IEC 60034-1

Edition 14.0 2022-02
REDLINE VERSION

INTERNATIONAL STANDARD

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Rotating electrical machines –
Part 1: Rating and performance

IEC 60034-1:2022-02 RLV(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.160.01 ISBN 978-2-8322-1082-6

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ROTATING ELECTRICAL MACHINES –

Part 1: Rating and performance

FOREWORD

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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 Clarification on the capability to withstand impulse voltages
7.3	New subclause on voltage deviation during starting
7.4	Extended variation of supply frequency Note added on design for operation with extended voltage and frequency 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 Test voltage for variable speed AC machines added 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 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 Note on measurement uncertainty added

Clause or subclause	Change
12.2	Change in the tolerance on efficiency Clarification on the tolerance on locked-rotor current 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. The main document types developed by IEC are described in greater detail at 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 in the data related to the specific document. At this date, the document will be

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- withdrawn,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

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

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

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

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

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 ($I_{\max}$) and minimum ($I_{\min}$) 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 60034-24:2009, 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.

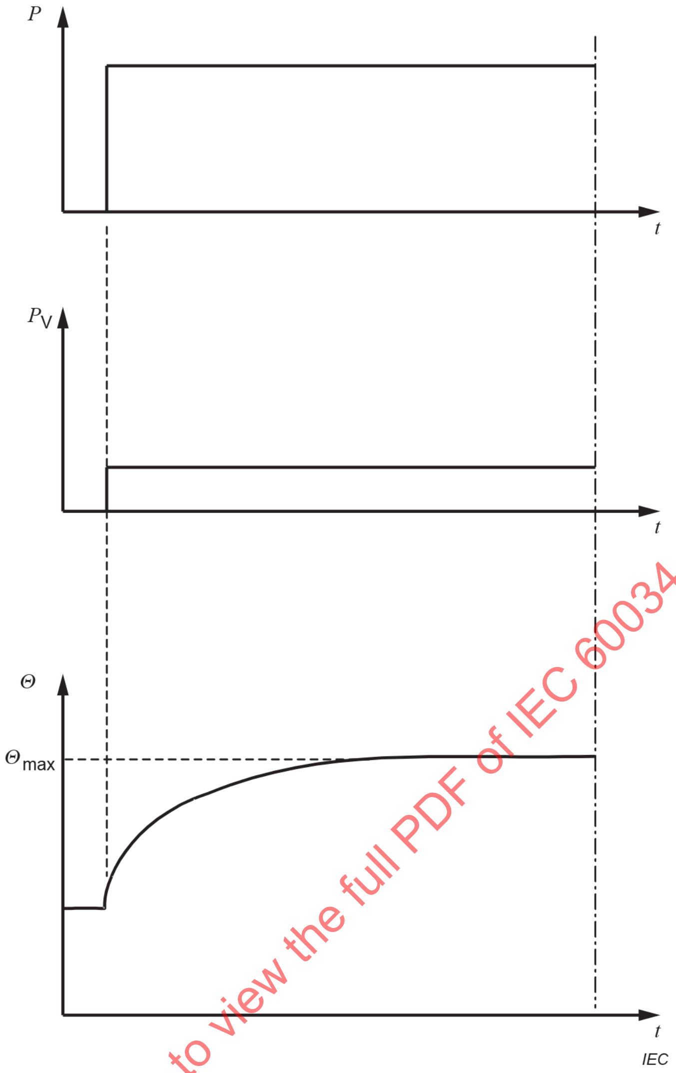
Where the purchaser does not declare a duty, the manufacturer shall assume that duty type S1 (continuous running duty) applies.

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

Θ temperature

$Θ_{max}$ maximum temperature attained

t time

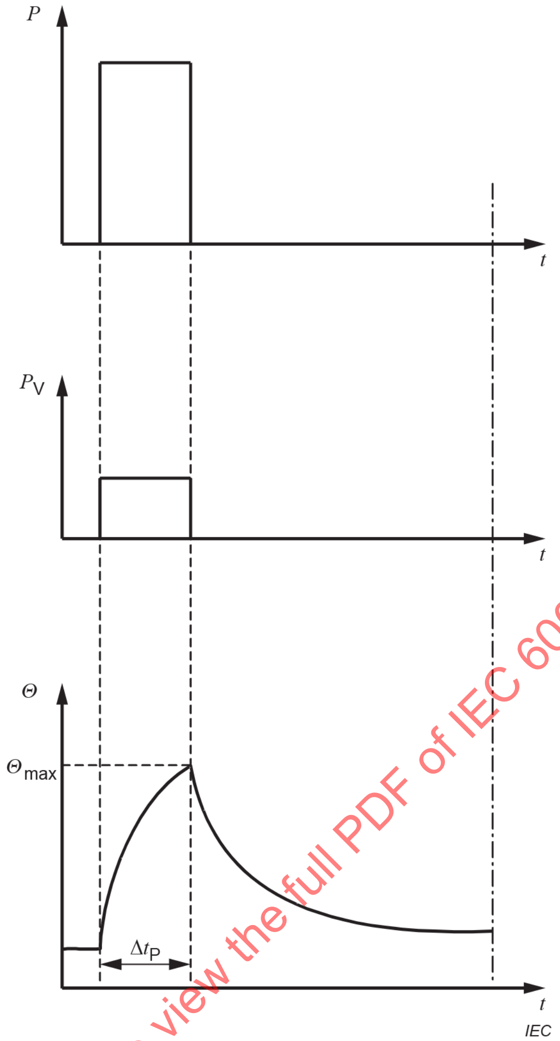
Figure 1 – Continuous running duty – Duty type S1

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
Θ	temperature
Θ_{max}	maximum temperature attained
t	time
Δt_P	operation time at constant load, e. g. Δt_P = 60 min for S2 60 min

Figure 2 – Short-time duty – Duty type S2

4.2.3 Duty type S3 – Intermittent periodic duty

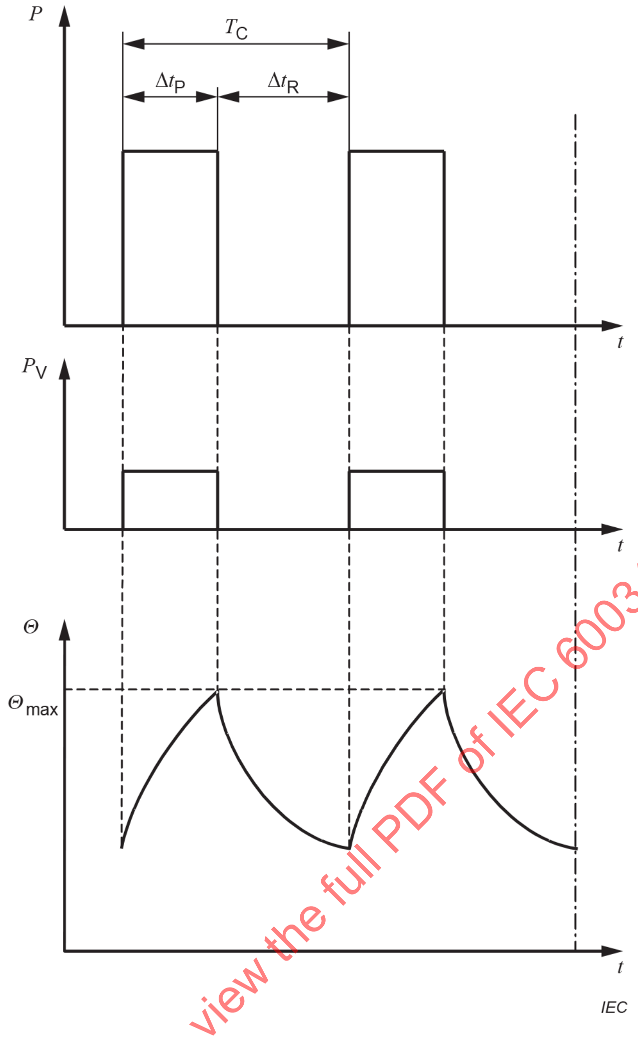
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

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

Θ temperature

Θ_{max} maximum temperature attained

t time

T_C time of one load cycle

Δt_P operation time at constant load

Δt_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

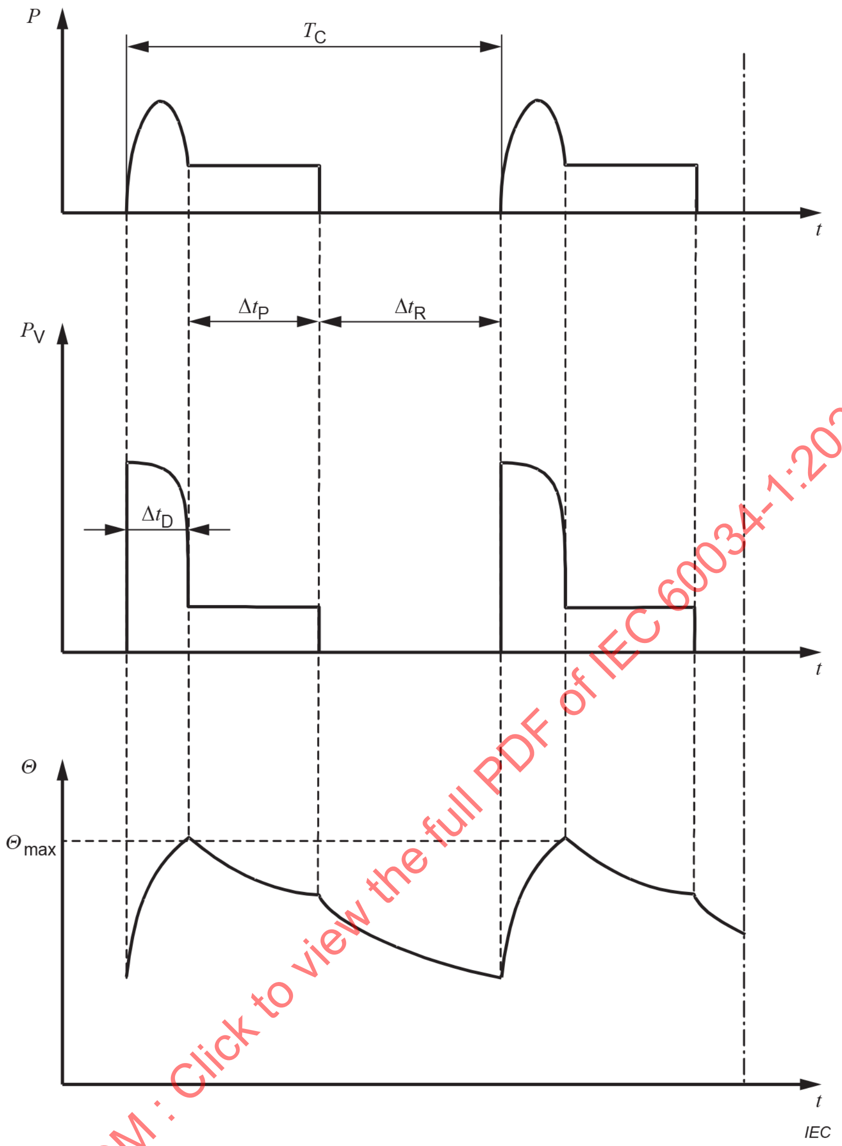
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

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_{ext}), both referred to the motor shaft.

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



Key

P	load	t	time
P_V	electrical losses	T_C	time of one load cycle
Θ	temperature	Δt_D	starting/accelerating time
$Θ_{max}$	maximum temperature attained	Δt_P	operation time at constant load
		Δt_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

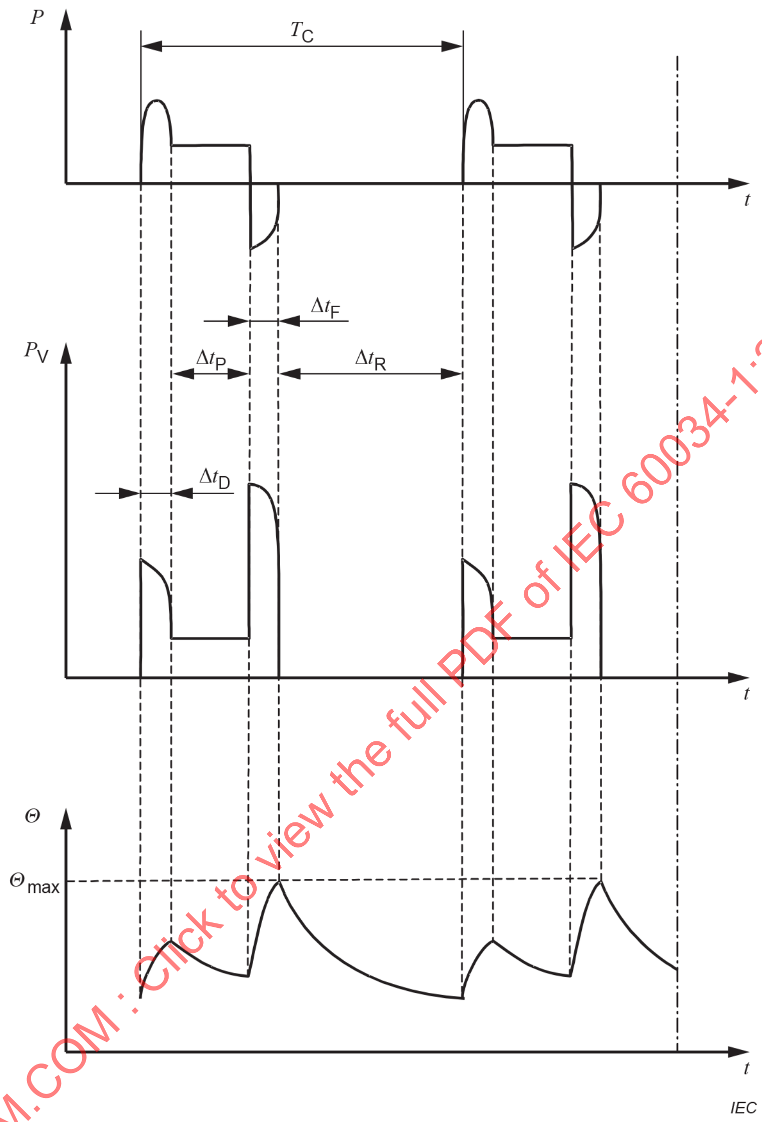
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

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 kg × m^2 J_{ext} = 0,7 kg × m^2.



