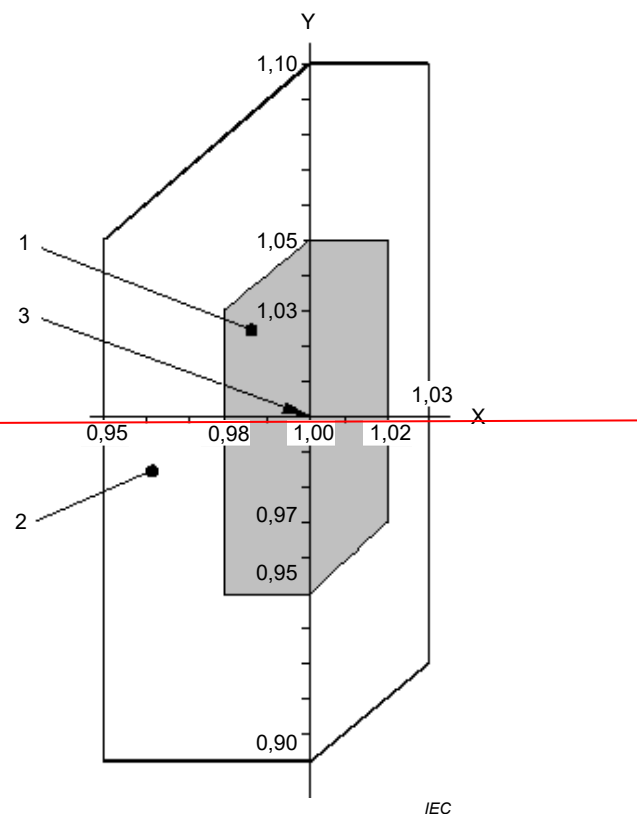
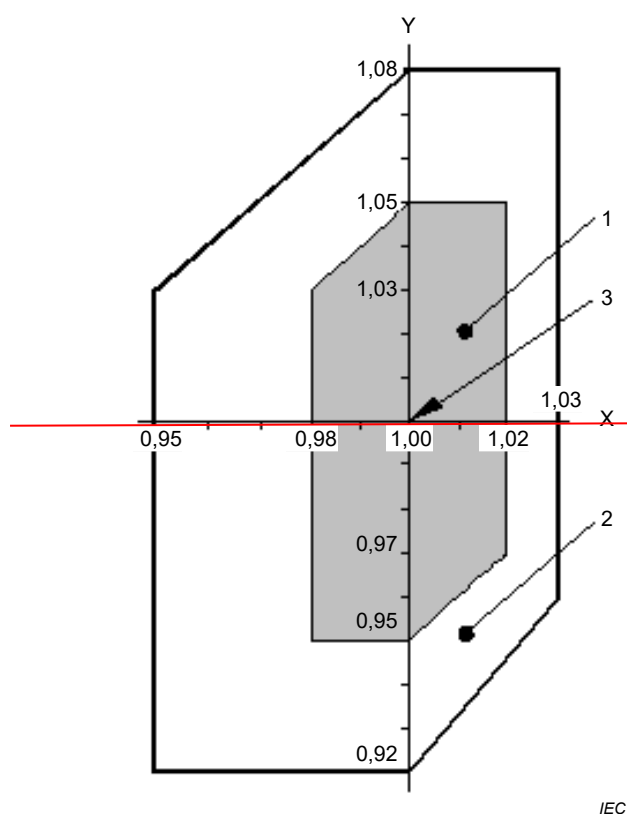
NOTE 2 ~~An a.c. motor will start at the lower limit of voltage only if its starting torque is adequately matched to the counter torque of the load, but this is not a requirement of this clause. For starting performance of design N motors, see IEC 60034-12.~~

In case it is required for operational reasons to operate a machine continuously at the perimeter of zone B at rated power, this requirement can be considered beforehand by the customer to specify the required motor ratings (i.e. rated power at rated voltage and rated frequency or specifying a range of rated voltages) and to have them duly taken into account in the motor design.