Key

P	load	T_C	time of one load cycle
P_V	electrical losses	Δt_D	starting/accelerating time
Θ	temperature	Δt_P	operation time at constant load
Θ_{max}	maximum temperature attained	Δt_F	time of electric braking
t	time	Δt_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

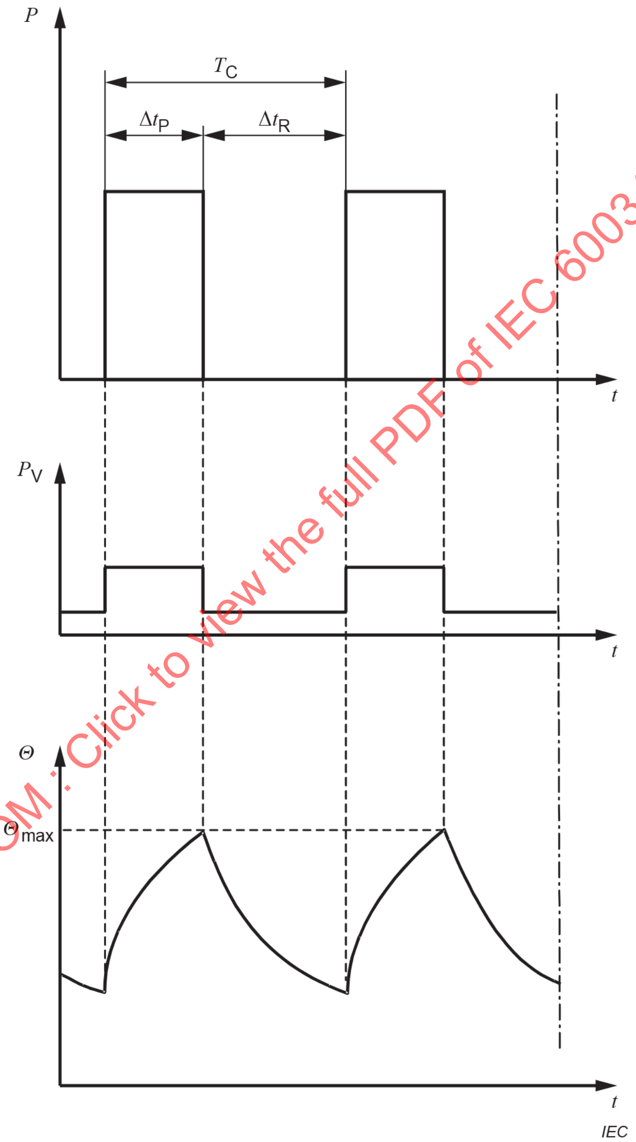
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

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
Θ	temperature	Δt_P	operation time at constant load
Θ_{max}	maximum temperature attained	Δt_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

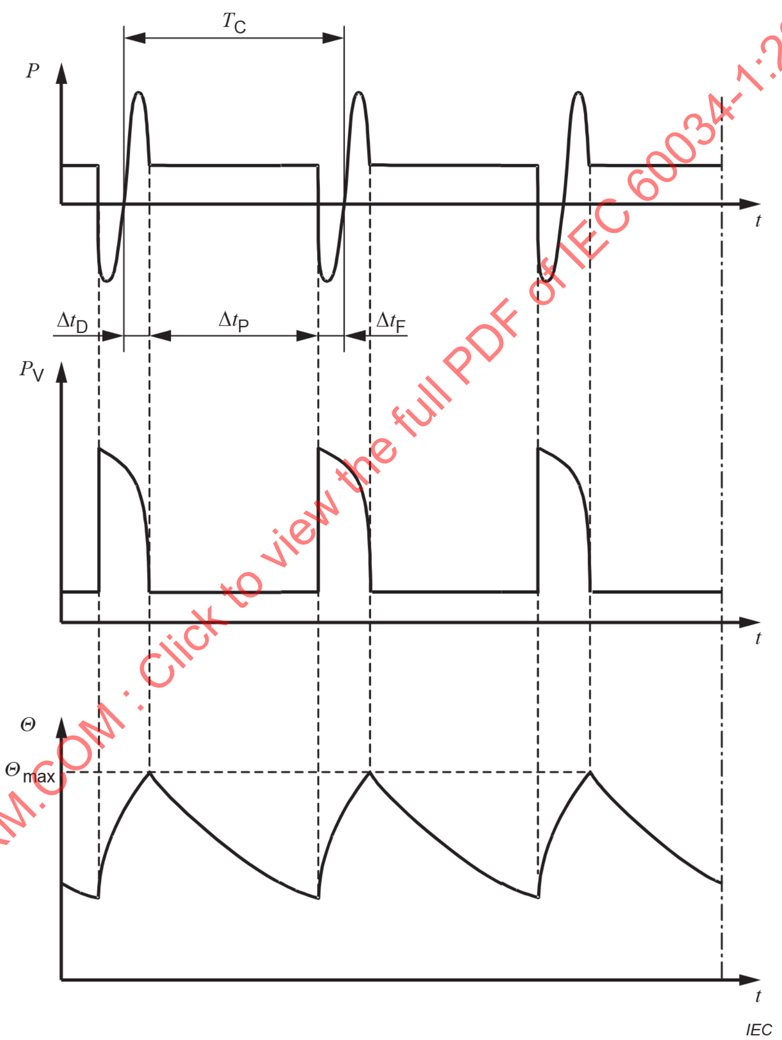
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

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 kg × m^2 J_{ext} = 7,5 kg × m^2



Key

P	load	t	time
P_V	electrical losses	T_C	time of one load cycle
Θ	temperature	Δt_D	starting/accelerating time
Θ_{max}	maximum temperature attained	Δt_P	operation time at constant load
Cyclic duration factor = 1		Δt_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

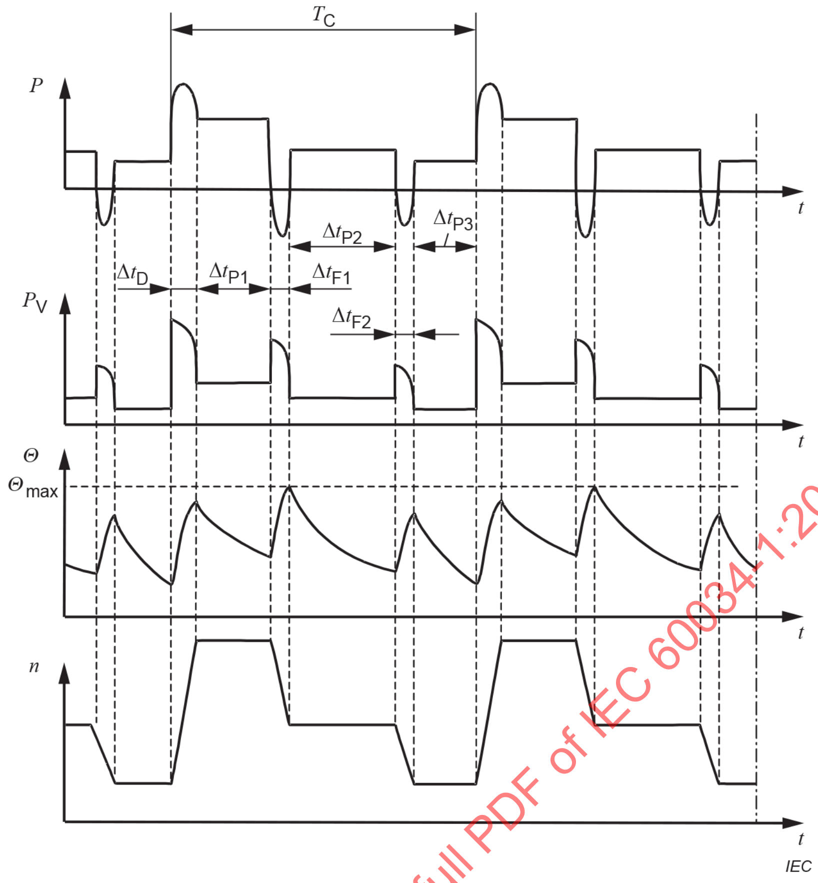
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

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 kg × m^2	J_{ext} = 6 kg × m^2	16 kW	740 min^{-1}	30 %
			40 kW	1 460 min^{-1}	30 %
			25 kW	980 min^{-1}	40 %.



Key

P	load	t	time
P_V	electrical losses	T_C	time of one load cycle
Θ	temperature	$Δt_D$	starting/accelerating time
$Θ_{max}$	maximum temperature attained	$Δt_P$	operation time at constant load (P1, P2, P3)
n	speed	$Δt_F$	time of electric braking (F1, F2)

Cyclic duration factor = $(Δt_D + Δt_{P1})/T_C$; $(Δt_{F1} + Δt_{P2})/T_C$; $(Δt_{F2} + Δt_{P3})/T_C$

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

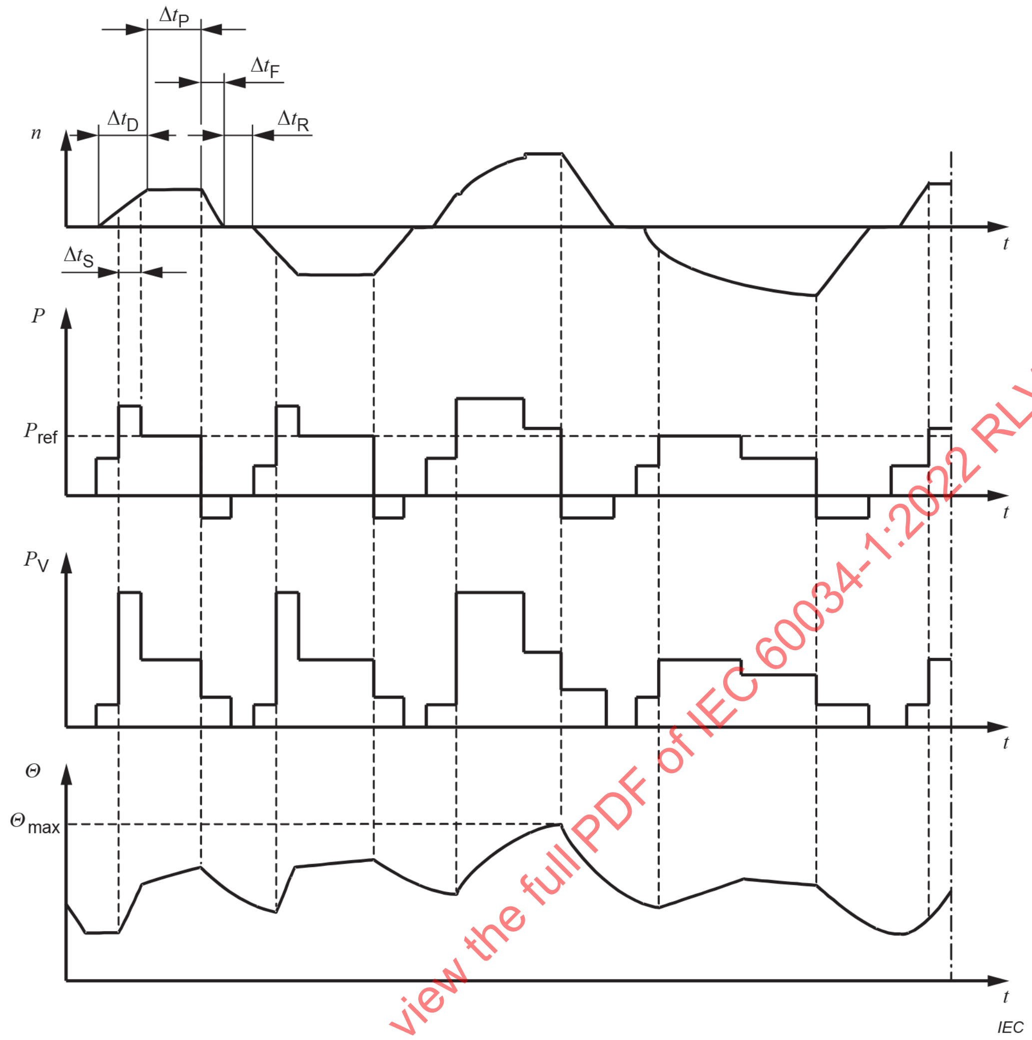
4.2.9 Duty type S9 – Duty with non-periodic load and speed variations

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_{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	Δt_D	starting/accelerating time
P_V	electrical losses	Δt_P	operation time at constant load
Θ	temperature	Δt_F	time of electric braking
Θ_{max}	maximum temperature attained	Δt_R	time at rest and de-energized
n	speed	Δt_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.

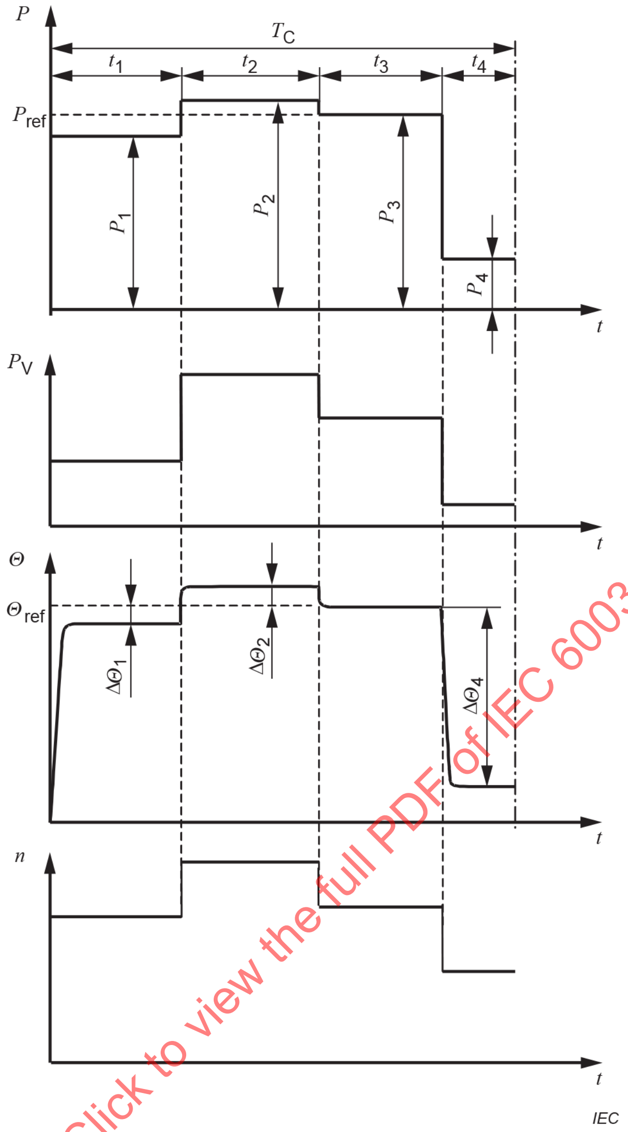
Example: S10 $p/\Delta t$ = 1,1/0,4; 1/0,3; 0,9/0,2; r/0,1 TL = 0,60.

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
Θ	temperature	n	speed
Θ_{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

Rated voltage kV	Minimum rated output kW (or kVA)
1,0 < U_N ≤ 3,0	100
3,0 < U_N ≤ 6,0	150
6,0 < U_N ≤ 11,0	800
11,0 < U_N ≤ 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^{-1};

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 ≤ 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:

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

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 $(I_{(2)}/I_{\mathrm{N}})^2$ 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 ~~condensers~~ compensators	0,1	20
2	Direct cooled (inner cooled) stator and/or field windings		
	motors	0,08	15
	generators	0,05	15
	synchronous ~~condensers~~ 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

[a] For these machines, the value of $I_{(2)}/I_N$ is calculated as follows:

~~$\frac{I_2}{I_N} = 0{,}08 - \frac{S_N - 350}{3 \times 10^4}$~~ $\frac{I_{(2)}}{I_N} = 0{,}08 - \frac{S_N - 350}{3 \times 10^4}$

[b] For these machines, the value of $(I_{(2)}/I_N)^2 \times t$, in seconds, is calculated as follows:
$(I_{(2)}/I_N)^2 \times t = 8 - 0{,}005\,45\,(S_N - 350)$
where in the two footnotes, S_N is the rated apparent power in MVA.

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 *CCC*	1-pair configuration (configuration name)	Pair number "m" for arms in IEC 61148	Clause No. and title in IEC 61148
A-Type	Thyristor + Thyristor (Full bridge)	m = 3	5.1.3.2 Bridge connection
B-Type	Thyristor + Diode (Mixed bridge)	m = 3	Same as above
C-Type	Thyristor + Thyristor (Full bridge)	m = 2	Same as above
D-Type	Thyristor + Diode (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:

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

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.

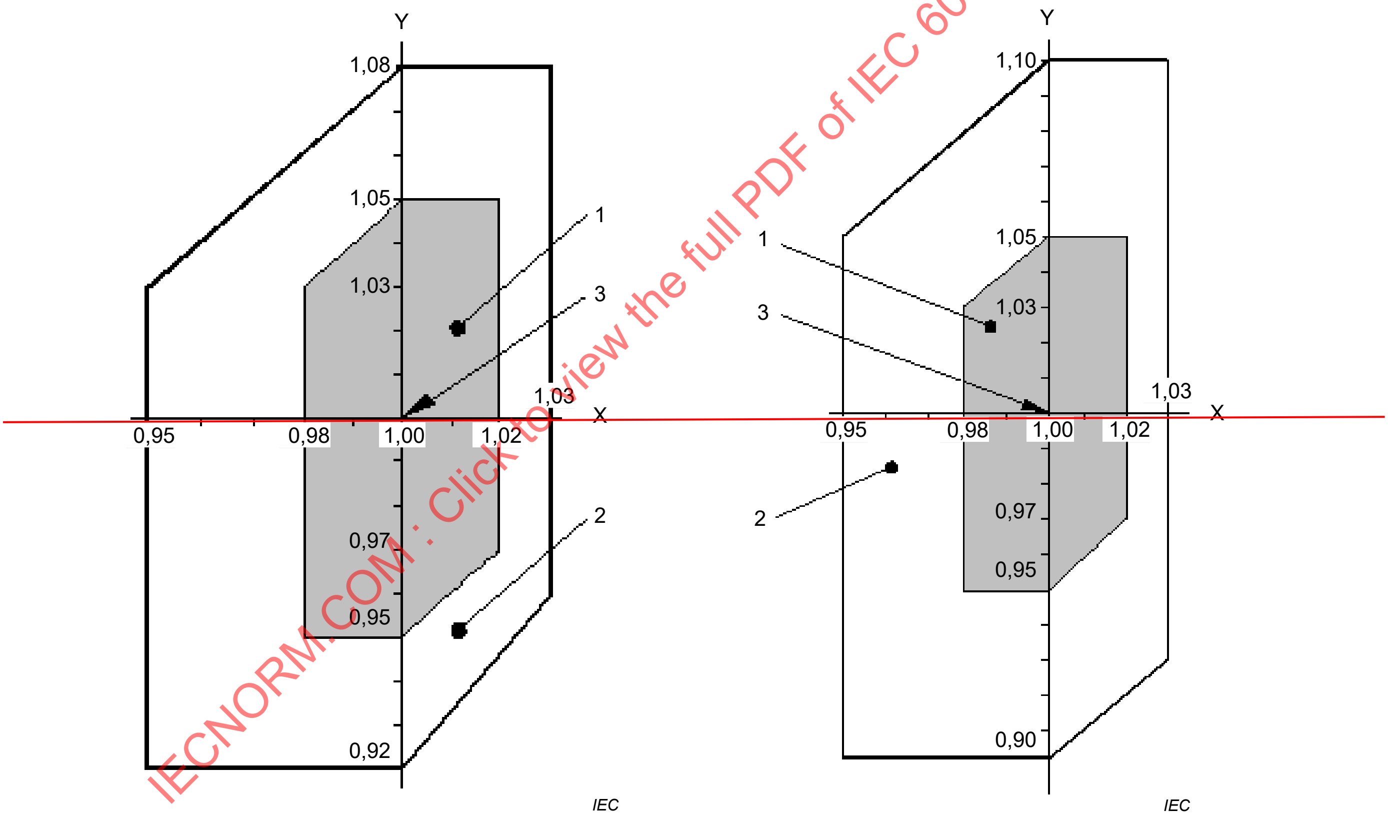
NOTE 2 An a.c. motor will start at the lower limit of voltage only if its starting torque is adequately matched to the counter-torque of the load, but this is not a requirement of this clause. For starting performance of design N motors, see IEC 60034-12.

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 ~~condenser~~ compensator, excluding item 5	Rated reactive power (~~kVAr~~ 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 ≥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.~~

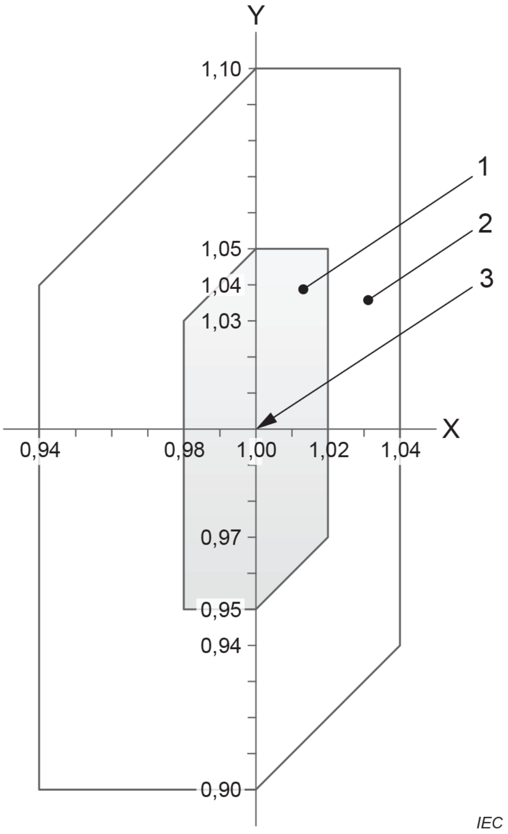
~~1 zone A~~

~~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

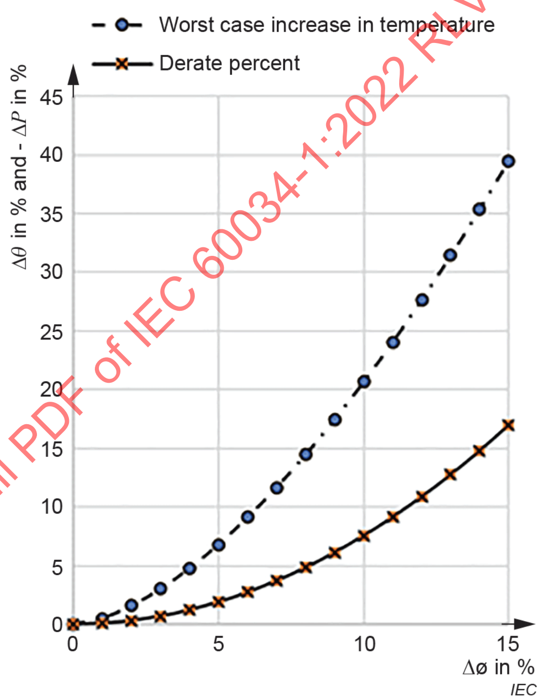


Figure 12 – Worst case increase in temperature rise ($\Delta\theta$) and recommended reduction of output power (ΔP) of motors as a function of the combined change of voltage and frequency $|\Delta\varnothing|$ (indicative guideline to users of motors and generators only)

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	~~7~~8	Temperature rise	Ambient air
2	Air	Indirect	Air	~~7~~8		Reference temperature: 40 °C
3	Air	Indirect	Water	~~7~~8		~~Coolant at inlet to machine or ambient water reference temperature of cooling gas at inlet to machine: 40 °C~~
4	Hydrogen	Indirect	Water	~~8~~9		~~Reference temperature of ambient water: 25 °C (see note)~~ Reference temperature of primary coolant at inlet to machine: 40 °C Reference temperature of ambient water: 25 °C
5	Air	Direct	None	~~12~~13	Temperature	Ambient air
6	Air	Direct	Air	~~12~~13		Reference temperature: 40 °C
7	Air	Direct	Water	~~12~~13		Gas at entry to machine or liquid at entry to the windings
8	Hydrogen or liquid	Direct	Water	~~12~~13		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 ±0,1 % of the rated frequency, the average supply voltages shall be within ±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 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

θ_1 is the temperature (°C) of the winding (cold) at the moment of the initial resistance measurement;

θ_2 is the temperature (°C) of the winding at the end of the thermal test;

θ_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 θ_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.

8.6.2.3.4 Windings with one coil-side per slot

For machines with one coil-side per slot, the resistance method by direct measurement may be used if the machine comes to rest within the time interval specified in Table 6. If the machine takes more than 90 s to come to rest after switching off the power, the superposition method (see 8.6.2.1) may be used if previously agreed.

8.6.3 Determination by ETD method

8.6.3.1 General

The detectors shall be suitably distributed throughout the winding and the number of detectors installed shall be not less than six.

All reasonable efforts, consistent with safety, shall be made to place the detectors at the points where the highest temperatures are likely to occur, in such a manner that they are effectively protected against contact with the primary coolant.

The highest reading from the ETD elements shall be used to determine the temperature of the winding.

ETD elements or their connections may fail and give incorrect readings. Therefore, if one or more readings are shown to be erratic, after investigation they should be eliminated.

8.6.3.2 Two or more coil-sides per slot

The detectors shall be located between the insulated coil-sides within the slot in positions at which the highest temperatures are likely to occur.

8.6.3.3 One coil-side per slot

The detectors shall be located between the wedge and the outside of the winding insulation in positions at which the highest temperatures are likely to occur, but see also 8.6.1.

8.6.3.4 End windings

The temperature detectors shall be located between two adjacent coil-sides within the end windings in positions where the highest temperatures are likely to occur. The sensing point of each detector shall be in close contact with the surface of a coil-side and be adequately protected against the influence of the coolant, but see also 8.6.1.

When placing a temperature detector in the end windings of high voltage machines, care shall be taken that the stress grading of the insulation is not compromised and that the difference of potential along the winding overhang does not cause problems. In addition, the ground of the measuring system is thus directly capacitive coupled to the HV-system. Disconnection of the measurement ground will in this case immediately lead to over voltages on the measuring system. Measures have to be taken to prevent consequential damage up to lethal injuries.

NOTE If the stator winding is a direct liquid cooled bar type, a temperature detector installed in the nozzle area of each bar monitoring water outlet temperature can give an indication of conductor strand cooling passage blocking.

8.6.4 Determination by thermometer method

All reasonable efforts, consistent with safety, shall be made to place thermometers at the point, or points where the highest temperatures are likely to occur (e.g. in the end windings close to the core iron) in such a manner that they are effectively protected against contact with the primary coolant and are in good thermal contact with the winding or other part of the machine.

The highest reading from any thermometer shall be taken to be the temperature of the winding or other part of the machine.

8.7 Duration of thermal tests

8.7.1 Rating for continuous running duty

The test shall be continued until thermal equilibrium has been reached.

8.7.2 Rating for short-time duty

The duration of the test shall be the time given in the rating.

8.7.3 Rating for periodic duty

Normally the rating for equivalent loading assigned by the manufacturer (see 5.2.6) shall be applied until thermal equilibrium has been reached. If a test on the actual duty is agreed, the load cycle specified shall be applied and continued until practically identical temperature cycles are obtained. The criterion for this shall be that a straight line between the corresponding points of successive duty cycles on a temperature plot has a gradient of less than 1 K per half hour. If necessary, measurements shall be taken at reasonable intervals over a period of time (see 3.25).