NOTE 3 ~~For machines covered by IEC 60034-3, different voltage and frequency limits apply.~~

**Table 4 – Primary functions of machines**

| Item | Machine type                                                                                                                           | Primary function                                                                                                                      |
|------|----------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| 1    | AC generator, excluding item 5                                                                                                         | Rated apparent power (kVA), at rated power factor where this is separately controllable                                               |
| 2    | AC motor, excluding item 3                                                                                                             | Rated torque (Nm)                                                                                                                     |
| 3    | Synchronous motor                                                                                                                      | Rated torque (Nm), the excitation maintaining either rated field current or rated power factor, where this is separately controllable |
| 4    | Synchronous <del>condenser</del> compensator, excluding item 5                                                                         | Rated reactive power ( <del>kVA</del> kVA) within the zone applicable to a generator, see Figure 11, unless otherwise agreed          |
| 5    | Synchronous generator driven by steam turbines or combustion gas turbines and synchronous compensators with rated output $\geq 10$ MVA | See IEC 60034-3                                                                                                                       |
| 6    | DC generator                                                                                                                           | Rated output (kW)                                                                                                                     |
| 7    | DC motor                                                                                                                               | Rated torque (Nm), the excitation of a shunt motor maintaining rated speed, where this is separately controllable                     |

**Key**

X-axis—frequency p.u.

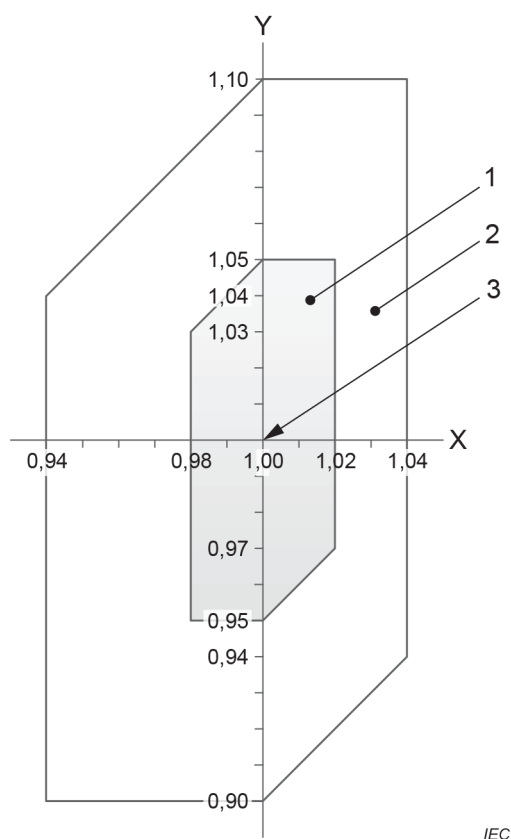
Y-axis—voltage p.u.

1—zone A

2—zone B (outside zone A)

3—rating point

**Figure 11 – Voltage and frequency limits for generators****Figure 12 – Voltage and frequency limits for motors**



#### Key

X axis frequency p.u.

Y axis Voltage p.u.

1 Zone A

2 Zone B (outside zone A)

3 rating point

**Figure 11 – Voltage and frequency limits for motors and for generators except generators or synchronous compensators within the scope of IEC 60034-3 and hydro generators within the scope of IEC 60034-33**

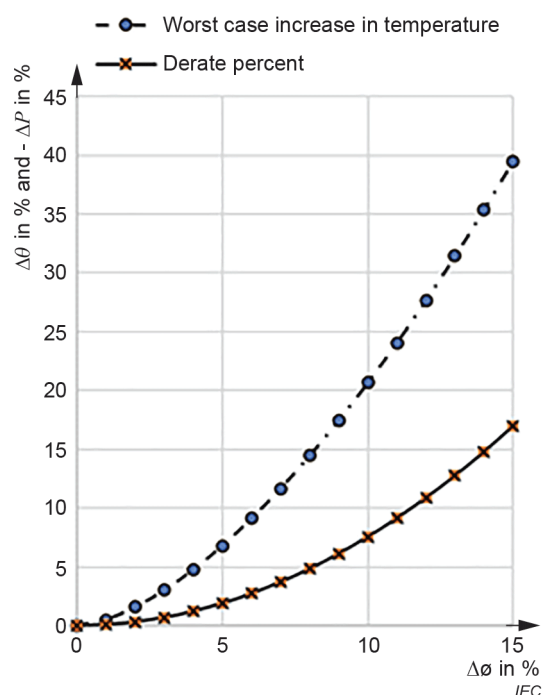


**Figure 12 – Worst case increase in temperature rise ( $\Delta\theta$ ) and recommended reduction of output power ( $\Delta P$ ) of motors as a function of the combined change of voltage and frequency  $|\Delta\phi|$  (indicative guideline to users of motors and generators only)**

### 7.5 Three-phase AC machines operating on unearthed systems

Three-phase AC machines shall be suitable for continuous operation with the neutral at or near earth potential. They shall also be suitable for operation on unearthed systems with one line at earth potential for infrequent periods of short duration, for example as required for normal fault clearance. If it is intended to run the machine continuously or for prolonged periods in this condition, a machine with a level of insulation suitable for this condition will be required.