8.7.4 Ratings for non-periodic duty and for duty with discrete constant loads

The rating for equivalent loading assigned by the manufacturer (see 5.2.6) shall be applied until thermal equilibrium has been reached.

8.8 Determination of the thermal equivalent time constant for machines of duty type S9

The thermal equivalent time constant with ventilation as in normal operating conditions, suitable for approximate determination of the temperature course, can be determined from the cooling curve plotted in the same manner as in 8.6.2.3. The value of the time constant is 1,44 times (that is to say, 1/ln(2) times) the time taken by the machine to cool to one-half of the full load temperature rise, after its disconnection from the supply.

8.9 Measurement of bearing temperature

Either the thermometer method or the ETD method may be used.

The measuring point shall be as near as possible to one of the two locations specified in Table 7.

Table 7 – Measuring points

Type of bearing	Measuring point	Location of measuring point
Ball or roller	A	In the bearing housing preferably in contact with the outer ring of the bearing, but not more than 10 mm[a] from it[b]
	B	Outer surface of the bearing housing as close as possible to the outer ring of the bearing
Sleeve or tilting pad	A	In the pressure zone of the bearing shell[c] and not more than 10 mm[a] from the oil-film gap[b].
	B	Elsewhere in the bearing shell

[a] The distance is measured to the nearest point of the ETD or thermometer bulb.

[b] In the case of an 'inside out' machine, point A will be in the stationary part not more than 10 mm from the inner ring and point B on the outer surface of the stationary part as close as possible to the inner ring.

[c] The bearing shell is the part supporting the bearing material and which is secured in the housing. The pressure zone is the portion of the circumference which supports the combination of rotor weight and radial loads.

The thermal resistance between the temperature detector and the object whose temperature is to be measured shall be minimized; for example, air gaps shall be packed with thermally conducting paste.

NOTE Between the measuring points A and B, as well as between these points and the hottest point of the bearing, there are temperature differences which depend, among other things, on the bearing size. For sleeve bearings with pressed-in bushings and for ball and roller bearings with an inside diameter of up to 150 mm, the temperature difference between points A and B may be assumed to be negligible. In the case of larger bearings, the temperature difference between measuring points A and B is approximately 15 K.

8.10 Limits of temperature and of temperature rise

8.10.1 General

Limits are given for operation under site operating conditions specified in Clause 6 and at rating for continuous running duty (reference conditions), followed by rules for the adjustment of those limits when operating at site under other conditions and on other ratings. Further rules give adjustments to the limits during thermal testing when conditions at the test site differ from those at the operating site.

It is understood that the temperature of the hottest point of each winding under reference conditions, i.e. the rated conditions, generally does not exceed the agreed thermal class temperature of the insulation system.

The limits are stated relative to the reference coolant specified in Table 5.

A rule is given to allow for the purity of hydrogen coolant.

8.10.2 Indirect cooled windings

Temperature rises under reference conditions shall not exceed the limits given in Table 8 (air coolant) or Table 9 (hydrogen coolant) as appropriate for both, ETD and R method if applicable.

NOTE The measured temperature differences between method ETD and method R may be significantly higher or lower than the temperature limits specified in Table 8 or Table 9, depending on the machine design and the cooling system. It is not intended to compare ETD and R method against each other.

For other operating site conditions, for ratings other than continuous running duty, and for rated voltages greater than 12 000 V, the limits shall be adjusted according to Table 10. (See also Table 11 for limit on coolant temperature which is assumed in Table 10.)

In the case of thermometer readings made in accordance with 8.6.1, the limit of temperature rise shall be according to Table 8.

If, for windings indirectly cooled by air, conditions at the test site differ from those at the operating site, the adjusted limits given in Table 12 shall apply at the test site.

If the adjusted limits given in Table 12 lead to permissible temperatures at the test site which the manufacturer considers to be excessive, the testing procedure and the limits shall be agreed.

If temperature rise is to be measured above the temperature of the water where it enters the cooler, the effect of altitude on the temperature difference between air and water should strictly be allowed for. However, for most cooler designs, the effect will be small, the difference increasing with increasing altitude at the rate of roughly 2 K per 1 000 m. If an adjustment is necessary, it should be by agreement.

No adjustments at the test site are given for windings indirectly cooled by hydrogen, because it is very unlikely that they will be tested at rated load anywhere other than at the operating site.

Table 8 – Limits of temperature rise of windings indirectly cooled by air

Thermal class		130 (B)			155 (F)			180 (H)			200 (N)		
Method of measurement	Th = Thermometer,-R = Resistance, ETD = Embedded temperature detector	**Th** K	**R** K	**ETD** K	**Th** K	**R** K	**ETD** K	**Th** K	**R** K	**ETD** K	**Th** K	**R** K	**ETD** K
Item	**Part of machine**												
1a)	AC windings of machines having outputs of 5 000 kW (or kVA) or more	–	80	85 [a]	–	105	110 [a]	–	125	130 [a]	–	145	150 [a]
1b)	AC windings of machines having outputs above 200 kW (or kVA), but less than 5 000 kW (or kVA)	–	80	90 [a]	–	105	115 [a]	–	125	140 [a]	–	145	160 [a]
1c)	AC windings of machines having outputs of 200 kW (or kVA) or less, other than those in items 1d) or 1e) [b]	–	80	–	–	105	–	–	125	–	–	145	–
1d)	AC windings of machines having rated outputs of less than 600 W (or VA) [b]	–	85	–	–	110	–	–	130	–	–	150	–
1e)	AC windings which are self-cooled without a fan (IC 40) and/or with encapsulated windings [b]	–	85	–	–	110	–	–	130	–	–	150	–
2	Windings of armatures having commutators	70	80	–	85	105	–	105	125	–	125	145	–
3	Field windings of AC and DC machines other than those in item 4	70	80	–	85	105	–	105	125	–	125	145	–
4a)	Field windings of synchronous machines with cylindrical rotors having a DC excitation winding embedded in slots, except synchronous induction motors	–	90	–	–	115	–	–	135	–	–	155	–
4b)	Insulated stationary field windings of DC machines having more than one layer	70	80	90	85	105	115	105	125	140	125	145	160
4c)	Low-resistance field windings of DC machines having more than one layer and compensating windings of DC machines	80	80	–	100	105	–	125	125	–	145	145	–
4d)	Single-layer windings of AC and DC machines with exposed bare or varnished metal surfaces [c]	90	90	–	110	115	–	135	135	–	155	155	–

[a] For adjustment for high-voltage AC windings, see item 4 of Table 10.

[b] With the application of the superposition test method to windings of machines rated at 200 kW (or kVA) or less with thermal classes 130 (B) and 155 (F), the limits of temperature rise given for the resistance method may be exceeded by 5 K.

[c] Also includes multiple layer windings, provided that the under layers are each in contact with the circulating primary coolant.

Table 9 – Limits of temperature rise of windings indirectly cooled by hydrogen

Thermal class			130 (B)		155 (F)	
Method of measurement ETD = Embedded temperature detector			**Resistance** K	**ETD** K	**Resistance** K	**ETD** K
Item						
1	AC windings of machines having outputs of 5 000 kW (or kVA) or more or having a core length of 1 m or more					
	Absolute hydrogen pressure [b]	≤ 150 kPa (1,5 bar)	–	85 [a]	–	105 [a]
	> 150 kPa	≤ 200 kPa (2,0 bar)	–	80 [a]	–	100 [a]
	> 200 kPa	≤ 300 kPa (3,0 bar)	–	78 [a]	–	98 [a]
	> 300 kPa	≤ 400 kPa (4,0 bar)	–	73 [a]	–	93 [a]
	> 400 kPa		–	70 [a]	–	90 [a]
2a	AC windings of machines having outputs of less than 5 000 kW (or kVA), or having a core length of less than 1 m		80	85 [a]	100	110 [a]
2b	DC field windings of AC and DC machines other than those in items 3 and 4		80	–	105	–
3	DC field windings of machines having cylindrical rotors		85	–	105	–
4a	Low-resistance field windings of more than one layer and compensating windings		80	–	100	–
4b	Single-layer windings with exposed bare or varnished metal surfaces [c]		90	–	110	–

[a] For adjustment for high-voltage AC windings, see item 4 of Table 10.

[b] This is the only item where the limit of temperature rise is dependent on hydrogen pressure.

[c] Also includes multi-layer field windings provided that the under layers are each in contact with the circulating primary coolant.

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

Item	Operation conditions or rating	Adjustment to limit of temperature rise ($\Delta\theta$) in Table 8 and Table 9	Item
1a	Maximum temperature of ambient air or of the cooling gas at inlet to the machine (θ_c) and for altitudes of up to 1 000 m. If the difference between the thermal class and the observable limit of temperature, consisting of the sum of the reference cold coolant inlet temperature of 40 °C and the limit of temperature rise according to Table 8 and Table 9 is less or equal to 5 K: For a higher altitude replace 40 °C with the value given in Table 11.	0 °C ≤ θ_c ≤ 40 °C	Increased by the amount by which the coolant temperature is less than 40 °C.
1b	Maximum temperature of ambient air or of the cooling gas at the inlet to the machine (θ_c) and for altitudes of up to 1 000 m. If the difference between the thermal class and the observable limit of the temperature, consisting of the sum of the reference cold coolant inlet temperature of 40 °C and the limit of temperature rise according to Table 8 and Table 9 is larger than 5 K: For a higher altitude replace 40 °C with the value given in Table 11.	0 °C ≤ θ_c ≤ 40 °C	The limit of temperature rise $\Delta\theta$ for cold gas temperature θ_c shall be $\Delta\theta = \Delta\theta_{ref}\frac{\theta_{ThCl} - \theta_C}{\theta_{ThCl} - \theta_{C\cdot ref}}$ where $\Delta\theta_{ref}$ is the limit of temperature rise according to Table 8 or Table 9 at 40 °C; θ_{ThCl} is the temperature of the thermal class (for example 130 °C or 155 °C); θ_{Cref} is the reference cold coolant temperature (40 °C).
1c		40 °C < θ_c ≤ 60 °C	Reduced by the amount by which the coolant temperature exceeds 40 °C
1d		θ_c < 0 °C or θ_c > 60 °C	By agreement

Item	Operation conditions or rating	Adjustment to limit of temperature rise ($\Delta\theta$) in Table 8 and Table 9	Item
2	Maximum temperature of the water at the inlet to water-cooled heat exchangers or maximum temperature of the ambient water for submersible machines with surface cooling or machines with water jacket cooling (θ_w)	5 °C ≤ θ_w ≤ 25 °C	Increased by 15 K and by the difference between 25 °C and θ_w
		θ_w > 25 °C	Increased by 15 K and reduced by the difference between θ_w and 25 °C
3a	Altitude (H) – general rule	1 000 m < H ≤ 4 000 m and maximum ambient air temperature not specified	No adjustment. It shall be assumed that the reduced cooling resulting from altitude is compensated by a reduction of maximum ambient temperature below 40 °C and that the total temperature will therefore not exceed 40 °C plus the Table 8 and Table 9 temperature rises [a]
		H > 4 000 m	By agreement
3b	Altitude (H) – power plant generator specific	according specification of the purchaser	The capability of power plant generators should be adjusted and is a function of the altitude (air pressure). No adjustment of the capability is needed for power plant generators if the absolute coolant pressure is maintained constant regardless of the altitude.
4	Rated stator winding voltage (U_N)	12 kV < U_N ≤ 24 kV	$\Delta\theta$ for embedded temperature detectors (ETD) shall be reduced by 1 K for each 1 kV (or part thereof) from 12 kV up to and including 24 kV
		U_N > 24 kV	By agreement
5 [b]	Rating for short-time duty (S2), with rated output less than 5 000 kW (kVA)		Increased by 10 K
6 [b]	Rating for non-periodic duty (S9)		$\Delta\theta$ may be exceeded for short periods during the operation of the machine
7 [b]	Rating for duty with discrete loads (S10)		$\Delta\theta$ may be exceeded for discrete periods during the operation of the machine

[a] Assuming the decrease in ambient temperature is 1 % of the limiting rises for every 100 m of altitude above 1 000 m, the maximum ambient air temperature at the operating site can be as shown in Table 11.

[b] For air-cooled windings only.

Table 11 – Assumed maximum ambient temperature

Altitude m	Thermal class			
	130 (B)	155 (F)	180 (H)	200 (N)
	Temperature °C			
1 000	40	40	40	40
2 000	32	30	28	26
3 000	24	19	15	12
4 000	16	9	3	0

8.10.3 Direct cooled windings

Temperatures under reference conditions shall not exceed the limits given in Table 13.

For other operating site conditions the limits shall be adjusted according to Table 14.

If conditions at the test site differ from those at the operating site, the adjusted limits given in Table 15 shall apply at the test site.

If the adjusted limits given in Table 15 lead to temperatures at the test site which the manufacturer considers to be excessive, the testing procedure and the limits shall be agreed.

8.10.4 Adjustments to take account of hydrogen purity on test

For windings directly or indirectly cooled by hydrogen, no adjustment shall be made to limits of temperature rise or of total temperature if the proportion of hydrogen in the coolant is between 95 % and 100 %.

8.10.5 Permanently short-circuited windings, magnetic cores and all structural components (other than bearings) whether or not in contact with insulation

The temperature rise or the temperature shall not be detrimental to the insulation of that part or to any other part adjacent to it.

8.10.6 Commutators and sliprings, open or enclosed and their brushes and brushgear

The temperature rise or temperature of any commutator, slipring, brush or brushgear shall not be detrimental to the insulation of that part or any adjacent part.

The temperature rise or temperature of a commutator or slipring shall not exceed that at which the combination of brush grade and commutator or slipring material can handle the current over the full operating range.

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

Item	Test condition		Adjusted limit at test site $\Delta\theta_T$
1	Temperature difference of reference coolant at test site (θ_{cT}) and operating site (θ_c)	Absolute value of ($\theta_c - \theta_{cT}$) ≤ 30 K	$\Delta\theta_T = \Delta\theta$
		Absolute value of ($\theta_c - \theta_{cT}$) > 30 K	By agreement
2	Difference of altitudes of test site (H_T) and operating site (H)	1 000 m < H ≤ 4 000 m H_T ≤ 1 000 m	$\Delta\theta_T = \Delta\theta\left(1 - \frac{H - 1\,000\text{ m}}{10\,000\text{ m}}\right)$
		H ≤ 1 000 m 1 000 m < H_T ≤ 4 000 m	$\Delta\theta_T = \Delta\theta\left(1 + \frac{H_T - 1\,000\text{ m}}{10\,000\text{ m}}\right)$
		1 000 m < H ≤ 4 000 m 1 000 m < H_T ≤ 4 000 m	$\Delta\theta_T = \Delta\theta\left(1 + \frac{H_T - H}{10\,000\text{ m}}\right)$
		H > 4 000 m or H_T > 4 000 m	By agreement

NOTE ~~1~~ $\Delta\theta$ is given in Table 8 and adjusted if necessary in accordance with Table 10.

~~NOTE 2 If temperature rise is to be measured above the temperature of the water where it enters the cooler, the effect of altitude on the temperature difference between air and water should strictly be allowed for. However, for most cooler designs, the effect will be small, the difference increasing with increasing altitude at the rate of roughly 2 K per 1 000 m. If an adjustment is necessary, it should be by agreement.~~

Table 13 – Limits of temperature of directly cooled windings and their coolants

Thermal class		130 (B)			155 (F)		
Method of measurement		Thermo-meter °C	Resistance °C	ETD °C	Thermo-meter °C	Resistance °C	ETD °C
Item	**Part of the machine**						
1	Coolant at the outlet of direct-cooled AC windings. These temperatures are preferred to the values given in item 2 as the basis of rating.						
1a)	Gas (air, hydrogen, helium, etc.)	110	–	–	130	–	–
1b)	Liquid (water, oil, etc.)	90	–	–	90	–	–
2	AC windings						
2a)	Gas cooled	–	–	120 [a]	–	–	145 [a]
2b)	Liquid or evaporative cooled						
3	Field windings of turbine type machines						
3a)	Cooled by gas leaving the rotor through the following number of outlet regions [b]						
	1 and 2	–	100	–	–	115	–
	3 and 4	–	105	–	–	120	–
	5 and 6	–	110	–	–	125	–
	7 to 14	–	115	–	–	130	–
	above 14	–	120	–	–	135	–
3b)	Liquid or evaporative cooled	Observance of the maximum coolant temperature given in item 1b) will ensure that the hotspot temperature of the winding is not excessive					
4	Field windings of AC and DC machines having DC excitation other than in item 3.						
4a)	Gas cooled	–	130	–	–	150	–
4b)	Liquid or evaporative cooled	Observance of the maximum coolant temperature given in item 1b) will ensure that the hotspot temperature of the winding is not excessive					

[a] No adjustment in the case of high-voltage AC windings is applicable to these items, see Table 14, item 2.

[b] The rotor ventilation is classified by the number of radial outlet regions on the total length of the rotor. Special outlet regions for the coolant of the end windings are included as one outlet for each end. The common outlet region of two axially opposed flows is to be counted as two regions.

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

Item	Operating condition or rating		Adjustment to limit of temperature in Table 13
1	Temperature θ_c of reference coolant	0 °C ≤ θ_c ≤ 40 °C	Reduction by the amount of the difference between 40 °C and θ_c. However, by agreement, a smaller reduction may be applied, provided that for θ_c < 10 °C the reduction is made at least equal to the difference between 10 °C and θ_c.
		40 °C < θ_c ≤ 60 °C	No adjustment
		θ_c < 0 °C or θ_c > 60 °C	By agreement
2	Rated stator winding voltage (U_N)	U_N > 11 kV	No adjustment The heat flow is mainly towards the coolant inside the conductors and not through the main insulation of the winding.

Table 15 – Adjusted limits of temperature at the test site θ_T for windings directly cooled by air to take account of test site operating conditions

Item	Test condition		Adjusted limit of temperature at test site θ_T
1	Difference of reference coolant temperatures of test site (θ_{cT}) and operating site (θ_c)	Absolute value of $(\theta_c - \theta_{cT}) \le 30$ K	$\theta_T = \theta$
		Absolute value of $(\theta_c - \theta_{cT}) > 30$ K	By agreement
2	Difference of altitudes of test site (H_T) and operating site (H)	1 000 m < $H \le$ 4 000 m $H_T \le$ 1 000 m	$\theta_T = (\theta - \theta_c)\left(1 - \frac{H - 1000\ \text{m}}{10\,000\ \text{m}}\right) + \theta_{cT}$
		$H \le$ 1 000 m 1 000 m < $H_T \le$ 4 000 m	$\theta_T = (\theta - \theta_c)\left(1 + \frac{H_T - 1000\ \text{m}}{10\,000\ \text{m}}\right) + \theta_{cT}$
		1 000 m < $H \le$ 4 000 m 1 000 m < $H_T \le$ 4 000 m	$\theta_T = (\theta - \theta_c)\left(1 + \frac{H_T - H}{10\,000\ \text{m}}\right) + \theta_{cT}$
		$H >$ 4 000 m or $H_T >$ 4 000 m	By agreement
NOTE θ is given in Table 13 and adjusted if necessary in accordance with Table 14.			

9 Other performance and tests

9.1 Routine tests

Routine tests are always factory tests. They shall be performed on all machines which are assembled at the factory of the manufacturer. The machines need not be completely assembled. They can lack components which are not significant for the testing. Routine tests do not need the machines to be coupled except for the open-circuit test on synchronous machines.

The minimum test schedule is listed in Table 16 and is applicable for machines with rated output ≤ 20 MW (MVA) that are assembled and tested in the factory. Additional routine tests may be performed especially on machines with ratings above 200 kW (kVA). The term synchronous machines includes brushless permanent magnet machines.

For DC machines, depending on size and design, a commutation test under load may be performed as a routine test.

Table 16 – Minimum routine tests for machines assembled and tested in the factory of the manufacturer

Number	Test	Induction machines (including synchronous induction motors) [a]	Synchronous machines		DC machines with separate or shunt excitation
			Motors	Generators	
1	Resistance of windings (cold)	Yes	Yes		Yes
2	No-load losses and current [e]	Yes	–		–
3a	No-load losses at unity power factor [b]	–	Yes [d]		–
3b	No-load excitation current at rated voltage by open-circuit test [b]	–	Yes [d]		–
4	Excitation current at rated speed and rated armature voltage	–	–		Yes
5	Open circuit secondary induced voltage at standstill (wound rotor) [c]	Yes	–		–
6a	Direction of rotation	Yes	Yes	–	Yes
6b	Phase sequence	–	–	Yes	–
7	Withstand voltage test according to 9.2	Yes	Yes		Yes

[a] IEC 60050-411:1996, 411-33-04.

[b] Permanent magnet machines excluded.

[c] For safety considerations this test may be performed at reduced voltage.

[d] Only one of the tests 3a or 3b is required.

[e] No stabilization of temperature required for measurement of no-load losses.

Item	Test	Induction machines (including synchronous induction machines) [a]	Electrically excited synchronous machines	Synchronous reluctance machines and PM excited synchronous machines	DC machines with separate or shunt excitation
1	Resistance of windings (cold)	Yes	Yes	Yes	Yes
2	No-load losses and current [d]	Yes	–	Yes	–
3a	No-load losses at unity power factor [c]	–	Yes [c]	–	–
3b	No-load excitation current at rated voltage by open-circuit test [c]	–	Yes [c]	–	–
4	Excitation current at rated speed and rated armature voltage	–	–	–	Yes
5	Open circuit secondary induced voltage at standstill (wound rotor)[b]	Yes	–	–	–
6	Direction of rotation (motors) or phase sequence (generators)	Yes	Yes	Yes	Yes
7	Withstand voltage test according to 9.2	Yes	Yes	Yes	Yes

[a] IEC 60050-411:1996, 411-33-04.

[b] For safety considerations this test may be performed at reduced voltage.

[c] Only one of the tests 3a or 3b is required.

[d] No stabilization of temperature required for measurement of no-load losses.

9.2 Withstand voltage test

A test voltage, as specified below, shall be applied between the windings under test and the frame of the machine, with the core and the windings not under test connected to the frame. It shall be applied only to a new and completed machine with all its parts in place under conditions equivalent to normal working conditions and shall be carried out at the manufacturer's factory or after erection on site. A withstand voltage test shall be carried out after the completion of the full test sequence.

For equipment manufactured for stock holding, the withstand voltage test carried out for acceptance on completion of manufacture remains valid and shall not be repeated provided the test voltage is equal to, or greater than, the test voltage given in Table 17 based on the rated voltage noted on the rating plate.

NOTE 1 For high voltage machines, additional methods as described in the parts of IEC 60034-27 can be used to prove the suitability of the machine winding insulation system.

Except as stated below, the frequency of the test voltage shall be the power frequency at the factory of the manufacturer, and the voltage waveform shall be as near as possible to a sine wave form. The final value of the voltage shall be in accordance with Table 17. However, for machines with a rated voltage 6 kV or greater, when power frequency equipment is not available, then by agreement a DC test may be carried out at a voltage 1,7 times the r.m.s. value given in Table 17.

NOTE 2 It is recognized that, during a DC test, the surface potential distribution along the end winding insulation and the ageing mechanisms are different from those occurring during an AC test.

In the case of polyphase machines with rated voltage above 1 kV having both ends of each phase individually accessible, the test voltage shall be applied between each phase and the frame, with the core and the other phases and windings not under test connected to the frame. The test shall be commenced at a voltage not exceeding half of the full test voltage. The voltage shall then be increased to the full value, steadily or in steps of not more than 5 % of the full value, the time allowed for the voltage increase from half to full value being not less than 10 s. The full test voltage shall then be maintained for 1 min in accordance with the value as specified in Table 17. The voltage test equipment shall be capable of maintaining the test voltage throughout the test within ±5 % of the specified value. There shall be no failure (see IEC 60060-1) during this period.

During the routine testing of quantity produced machines up to 200 kW (or kVA) and rated for $U_N \leq 1$ kV, the 1 min test may be replaced by a test of 1 s at 120 % of the test voltage specified in Table 17. In the case applying this for very small sized machines rated up to 1 kW (or kVA) with IVIC C or D assigned (item 2b in Table 17), 120 % of the test voltage according to item 2b in Table 17 (i. e. including the test voltage factor according to Table 18) for 1s may be too excessive. In this case, 100 % of the test voltage specified in Table 17 can be used for 1 s test.

The withstand voltage test at full voltage made on the windings on acceptance shall not be repeated. If, however, a second test is made at the request of the purchaser, after further drying if considered necessary, the test voltage shall be 80 % of the voltage specified in Table 17.

To determine the test voltage from Table 17 for DC motors supplied by static power converters, the direct voltage of the motor or the r.m.s. phase-to-phase value of the rated alternating voltage at the input terminals of the static power converter shall be used, whichever is the greater.

Voltage variation according to 7.3 should not be considered when determining the test voltage.

For variable speed AC machines that are subjected to impulse voltages during operation having assigned an Impulse Voltage Insulation Class (IVIC) according to IEC 60034-18-41 or IEC60034-18-42, the test voltage shall be chosen according to the IVIC of its insulation system as defined in IEC 60034-18-41 or IEC 60034-18-42, respectively (see item 2b in Table 17).

Completely rewound windings shall be tested at the full test voltage for new machines.

When a user and a repair contractor have agreed to carry out withstand voltage tests in cases where windings have been partially rewound or in the case of an overhauled machine, the following procedure is recommended:

a) Partially rewound windings are tested at 75 % of the test voltage for a new machine. Before the test, the old part of the winding shall be carefully cleaned and dried.
b) Overhauled machines, after cleaning and drying, are subjected to a test at a voltage equal to 1,5 times the rated voltage, with a minimum of 1 000 V if the rated voltage is equal to or greater than 100 V and a minimum of 500 V if the rated voltage is less than 100 V.

Table 17 – Withstand voltage tests

Item	Machine or part	Test voltage [e] (r.m.s.)
1	Insulated windings of rotating machines of rated output less than 1 kW (or kVA) and of rated voltage less than 100 V with the exception of those in items 4 to 8	500 V + twice the rated voltage
2	Insulated windings of rotating machines of rated output less than 10 000 kW (or kVA) with the exception of those in item 1 and items 4 to 8 [b]	
2a)	for sinusoidal supply or for frequency converter supply with the exception of those in item 2b	1 000 V + twice the rated voltage with a minimum of 1 500 V [a]
2b)	with an IVIC assigned according to IEC 60034-18-41 or IEC 60034-18-42, i.e. subjected to repetitive impulse voltages, such as those generated by pulse width modulation (PWM) voltage-source converters [f]	1 000 V + twice the rated voltage multiplied with the test voltage factor (TVF) according to Table 18, i.e. 1 000 V + (2 × U_N × *TVF*)
3	Insulated windings of rotating machines of rated output 10 000 kW (or kVA) or more with the exception of those in items 4 to 8 [b] Rated voltage [a]: - up to and including 24 000 V - above 24 000 V	 1 000 V + twice the rated voltage Subject to agreement
4	Separately excited field windings of DC machines	1 000 V + twice the maximum rated circuit voltage with a minimum of 1 500 V
5	Field windings of synchronous generators, synchronous motors and synchronous ~~condensers~~ compensators.	
5a)	Rated field voltage: - up to, and including 500 V, - above 500 V.	 Ten times the rated field voltage with a minimum of 1 500 V 4 000 V + twice the rated field voltage
5b)	When a machine is intended to be started with the field winding short-circuited or connected across a resistance of value less than ten times the resistance of the winding	Ten times the rated field voltage with a minimum of 1 500 V and a maximum of 3 500 V.
5c)	When the machine is intended to be started either with the field winding connected across a resistance of value equal to, or more than, ten times the resistance of the winding, or with the field windings on open circuit with or without a field-dividing switch	1 000 V + twice the maximum value of the r.m.s. voltage, which can occur under the specified starting conditions, between the terminals of the field winding, or in the case of a sectionalized field winding between the terminals of any section, with a minimum of 1 500 V [c]
6	Secondary (usually rotor) windings of induction machines or synchronous induction motors if not permanently short-circuited (e.g. if intended for rheostatic starting)	
6a)	For non-reversing motors or motors reversible from standstill only	1 000 V + twice the open-circuit standstill voltage as measured between slip-rings or secondary terminals with rated voltage applied to the primary windings
6b)	For motors to be reversed or braked by reversing the primary supply while the motor is running	1 000 V + four times the open-circuit standstill secondary voltage as defined in item 6a)
7	Exciters (except as below) Exception 1: exciters of synchronous motors (including synchronous induction motors) if connected to earth or disconnected from the field windings during starting Exception 2: separately excited field windings of exciters (see item 4)	As for the windings to which they are connected 1 000 V + twice the rated exciter voltage, with a minimum of 1 500 V

Item	Machine or part	Test voltage [e] (r.m.s.)
8	Electrically interconnected machines and apparatus	A repetition of the tests in items 1 to 7 above should be avoided if possible, but if a test is performed on a group of machines and apparatus, each having previously passed its withstand voltage test, the test voltage to be applied to such an electrically connected arrangement shall be 80 % of the lowest test voltage appropriate for any individual piece of the arrangement [d]
9	Devices that are in physical contact with windings, for example, temperature detectors, shall be tested to the machine frame. During the withstand voltage test on the machine winding, all devices in physical contact with the winding shall be connected to the machine frame.	1 500 V
10	For devices used on extra-low voltage circuits with protective-separation, which are not used in explosive atmospheres, it is sufficient to connect them to the frame when performing the tests according to the previous items.	no test required

[a] For two-phase windings having one terminal in common, the voltage in the formula shall be the highest r.m.s. voltage arising between any two terminals during operation.