If the winding does not have the same insulation at the line and neutral ends, this shall be stated by the manufacturer.

The earthing or interconnection of the machine's neutral points should not be undertaken without consulting the machine manufacturer because of the danger of zero-sequence components of currents of all frequencies under some operating conditions and the risk of mechanical damage to the windings under line-to-neutral fault conditions.

## 7.6 Voltage (peak and gradient) withstand levels

For AC machines, the manufacturer shall declare a limiting value for the peak voltage and for the voltage gradient in continuous operation, if required by the customer.

For machines used in power drive systems (PDS), see also IEC TS 60034-25.

For machines with a specified Impulse Voltage Insulation Class IVIC, see IEC 60034-18-41 in the case of machines designed to operate without partial discharges.

For ~~high-voltage~~ AC machines with rated voltage  $U_N > 1$  kV, see also IEC 60034-15.

For creepage and clearance distances of bare live conductive materials like copper or aluminium, e.g. in the terminal area, see IEC 60664-1. Enamelled wires are not considered as bare live materials. For the evaluation of winding insulation systems (base and functional insulation), see 9.2.

## 8 Thermal performance and tests

### 8.1 Thermal class

A thermal class in accordance with IEC 60085 shall be assigned to the insulation systems used in machines.

It is the responsibility of the manufacturer of the machine to interpret the results obtained by thermal endurance testing according to the appropriate part of IEC 60034-18.

NOTE 1 The thermal class of a new insulation system ~~should not be assumed to be~~ is not directly related to the thermal capability of the individual materials used in it.

NOTE 2 The continued use of an existing insulation system is acceptable where it has been proved by satisfactory service experience.

### 8.2 Reference coolant

The reference coolant for a given method of cooling the machine is specified in Table 5.

**Table 5 – Reference coolant (see also Table 11)**

| Item | Primary coolant    | Method of cooling | Secondary coolant | Table number | Table referred to in column 5 specifies limits of: | Reference coolant                                                                                                                                                                           |
|------|--------------------|-------------------|-------------------|--------------|----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1    | Air                | Indirect          | None              | 78           | Temperature rise                                   | Ambient air                                                                                                                                                                                 |
| 2    | Air                | Indirect          | Air               | 78           |                                                    | Reference temperature: 40 °C                                                                                                                                                                |
| 3    | Air                | Indirect          | Water             | 78           |                                                    | <del>Coolant at inlet to machine or ambient water reference temperature of cooling gas at inlet to machine: 40 °C</del>                                                                     |
| 4    | Hydrogen           | Indirect          | Water             | 89           |                                                    | <del>Reference temperature of ambient water: 25 °C (see note)</del><br>Reference temperature of primary coolant at inlet to machine: 40 °C<br>Reference temperature of ambient water: 25 °C |
| 5    | Air                | Direct            | None              | 1213         | Temperature                                        | Ambient air                                                                                                                                                                                 |
| 6    | Air                | Direct            | Air               | 1213         |                                                    | Reference temperature: 40 °C                                                                                                                                                                |
| 7    | Air                | Direct            | Water             | 1213         |                                                    | Gas at entry to machine or liquid at entry to the windings                                                                                                                                  |
| 8    | Hydrogen or liquid | Direct            | Water             | 1213         |                                                    | Reference temperature: 40 °C                                                                                                                                                                |

**NOTE**—A machine with indirect cooled windings and a water cooled heat exchanger may be rated using either the primary or secondary coolant as the reference coolant (see also 10.2 for information to be given on the rating plate). A submersible machine with surface cooling or a machine with water jacket cooling should be rated using the secondary coolant as reference coolant.

If a third coolant is used, temperature rise shall be measured above the temperature of the primary or secondary coolant as specified in Table 5.

**NOTE** A machine may be so arranged and cooled that more than one item of Table 5 applies, in which case different reference coolants may apply for different windings.

### 8.3 Conditions for thermal tests

#### 8.3.1 Electrical supply

During thermal testing of an AC machine the *HVF* of the supply shall not exceed 0,015 and the negative-sequence component of the system of voltages shall be less than 0,5 % of the positive-sequence component, the influence of the zero-sequence component being eliminated.

During thermal tests done at full load of machines with a rated voltage up to 1000 V, the average supply frequency shall be within  $\pm 0,1$  % of the rated frequency, the average supply voltages shall be within  $\pm 0,5$  % of the rated voltage and the average load shall not be less than the rated power for the test being conducted.

**NOTE** For machines with a rated voltage above 1 000 V, the thermal test can be made without the restrictions in voltage and frequency accuracy due to equipment limitations.

By agreement, the negative-sequence component of the system of currents may be measured instead of the negative-sequence component of the system of voltages. The negative-sequence component of the system of currents shall be less than 0,5 % of the positive-sequence component.

component of the system of currents shall not exceed 2,5 % of the positive-sequence component.

### **8.3.2 Temperature of machine before test**

If the temperature of a winding is to be determined from the increase of resistance, the initial winding temperature shall not differ from the coolant by more than 2 K.

When a machine is to be tested on a short-time rating (duty type S2) its temperature at the beginning of the thermal test shall be within 5 K of the temperature of the coolant.

### **8.3.3 Temperature of coolant**

A machine may be tested at any convenient value of coolant temperature. See Table 12 (for indirect cooled windings) or Table 15 (for direct cooled windings).

### **8.3.4 Measurement of coolant temperature during test**

#### **8.3.4.1 General**

The value to be adopted for the temperature of a coolant during a test shall be the mean of the readings of the temperature detectors taken at equal intervals of time during the last quarter of the duration of the test. To reduce errors due to the time lag of the change of temperature of large machines following variations in the temperature of the coolant, all reasonable precautions shall be taken to minimize such variations.

#### **8.3.4.2 Closed machines without heat exchangers (cooled by surrounding ambient air or gas)**

The temperature of the ambient air or gas shall be measured by means of several detectors placed at different points around and halfway up the machine at 1 m to 2 m from it. Each detector shall be protected from radiant heat and draughts.

#### **8.3.4.3 Open machines and machines cooled by air or gas from a remote source through ventilation ducts and machines with separately mounted heat exchangers**

The temperature of the primary coolant shall be measured where it enters the machine.

#### **8.3.4.4 Closed machines with machine-mounted or internal heat exchangers**

The temperature of the primary coolant shall be measured where it enters the machine. The temperature of the secondary coolant shall be measured where it enters the heat exchanger.

## **8.4 Temperature rise of a part of a machine**

The temperature rise,  $\Delta\theta$ , of a part of a machine is the difference between the temperature of that part measured by the appropriate method in accordance with 8.5, and the temperature of the coolant measured in accordance with 8.3.4.

For comparison with the limits of temperature rise (see Table 8 or Table 9) or of temperature (see Table 13), when possible, the temperature shall be measured immediately before the machine is shut down at the end of the thermal test, as described in 8.7.

When this is not possible, for example, when using the direct measurement of resistance method, see 8.6.2.3.

For machines tested on actual periodic duty (duty types S3 to S8) the temperature at the end of the test shall be taken as that at the middle of the rise period causing the greatest heating in the last cycle of operation (but see also 8.7.3).

## **8.5 Methods of measurement of temperature**

### **8.5.1 General**

Three methods of measuring the temperature of windings and other parts are recognized:

- resistance method;
- embedded temperature detector (ETD) method;
- thermometer method.

Different methods shall not be used as a check upon one another.

For indirect testing, see IEC 60034-29.

### **8.5.2 Resistance method**

The temperature of the windings is determined from the increase of the resistance of the windings.

### **8.5.3 Embedded temperature detector (ETD) method**

The temperature is determined by means of temperature detectors (e.g. resistance thermometers, thermocouples or semi-conductor negative coefficient detectors) built into the machine during construction, at points which are inaccessible after the machine is completed.

### **8.5.4 Thermometer method**

The temperature is determined by thermometers applied to accessible surfaces of the completed machine. The term 'thermometer' includes not only bulb-thermometers, but also non-embedded thermocouples and resistance thermometers. When bulb-thermometers are used in places where there is a strong varying or moving magnetic field, alcohol thermometers shall be used in preference to mercury thermometers.

## **8.6 Determination of winding temperature**

### **8.6.1 Choice of method**

In general, for measuring the temperature of the windings of a machine, the resistance method in accordance with 8.5.2 shall be applied (but see also 8.6.2.3.3).

For AC stator windings of machines having a rated output of 5 000 kW (or kVA) or more the ETD method shall be used.

**NOTE** If agreed between manufacturer and customer, the resistance method may be used also for machines having a rated output of 5 000 kW (or kVA).

For AC stator windings of machines having a rated output less than 5 000 kW (or kVA) but greater than 200 kW (or kVA), the manufacturer shall choose either the resistance or the ETD method, unless otherwise agreed.

For AC stator windings of machines having a rated output less than or equal to 200 kW (or kVA) the manufacturer shall choose the direct measurement version or the superposition version of the resistance method (see 8.6.2.1), unless otherwise agreed (but see also below).