[b] Withstand tests on machines having graded insulation should be the subject of agreement.

[c] The voltage occurring between the terminals of the field windings, or sections thereof, under the specified starting conditions, may be measured at any convenient reduced supply voltage, and the voltage so measured shall be increased in the ratio of the specified starting supply voltage to the test supply voltage.

[d] For windings of one or more machines connected together electrically, the voltage to be considered is the maximum voltage that occurs in relation to earth.

[e] The leakage current drawn by the machine during withstand voltage test will vary according to the size of the machine.

[f] In case of an IVIC assigned, it is sufficient to test the phase-to-ground insulation only.

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

Windings within the scope of IEC 60034-18-41		Windings within the scope of IEC 60034-18-42	
IVIC phase-to-ground	**Test voltage factor**	**IVIC phase-to-ground**	**Test voltage factor**
A	1,0	1 to 4	1,0
B	1,0	5	1,2
C	1,3	6	1,3
D	1,7	7	1,5
S [a]	$\frac{Y}{2\sqrt{2}}$	S [a]	$\frac{Y}{2\sqrt{2}}$

[a] In case of the manufacturer specified Impulse Voltage Insulation Class (IVIC) S, Y is the maximum allowable peak to peak operating value of the phase-to-ground voltage in units of the rated voltage U_N.

9.3 Occasional excess current

9.3.1 General

The excess current capability of rotating machines is given for the purpose of co-ordinating these machines with control and protective devices. Tests to demonstrate these capabilities are not a requirement of this document. The heating effect in the machine windings varies approximately as the product of the time and the square of the current. A current in excess of the rated current will result in increased temperature. Unless otherwise agreed, it can be assumed that the machine will not be operated at the excess currents specified for more than a few short periods during the lifetime of the machine. When an AC machine is to be used as both a generator and a motor, the excess current capability should be the subject of agreement.

NOTE For the capability of synchronous machines concerning the occasional negative-sequence component of current under fault conditions, see 7.2.3.

9.3.2 Generators

AC generators having rated outputs not exceeding 1 200 MVA shall be capable of withstanding a current equal to 1,5 times the rated current for not less than 30 s.

AC generators having rated outputs above 1 200 MVA shall be capable of withstanding a current equal to 1,5 times the rated current for a period which shall be agreed, but this period shall be not less than 15 s.

9.3.3 Motors (except commutator motors and permanent magnet motors)

Polyphase motors having rated outputs not exceeding 315 kW and rated voltages not exceeding 1 kV shall be capable of withstanding:

– a current equal to 1,5 times the rated current for not less than 2 min.

NOTE For polyphase motors having rated outputs above 315 kW and all single-phase motors, no occasional excess current is specified.

9.3.4 Commutator machines

A commutator machine shall be capable of withstanding, for 60 s, 1,5 times rated current under the appropriate combination of conditions as follows:

a) speed:
   1) DC motor: highest full-field speed;
   2) DC generator: rated speed;
   3) AC commutator motor: highest full-field speed;

b) armature voltage: that corresponding to the specified speed.

~~NOTE~~ Attention should be given to the limits of commutation capability. The limits of commutation of a given DC machine are defined in IEC 60034-19.

9.4 Momentary excess torque for motors

9.4.1 Polyphase induction motors and DC motors

Motors, whatever their duty and construction, shall be capable of withstanding an excess torque of at least 60 % of their rated torque for 15 s without either stalling or exhibiting an abrupt change of speed (under gradual increase of torque). The voltage and frequency (for induction motors) shall be maintained at their rated values.

Higher torques are required for some motors manufactured according to IEC 60034-12.

For DC motors, the excess torque shall be expressed in terms of overload current.

Motors for duty type S9 shall be capable of withstanding momentarily an excess torque determined according to the duty specified.

For an approximate determination of the change in temperature due to the current-related losses, the thermal equivalent time constant determined according to 8.8 may be used.

Motors intended for specific applications that require a high torque (for example for hoisting) shall be the subject of agreement.

For cage-type induction motors specially designed to ensure a starting current of less than 4,5 times the rated current, the excess torque can be below the value of 60 % given in paragraph 1, but not less than 50 %, or the value of the excess torque shall be the subject of agreement.

In the case of special types of induction motors with special inherent starting properties, for example motors intended for use at variable frequency or induction motors supplied from static converters, the value of the excess torque shall be the subject of agreement.

9.4.2 Polyphase synchronous motors

Unless otherwise agreed, a polyphase synchronous motor, irrespective of the duty, shall be capable of withstanding an excess torque as specified below for 15 s without falling out of synchronism, the excitation being maintained at the value corresponding to rated load. When automatic excitation is used, the limits of torque shall be the same values with the excitation equipment operating under normal conditions:

– synchronous (wound rotor) induction motors: 35 % excess torque;
– synchronous (cylindrical rotor) motors: 35 % excess torque;
– synchronous (salient pole) motors: 50 % excess torque.

9.4.3 Other motors

The momentary excess torque and time for single-phase, commutator and other motors shall be the subject of agreement.

9.5 Pull-up torque and locked-rotor torque for cage induction motors with direct online starting

Unless otherwise specified (for example machines according to IEC 60034-12), the pull-up torque of cage induction motors under full voltage shall be not less than 0,3 times the rated torque. The locked rotor torque shall also not be less than 0,3 times the rated torque.

9.6 Safe operating speed of cage induction motors

All three-phase single-speed cage induction motors of frame number up to and including 315 and for voltages up to and including 1 000 V shall be capable of safe continuous operation at speeds up to the appropriate speed given in Table 19 unless otherwise stated on the rating plate.

Table 19 – Maximum safe operating speed (min^{-1}) of three-phase single-speed cage induction motors for voltages up to and including 1 000 V

Frame number	2 pole	4 pole	6 pole
≤ 100	5 200	3 600	2 400
112	5 200	3 600	2 400
132	4 500	2 700	2 400
160	4 500	2 700	2 400
180	4 500	2 700	2 400
200	4 500	2 300	1 800
225	3 600	2 300	1 800
250	3 600	2 300	1 800
280	3 600	2 300	1 800
315	3 600	2 300	1 800
NOTE The above values may have to be reduced to meet the requirements of IEC 60079.			

When operating at speeds above rated speed, for example, when used with adjustable speed controls, noise and vibration levels will increase. The user may require the manufacturer to fine balance the motor rotor for acceptable operation above rated speed. Bearing life may be reduced. Attention should be paid to the re-greasing intervals and the grease service life.

9.7 Overspeed

Machines shall be designed to withstand the speeds specified in Table 20.

An overspeed test is not normally considered necessary, but can be performed when this is specified and has been agreed. (For turbine-type AC generators, see also IEC 60034-3.) An overspeed test shall be considered as satisfactory if no permanent abnormal deformation is apparent subsequently, and no other weakness is detected which would prevent the machine from operating normally, and provided the rotor windings after the test comply with the required dielectric tests. The duration of any overspeed test shall be 2 min.

Due to settling of laminated rotor rims, laminated poles held by wedges or by bolts, etc., a minute permanent increase in the diameter is natural, and not to be considered as an abnormal deformation indicating that the machine is not suitable for normal operation.

During commissioning of a hydraulic-turbine driven synchronous generator, the machine shall be driven at the speed it can reach with the overspeed protection operating, so as to ascertain that the balance is satisfactory up to that speed.

Table 20 – Overspeeds

Item	Machine type	Overspeed
1	AC machines All machines other than those specified below:	 1,2 times the maximum rated speed
1a)	Water-turbine driven generators, and any auxiliary machines connected directly (electrically or mechanically) to the main machine	Unless otherwise specified, the runaway speed of the set but not less than 1,2 times the maximum rated speed
1b)	Machines which may under certain circumstances be driven by the load	The specified runaway speed of the set but not less than 1,2 times the maximum rated speed.
1c)	Series and universal motors	1,1 times the no-load speed at rated voltage. For motors integrally attached to loads that cannot become accidentally disconnected, the words 'no-load speed' shall be interpreted to mean the lightest load condition possible with the load
1d)	Three-phase single-speed cage induction motors according to 9.6	1,2 times the maximum safe operating speed
2	DC machines	
2a)	Shunt and separately excited motor	1,2 times the highest rated speed or 1,15 times the corresponding no-load speed, whichever is greater
2b)	Compound excited motors having speed regulation of 35 % or less	1,2 times the higher rated speed or 1,15 times the corresponding no-load speed, whichever is greater but not exceeding 1,5 times the highest rated speed
2c)	Compound excited motors having speed regulation greater than 35 % and series motors	The manufacturer shall assign a maximum safe operating speed which shall be marked on the rating plate. The overspeed for these motors shall be 1,1 times the maximum safe operating speed. The safe operating speed marking is not required on motors that are capable of an overspeed of 1,1 times the no-load speed at rated voltage
2d)	Permanent-magnet excited motors	Overspeed as specified in item 2a) unless the motor has a series winding and, in such a case, they shall withstand the overspeeds specified in items 2b) or 2c) as appropriate
2e)	Generators	1,2 times the rated speed

9.8 Short-circuit current for synchronous machines

Unless otherwise specified, the peak value of the short-circuit current for synchronous machines, including turbine-type machines not covered by IEC 60034-3, in the case of short circuit on all phases during operation at rated voltage, shall not exceed 15 times the peak value or 21 times the r.m.s. value of the rated current.

Verification may be carried out by calculation or by means of a test at a voltage of 0,5 times the rated voltage or above.

9.9 Short-circuit withstand test for synchronous machines

The three-phase short-circuit test for synchronous machines shall be carried out only at the request of the purchaser. In this case, the test shall be carried out on the machine running on no-load with an excitation corresponding to the rated voltage unless otherwise agreed. The test shall not be carried out with an excitation greater than that corresponding to 1,05 times the rated voltage at no load.

The excitation for the test, as determined, may be reduced by agreement, in order to take into account the impedance of the transformer which may be placed between the machines and the system. In this latter case, it may also be agreed that the test be made at the operating site with the over-excitation device in operation. The short circuit shall be maintained for 3 s.

The test is considered satisfactory if no harmful deformation occurs and if the requirements of the applied voltage dielectric test (see Table 17) are met after the short-circuit test. For three-phase turbine-type machines, see IEC 60034-3.

9.10 Commutation test for commutator machines

A DC or AC commutator machine shall be capable of operating from no-load to operation with the excess current or excess torque, specified in 9.3 and 9.4 respectively, without permanent damage to the surface of the commutator or brushes and without injurious sparking, the brushes remaining in the same set position. If possible, the commutation test shall be performed in warm conditions.

NOTE Annex A of IEC 60276:2018 gives clarification on how to assess these criteria. In 8.3.2 of IEC 60034-19:2014, it is further specified that "Commutation is assessed by any means that the manufacturer considers reliable".

9.11 Total harmonic distortion (*THD*) for synchronous machines

9.11.1 General

The requirements of this subclause apply only to synchronous machines having rated outputs of 300 kW (or kVA) or more, intended for connection to power networks operating at nominal frequencies of 16 $^{2/3}$ Hz to 100 Hz inclusive, with a view to minimizing interference caused by the machines.

9.11.2 Limits

When tested on open-circuit and at rated speed and voltage, the total harmonic distortion (*THD*) of the line-to-line terminal voltage, as measured according to the methods laid down in 9.11.3, shall not exceed 5 %.

NOTE Limiting values of individual harmonics are not specified as it is considered that machines which meet the above requirements will operate satisfactory.

9.11.3 Tests

Type tests shall be carried out on AC machines to verify compliance with 9.11.2. The range of frequencies measured shall cover all harmonics from rated frequency up to the 100th harmonic. Synchronous motors do not need to be measured.

Either the *THD* may be measured directly by means of a meter and associated network specially designed for the purpose, or each individual harmonic shall be measured and from the measured values the *THD* shall be computed using the following formula:

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

where

u_n is the ratio of the line-to-line terminal voltage U_n of the harmonic n of the machine to the line-to-line terminal fundamental voltage U_1 of the machine;

n is the order of harmonic;

k = 100.

9.12 Protective earth test

In a type test of a machine with rated voltage not exceeding AC 1 000 V or DC 1 500 V, respectively, a protective earth test shall be performed in addition.