For machines having a rated output less than or equal to 600 W (or VA), when the windings are non-uniform or severe complications are involved in making the necessary connections, the temperature may be determined by means of thermometers. Temperature rise limits in accordance with Table 8, item 1d) for resistance method shall apply.

The thermometer method is recognized in the following cases:

- a) when it is not practicable to determine the temperature rise by the resistance method as, for example, with low-resistance commutating coils and compensating windings and, in general, in the case of low-resistance windings, especially when the resistance of joints and connections forms a considerable proportion of the total resistance;
- b) single layer windings, rotating or stationary;
- c) during routine tests on machines manufactured in large numbers.

For AC stator windings having only one coil-side per slot, the ETD method shall not be used for verifying compliance with this document: the resistance method shall be used.

**NOTE**—For checking the temperature of such windings in service, an embedded detector at the bottom of the slot is of little value because it gives mainly the temperature of the iron core. A detector placed between the coil and the wedge will follow the temperature of the winding much more closely and is, therefore, better for checks in service. Because the temperature there may be rather low, the relation between it and the temperature measured by the resistance method should be determined by a thermal test.

For other windings having one coil-side per slot and for end windings, the ETD method shall not be used for verifying compliance with this document.

For windings of armatures having commutators and for field windings, the resistance method is recognized. For stationary field windings of DC machines having more than one layer the ETD method may be used.

## 8.6.2 Determination by resistance method

### 8.6.2.1 Measurement

One of the following **versions of the** method shall be used:

- direct measurement at the beginning and the end of the test, using an instrument having a suitable range;
- measurement by DC current/voltage in DC windings, by measuring the current in and the voltage across the winding, using instruments having suitable ranges;
- measurement by DC current/voltage in AC windings, by injecting direct current into the winding when de-energized;
- measurement by DC current/voltage in AC windings, by superposing small amount of DC current into the winding, when energized.

### 8.6.2.2 Calculation

The temperature rise,  $\theta_2 - \theta_a$ , may be obtained from the formula:

$$\frac{\theta_2 + k}{\theta_1 + k} = \frac{R_2}{R_1}$$

where

$\theta_1$  is the temperature (°C) of the winding (cold) at the moment of the initial resistance measurement;

$\theta_2$  is the temperature (°C) of the winding at the end of the thermal test;

$\theta_a$  is the temperature (°C) of the coolant at the end of the thermal test;

$R_1$  is the resistance of the winding at temperature  $\theta_1$  (cold);

$R_2$  is the resistance of the winding at the end of the thermal test;

$k$  is the reciprocal of the temperature coefficient of resistance at 0 °C of the conductor material.

For copper  $k = 235$ .

For aluminium  $k = 225$ , unless specified otherwise.

For practical purposes, the following alternative formula may be found convenient:

$$\theta_2 - \theta_a = \frac{R_2 - R_1}{R_1} \times (k + \theta_1) + \theta_1 - \theta_a$$

### 8.6.2.3 Correction for stopping time

#### 8.6.2.3.1 General

The measurement of temperatures at the end of the thermal test by the direct measurement resistance method requires a quick shutdown. A carefully planned procedure and an adequate number of people are required.

#### 8.6.2.3.2 Short stopping time

If the initial resistance reading is obtained within the time interval specified in Table 6, that reading shall be accepted for the temperature measurement.

**Table 6 – Time interval**

| Rated output ( $P_N$ )  | Time interval after switching off power |
|-------------------------|-----------------------------------------|
| kW or kVA               | s                                       |
| $P_N \leq 50$           | 30                                      |
| $50 < P_N \leq 200$     | 90                                      |
| $200 < P_N \leq 5\,000$ | 120                                     |
| $5\,000 < P_N$          | By agreement                            |

#### 8.6.2.3.3 Extended stopping time

If a resistance reading cannot be made in the time interval specified in Table 6, it shall be made as soon as possible but not after more than twice the interval specified in Table 6, and additional readings shall be taken at intervals of approximately 1 min until these readings have begun a distinct decline from their maximum value. A curve of these readings shall be plotted as a function of time and extrapolated to the appropriate time interval of Table 6 for the rated output of the machine. A semi-logarithmic plot is recommended where temperature or resistance is plotted on the logarithmic scale. The value of temperature thus obtained shall be considered as the temperature at shutdown. If successive measurements show increasing temperatures after shutdown the highest value shall be taken.

If a resistance reading cannot be made until after twice the time interval specified in Table 6, this method of correction shall only be used by agreement.