Machines with rated voltage not exceeding AC 1 000 V or DC 1 500 V, respectively, and with an earthing terminal require a protective earth type test to ensure sufficiently small internal resistances. If not defined by a different product standard, the type test can be done by determining the possible voltage drop between any point of the machine, which has the risk of coming into contact with live parts, and the earthing terminal. The test is considered successful, when the measured value of the resistance $R_{PE,M}$ between these two points does not exceed:

$$R_{PE,M} \leq 0{,}8 \cdot 30\ \text{V} / (K \cdot I_N) \text{ for AC circuits,}$$

$$R_{PE,M} \leq 0{,}8 \cdot 60\ \text{V} / (K \cdot I_N) \text{ for DC circuits,}$$

where

I_N is the rated current of the machine,

0,8 is a safety factor, and

K is a factor as shown in Figure 13.

The factor K is derived from the typical fuse size assigned to motors for direct online starting with a ratio of starting current to rated current of 10, multiplied by 2. This approach is valid for generators as well. For power ratings above 1 000 kW, K = 3,4 applies.

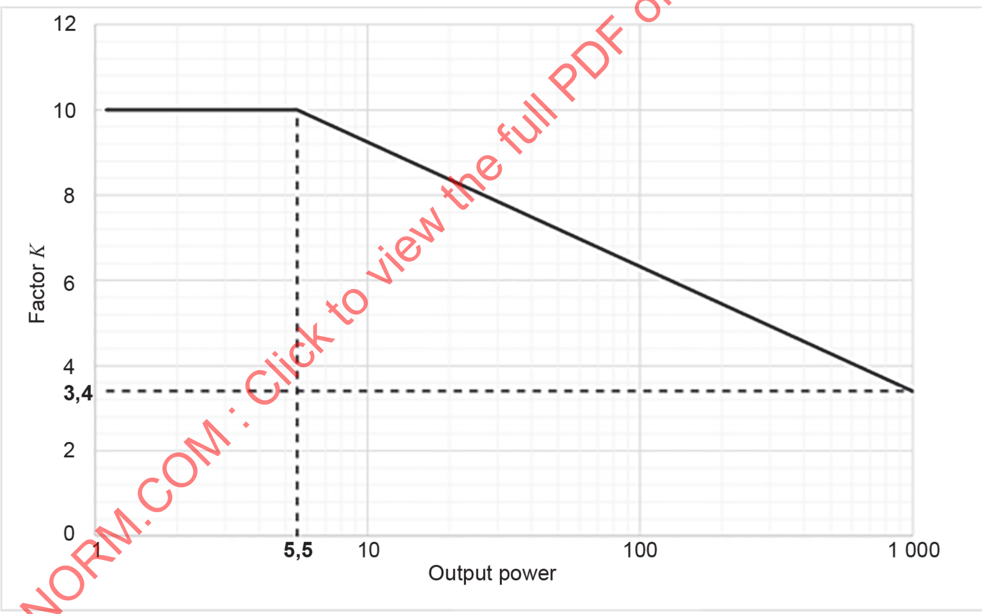


Figure 13 – Factor K for determining $R_{PE,M}$

The current used to determine the resistance $R_{PE,M}$ shall be at least 3 A.

NOTE The method is based on the protective equipotential bonding impedance type test described in IEC 62477-1.

9.13 Measurement of insulation resistance and polarization index of winding insulation

For measurement of insulation resistance and polarization index of a winding insulation, see IEC 60034-27-4.

9.14 Shaft-voltage test

A shaft-voltage test shall not be made in case of insulated bearings (1 MΩ or higher for sinusoidal or DC power supply) or in case safety aspects are concerned. The shaft voltage of (mainly) supply frequency (not to be mixed-up with a HF shaft voltage, see 3.37) shall be measured directly between the two shaft ends of an electrical machine being operated at rated voltage and rated frequency at no load and preferably uncoupled. It is not permitted to determine the shaft voltage by measuring the shaft-to-ground voltages across the two bearings and subtracting the values, as this may lead to false results. The shaft voltage has to be evaluated as RMS value. As long as no other limitation is agreed on between manufacturer and customer, the RMS value of the shaft voltage in case of non-insulated ball or roller bearings (or similar) should not exceed 350 mV.

10 Information requirements

10.1 General

Each electrical machine shall be delivered with appropriate documentation comprising the minimally required information (see 10.4) and a rating plate or rating plates (see 10.3).

10.2 Product documentation

The product documentation shall be delivered by the manufacturer including the data sheets and/or operating manual. This documentation can be supplied with the motor physically or in a digital form. For series production of standardized machines, this information can also be directly accessible in the manufacturer's website, which should be easily available. The minimum content of the product document is given in 10.4.

10.3 Rating plate

~~Every electrical machine shall be provided with a rating plate(s).~~ The plates shall be made of durable material and be securely mounted. The writing has to be made with durable marking (e.g. print, engraving).

The rating plate(s) shall preferably be mounted on the frame of the machine and be located so as to be easily legible in the position of use determined by the type of construction and mounting arrangement of the machine. If the electrical machine is so enclosed or incorporated in the equipment that its rating plate is not easily legible, the manufacturer shall, on request, supply a second plate to be mounted on the equipment.

Rating plate(s) shall be durably marked with the items in 10.4, as far as they apply. The items need not all be on the same plate. Letter symbols for units and quantities shall be in accordance with IEC 60027-1 and IEC 60027-4.

As an option, the rating plate or another part of the machine (e.g. inside the machine's terminal box) may carry an electronic identification symbol, e.g. a QR code, including a direct link to the product documentation at the manufacturer's website.

NOTE QR code according to ISO/IEC 18004:2015.

Except for normal maintenance (lubrification, cleaning, bearing replacement), when a machine is repaired or refurbished, an additional plate shall be provided to indicate the name of the company undertaking the work, the year of repair. In case of modification, the changes affecting the original rating plate data shall be displayed on this additional plate, as well. Additional information on the modifications and its influence to technical data not being displayed on the rating plate can be received from the company undertaking the work.

10.4 Marking Information content

Machines with rated outputs up to and including 750 W (or VA) and dimensions not covered by IEC 60072 shall be marked with the information given in items a), b), l), m), aa) and cc) below as a minimum. For special-purpose and built-in machines with rated outputs up to and including 3 kW (or kVA) items a), b), l) and m) shall be marked as a minimum and item bb) may be provided in another form.

In all other cases, rating plate(s) shall be durably marked with the items in the following list, as far as they apply. The items need not all be on the same plate. Letter symbols for units and quantities shall be in accordance with IEC 60027-1 and IEC 60027-4.

If the manufacturer gives more information, this needs not necessarily be marked on the rating plate(s).

The items are numbered for convenient reference, but the order in which they appear on the rating plate(s) is not standardized. Items may be suitably combined.

a) The manufacturer's name or mark.

b) The manufacturer's serial number, or identification mark.

NOTE 1 A single identification mark may be used to identify each member of a group of machines which are made to the same electrical and mechanical design and are produced in one batch using the same technology.

c) Information to identify the year of manufacture. This shall be marked on the rating plate or be given on a separate data sheet to be provided with the machine.

NOTE 2 If this information can be obtained from the manufacturer by quoting the data specified in item b), it may be omitted from both the rating plate and the separate data sheet.

d) The manufacturer's machine code.

e) For a.c. machines, the number of phases.

f) The number(s) of the rating and performance standard(s) which are applicable (IEC 60034-x and/or equivalent national standard(s)). If IEC 60034 is marked, this implies compliance with all the other relevant standards of the IEC 60034 series. If IEC 60034-1 is marked, this implies compliance with the standard itself, not with the references.

g) The degree of protection provided by the integral design of the rotating electrical machine (IP code) in accordance with IEC 60034-5.

h) The method of cooling (IC code) in accordance with IEC 60034-6 in case it is not IC411.

i) For motors within the scope of IEC 60034-30, the efficiency class (IE code) and the rated efficiency as specified in IEC 60034-30.

j) The thermal class and the limit of temperature or of temperature rise (when lower than that of the thermal class) and, if necessary, the method of measurement, followed in the case of a machine with a water-cooled heat exchanger by 'P' or 'S', depending on whether the temperature rise is measured above the primary or secondary coolant respectively (see 8.2). This information shall be given for both stator and rotor (separated by a slash) when their thermal class differ.

k) The class(es) of rating of the machine if designed for other than rating for continuous running duty S1, see 5.2.

l) The rated output(s) or range of rated output.

m) The rated voltage(s) or range of rated voltage.

n) For a.c. machines the rated frequency or range of rated frequency.

For universal motors, the rated frequency shall be followed by the appropriate symbol: for example, ~ 50 Hz/ ⎓ (IEC 60417-5031) or a.c. 50 Hz/DC.

o) For synchronous machines excited by permanent magnets the open circuit voltage at rated speed.

p) The rated current(s) or range of rated current.

q) The rated speed(s) or range of rated speed.

r) The permissible overspeed if other than specified in 9.7.

or

the maximum safe operating speed if less than in 9.6 or if the machine is designed especially for variable speed operation.

s) For d.c. machines with separate excitation or with shunt excitation and for synchronous machines, the rated field voltage and the rated field current.

t) For a.c. machines, the rated power factor(s).

u) For wound-rotor induction machines, the rated open-circuit voltage between slip-rings and the rated slip-ring current.

v) The rated form factor and the rated alternating voltage at the input terminals of the static power converter, when this exceeds the rated direct voltage of the motor armature circuit.

w) The maximum ambient air temperature, if other than 40 °C.

The maximum water coolant temperature, if other than 25 °C.

x) The minimum ambient air temperature if other than specified in 6.4.

y) The altitude for which the machine is designed (if exceeding 1 000 m above sea-level).

z) For hydrogen-cooled machines, the hydrogen pressure at rated output.

aa) When specified, the approximate total mass of the machine, if exceeding 30 kg.

bb) For machines suitable for operation in only one direction of rotation, the direction of rotation, indicated by an arrow. This arrow needs not be on the rating plate, but it shall be easily visible.

cc) The connecting instructions in accordance with IEC 60034-8 by means of a diagram or text located near the terminals.

dd) For motors within the scope of IEC 60034-12, the design letter(s) as specified in Clause 5 of IEC 60034-12:2016 indicating the starting requirements.

Two different rated values shall be indicated by X/Y and a range of rated values shall be indicated by X–Y (see IEC 61293).

For machines specified with an Impulse Voltage Insulation Class (IVIC), the IVIC according to IEC 60034-18-41 shall be listed in the documentation of the machine and should be marked on the rating plate.

Except for normal maintenance, when a machine is repaired or refurbished an additional plate shall be provided to indicate the name of the company undertaking the work, the year of repair and the changes made.

10.4.1 General

The items in 10.4.2 to 10.4.5 shall be given, when applicable, in the product documentation as well as on the rating plate(s). If the manufacturer gives more information in the product documentation, this need not necessarily be marked on the rating plate(s). The items in 10.4.6 are optional, but recommended at least for machines over 5 kW (or 5 kVA) rated output.

The items are numbered a) to jj) for convenient reference, but the order in which they appear in the product documentation and on the rating plate(s) is not standardized. Items may be suitably combined.

10.4.2 Minimum information requirements

The minimum information requirements for machines with all rated output sizes, including special-purpose and built-in machines, are:

a) The manufacturer's name or mark.

b) The manufacturer's serial number or identification mark.

NOTE 1 A single identification mark may be used to identify each member of a group of machines which are made to the same electrical and mechanical design and are produced in one batch using the same technology.

c) The manufacturer's machine code.

d) Information to identify the year of manufacture.

e) The rated voltage(s) or range of rated voltage;
two different rated values shall be indicated by “/” (e.g. 400V/230 V) while a range of rated values shall be indicated by “-“ (e.g. 380V-440 V).

NOTE 2 In all these cases, voltage (and frequency) variations according to 7.4 are valid and will not be indicated separately.

f) The rated current(s) or range of rated current.

g) The connecting instructions in accordance with IEC 60034-8 by means of a diagram (or text located near the terminals).

h) The rated output(s) or range of rated output power and the class(es) of rating of the machine if designed for other than rating for continuous running duty S1, see 5.2.

i) The rated speed(s) or range of rated speed and the permissible overspeed if other than specified in 9.7 or the maximum safe operating speed if less than in 9.6 or in case of a converter duty machine, given in the unit min^{-1} or 1/min. In case of a converter duty machine, the range of speed can also be given in per unit or percent of the rated speed.

j) For motors within the scope of IEC 60034-30-1 and IEC 60034-30-2, the efficiency class (IE code) and for motors within the scope of IEC 60034-30-1 also the rated efficiency.

k) When specified, the approximate total mass of the machine, if exceeding 30 kg.

l) The degree of protection provided by the integral design of the rotating electrical machine (IP code) in accordance with IEC 60034-5.

m) The thermal class and the limit of temperature or of temperature rise (when lower than that of the thermal class) in accordance with IEC 60085 and, if necessary, the method of measurement, followed in the case of a machine with a water-cooled heat exchanger by 'P' or 'S', depending on whether the temperature rise is measured above the primary or secondary coolant respectively (see 8.2). This information shall be given for both stator and rotor (separated by a slash) when their thermal class differ.

n) For motors within the scope of IEC 60034-12, the design letter(s) as specified in Clause 5 of IEC 60034-12: 2016 indicating the starting requirements in case it is not design N.

o) For machines suitable for operation in only one direction of rotation, the direction of rotation, indicated either by indicating cw (clockwise) or ccw (counter clockwise) on the rating plate or by an arrow. This arrow need not be on the rating plate, but it shall be easily visible.

p) The altitude for which the machine is designed if exceeding 1 000 m above sea level.

10.4.3 All AC machines

10.4.3.1

q) For AC machines, the number of phases.

r) For AC machines the rated frequency and in case of converter duty machines the term ‘converter duty’.
For universal motors, the rated frequency shall be followed by the appropriate symbol, for example, ~ 50 Hz / ⎓ (IEC 60417-5031) or AC 50 Hz / DC.

10.4.3.2 All synchronous machines

s) In case of machines excited by permanent magnets, the open circuit voltage at rated speed.

t) In case of electrical excitation, the rated field voltage and the rated field current.

u) In case of electrical excitation, the rated power factor.

10.4.3.3 All wound-rotor induction machines

v) The rated open-circuit voltage between slip-rings and the rated slip-ring current.

10.4.4 All DC machines

w) For machines with separate excitation or with shunt excitation, the rated field voltage and the rated field current.

x) The rated form factor and the rated alternating voltage at the input terminals of the static power converter, when this exceeds the rated direct voltage of the motor armature circuit.

10.4.5 Machines over 5 kW (or 5 kVA) rated output

y) The number(s) of the rating and performance standard(s) which are applicable (IEC 60034-x and/or equivalent national standard(s)). If IEC 60034 is marked, this implies compliance with all the other relevant standards of the IEC 60034 series. If IEC 60034-1 is marked, this implies compliance with the standard itself, not with the references.

z) The maximum ambient air temperature if other than 40 °C.

aa) The minimum ambient air temperature if other than specified in 6.4.

bb) The maximum water coolant temperature if other than 25 °C.

cc) For hydrogen-cooled machines, the hydrogen pressure at rated output.

10.4.6 Optional information

dd) The method of cooling (IC code) in accordance with IEC 60034-6 in case it is not IC411.

ee) For AC machines, the rated power factor(s).

ff) For induction machines, the locked rotor apparent power.

gg) The types of the bearings, the type of grease or oil and the lubrication interval in case of roller or ball bearings.

hh) For motors with duty type S9, the momentary excess torque capability at rated speed in percent of the rated torque, in case the value exceeds 160 %.

ii) For machines with an IVIC assigned, the IVIC level in accordance with IEC 60034-18-41 or IEC 60034-18-42, respectively.

jj) For converter capable machines (see 3.35), the term ‘converter capable’.

11 Miscellaneous requirements

11.1 Protective earthing of machines

Machines shall be provided with an earthing terminal or another device to permit the connection of a protective conductor or an earthing conductor.

The symbol  (IEC 60417-5019) or legend shall identify this device. However, machines shall neither be earthed nor be provided with an earthing terminal when:

a) they are fitted with supplementary insulation, or;

b) they are intended for assembly in apparatus having supplementary insulation, or;

c) they have rated voltages up to AC 50 V or DC 120 V and are intended for use on SELV circuits.

NOTE 1 The term SELV is defined in IEC 60884-2-4.

In the case of machines having rated voltages greater than AC 50 V or DC 120 V, but not exceeding AC 1 000 V or DC 1 500 V, the terminal for the earthing conductor shall be situated in the vicinity of the terminals for the line conductors, being placed in the terminal box, if one is provided. Machines having rated outputs in excess of 100 kW (or kVA) shall have in addition an earthing terminal fitted on the frame.

Machines for rated voltages greater than AC 1 000 V or DC 1 500 V shall have an earthing terminal on the frame, for example an iron strap, and in addition, a means inside the terminal box for connecting a conducting cable sheath, if any.

The earthing terminal shall be designed to ensure a good connection with the earthing conductor without any damage to the conductor or terminal. Accessible conducting parts which are not part of the operating circuit shall have good electrical contact with each other and with the earthing terminal if there is a risk that they will come into contact with live parts. When all bearings and the rotor winding of a machine are insulated, the shaft shall be electrically connected to the earthing terminal, unless the manufacturer and the purchaser agree to alternative means of protection.

When an earthing terminal is provided in the terminal box, it shall be assumed that the earthing conductor is made of the same metal as the lead conductors.

When an earthing terminal is provided on the frame, the earthing conductor may, by agreement, be made of another metal (for example, steel). In this case, in designing the terminal, proper consideration shall be given to the conductivity of the conductor.

The earthing terminal shall be designed to accommodate an earthing conductor of cross-sectional area in accordance with Table 21. If an earthing conductor larger than the size given in Table 21 is used, it is recommended that it should correspond as nearly as possible to one of the other sizes listed.

For other cross-sectional areas of phase conductors, the earthing or protective conductor shall have a cross-sectional area at least equivalent to:

– that of the phase conductor for cross-sectional areas less than 25 mm^2;
– 25 mm^2 for cross-sectional areas between 25 mm^2 and 50 mm^2;
– 50 % of that of the phase conductor for cross-sectional areas exceeding 50 mm^2.

For generators ≥ 20 MVA the earthing conductor cross-sectional area outside the machine should be calculated by the system integrator and the neutral point bus-bar cross-sectional area by the manufacturer to safely meet the short circuit current at double earth fault during the time needed until the machine has been disconnected by the protective system and is deexcited. The earthing terminal shall be identified in accordance with IEC 60445.

In the documentation of each machine with rated voltage not exceeding AC 1 000 V or DC 1 500 V, respectively, it shall be clearly stated that a protective earth test as required by IEC 60364, if applicable, or as stated by specific customer requirements shall be made after the installation of the machine. The responsibility for conducting this test is not with the machine manufacturer, but with the end-user or the system integrator.

NOTE 2 For small machines with frame sizes below 63 mm, proper earthing may be provided by the flange alone.

Table 21 – Cross-sectional areas of earthing conductors

Cross-sectional area of the phase conductor mm^2	Cross-sectional area of the earthing or protective conductor mm^2
4	4
6	6
10	10
16	16
25	25
35	25
50	25
70	35
95	50
120	70
150	70
185	95
240	120
300	150
400	185

11.2 Shaft-end key(s)

When a machine shaft end is provided with one or more keyways, each shall be provided with a full key of normal shape and length.

12 Tolerances

12.1 General

Tolerance is the maximum allowed deviation between the test result of a quantity from Table 22 and the declared value on the rating plate or in the catalogue. As long as test procedures and test equipment according to IEC standards are used, the test result shall not exceed the allowed deviation independent of test laboratory or equipment. Tolerance does not cover the uncertainty of a test procedure, i.e. the deviation between the test result and the true value. The tolerances of the test equipment itself are included in the tolerances specified in Table 22.

NOTE 1 In case of a series production the tolerance applies to any selected sample, i.e. tolerance covers variations in raw material properties and manufacturing procedures.

NOTE 2 Detailed information on the influence of measurement uncertainty can be found in IEC Guide 115:2021.

12.2 Tolerances on values of quantities

Unless stated otherwise, tolerances on declared values shall be as specified in Table 22.

Table 22 – Schedule of tolerances on values of quantities

Item	Quantity	Tolerance
1	Efficiency η [c]	–15 % of (1 – η)
	– machines up to and including 150 kW (or kVA)	–15 % of (1 – η)
	– machines above 150 kW (or kVA)	–10 % of (1 – η)
2	Rated field current of synchronous machines	+15 % of the value
3	Power-factor, cos ϕ, for induction machines and permanent magnet synchronous machines operating direct on-line	–1/6 (1 – cos ϕ) Minimum absolute value 0,02 Maximum absolute value 0,07
4	Speed of DC motors (at full load and at working temperature) [a]	
4a)	Shunt and separately excited motors	$1\,000\ P_N/n_N < 0{,}67$ ± 15 % $0{,}67 \le 1\,000\ P_N/n_N < 2{,}5$ ± 10 % $2{,}5 \le 1\,000\ P_N/n_N < 10$ ± 7,5 % $10 \le 1\,000\ P_N/n_N$ ± 5 %
4b)	Series motors	$1\,000\ P_N/n_N < 0{,}67$ ± 20 % $0{,}67 \le 1\,000\ P_N/n_N < 2{,}5$ ± 15 % $2{,}5 \le 1\,000\ P_N/n_N < 10$ ± 10 % $10 \le 1\,000\ P_N/n_N$ ± 7,5 %
4c)	Compound excited motors	Tolerances as for item 4b) unless otherwise agreed
5	Variation of speed of DC shunt and compound excited motors (from no-load to full load)	±20 % of the variation with a minimum of ±2 % of the rated speed
6	Inherent voltage regulation of DC generators, shunt or separately excited at any point on the characteristic	±20 % of the regulation at that point
7	Inherent voltage regulation of compound excited generators (at the rated power-factor in the case of alternating current)	±20 % of the regulation, with a minimum of ±3 % of the rated voltage. (This tolerance applies to the maximum deviation at any load between the observed voltage at that load and a straight line drawn between the points of no-load and full-load voltage.)
8 a)	Slip of induction machines (at full load and at working temperature) $P_N < 1$ kW $P_N \ge 1$ kW	 ±30 % of the slip ±20 % of the slip
8 b)	Speed of AC (commutator) motors with shunt characteristics (at full load and at working temperature)	– on the highest speed: –3 % of the synchronous speed – on the lowest speed: +3 % of the synchronous speed
9	Locked rotor current of cage induction motors with any specified starting apparatus	+20 % of the current; for motors within the scope of IEC 60034-12, the limit specified in IEC 60034-12 for the locked rotor apparent power shall not be exceeded.
10	Locked rotor torque of cage induction motors	$^{+25}_{-15}$ % of the torque. (+25 % may be exceeded by agreement)
11	Pull-up torque of cage induction motors	–15 % of the value

Item	Quantity	Tolerance
12	Breakdown torque of induction motors	−10 % of the torque except that after allowing for this tolerance the torque shall be not less than 1,6 or 1,5 times the rated torque, see 9.4.1
13	Locked rotor current of synchronous motors	+ 20 % of the value
14	Locked rotor torque of synchronous motors	$^{+25}_{-15}$ % of the value (+25 % may be exceeded by agreement)
15	Pull-out torque of synchronous motors	−10 % of the value except that after allowing for this tolerance, the torque shall be not less than 1,35 or 1,5 times the rated torque, see 9.4.2
16	Peak value of short-circuit current of an AC generator under specified conditions	±30 % of the value[b]
17	Steady short-circuit current of an AC generator at specified excitation	±15 % of the value
18	Moment of inertia	±10 % of the value
19	Average A-weighted sound pressure level or sound power level at no-load and sinusoidal supply	+ 3 dB(A)

NOTE When a tolerance is stated in only one direction, the value is not limited in the other direction.

[a] Tolerances in item 4 depend on the ratio of rated output P_N in kW, to rated speed in min^{-1}.

[b] For some simulations, tolerances in item 16 are too wide. Manufacturer and customer may agree on higher accuracy.

[c] The tolerance on efficiency implies a tolerance on the total losses of +15 % of the total losses.

13 Electromagnetic compatibility (EMC)

13.1 General

The EMC requirements specified in this clause apply to rotating electrical machines with rated voltages not exceeding AC 1 000 V or DC 1 500 V intended for operation and use in residential, commercial or industrial environments.

Electronic components mounted inside a rotating electrical machine and which are essential for its operation (for example rotating excitation devices) are part of the machine.

Requirements which apply to the final drive system and its components, for example power and control electronic equipment, coupled machines, monitoring devices, etc., whether mounted inside or outside the machine, are outside the scope of this document.

The requirements of this clause apply to machines that are supplied directly to the end-user.

NOTE 1 The purpose of this clause is to give advice for contractual agreements between supplier and end-user.

NOTE 2 Machines that are intended for incorporation as components in an apparatus, where the enclosure and assembly will affect the EMC emissions, are covered by the EMC standard that relates to the final product.

In synchronous machines, electronic power supplies of the exciter machine's stator being part of the synchronous machine shall comply with the EMC requirements of this document.

NOTE 3 As the generator in a power plant is often a very large machine having some higher magnetic fields outside the housing, it is possible to define boundaries around the generator in the machine hall, inside of which fields may be higher than according to CISPR requirements and access is forbidden for electronic devices and restricted to allowed staff only.

Transients (such as starting) are not covered by this clause.

13.2 Immunity

13.2.1 Machines not incorporating electronic circuits

Machines without electronic circuits are not sensitive to electromagnetic emissions under normal service conditions and, therefore, no immunity tests are required.

13.2.2 Machines incorporating electronic circuits

As electronic circuits which are incorporated in machines generally utilize components that are passive (for example diodes, resistors, varistors, capacitors, surge suppressors, inductors), immunity tests are not required.

13.3 Emission

For machines intended for use in residential environments, radiated and conducted emissions shall comply with the requirements of CISPR 11 for class B group 1 equipment, see Table B.1, in Annex B.

For machines intended for use in industrial environments, radiated and conducted emissions shall comply with the requirements of CISPR 11 for class A group 1 equipment with a rated input power of ≤ 20 kVA , independently from their actual rated input power. These limits are also found in Table B.2.

13.4 Immunity tests

Immunity tests are not required.

13.5 Emission measurements

For general purpose rotating electrical machines, type tests shall be carried out in accordance with CISPR 11 and the respective parts of the CISPR 16 standards series as applicable. Type tests on rotating electrical machines intended for assembly into final products in the scope of CISPR 14 shall be carried out also observing the advice found in CISPR 14.

For the measurements, the requirements specified in 13.3 apply.

Machines without brushes shall comply with the emission limits of 13.3 with any load condition.

Machines with brushes shall at least comply with the emission limits of CISPR 11 for class A group 1 equipment with a rated input power of ≤ 20 kVA , independently from their actual rated input power, when tested without a load. Such machines need to be denoted as class A components.

Cage induction machines do not need to be measured.

Emissions at terminals intended for earthing or grounding do not need to be measured.

14 ~~Safety~~ Application requirements

Rotating machines in accordance with this document shall comply with the requirements of IEC 60204-1 or IEC 60204-11 or, in the case of rotating machines incorporated in household and similar electrical appliances, IEC 60335-1, as appropriate unless otherwise specified in this document, and be designed and constructed as far as possible in accordance with internationally accepted best design practice, appropriate to the application.

NOTE It is the responsibility of the manufacturer or assembler of equipment incorporating electrical machines as components to ensure that the overall equipment is safe.

This may involve consideration of relevant product standards such as:

IEC 60079 (all parts), and other parts of IEC 60034 including:

IEC 60034-5, IEC 60034-6, IEC 60034-7, IEC 60034-8, IEC 60034-9, IEC 60034-11, IEC 60034-12 and IEC 60034-14.

In addition, it may be necessary to consider limitation of the surface temperature and similar characteristics; see for example IEC 60335-1:~~2010~~2020, Clause 11: Heating.

Annex A
(informative)

Guidance for the application of duty type S10 and for establishing the value of relative thermal life expectancy *TL*

A.1 The load of the machine at any moment is equivalent to duty type S1 corresponding to 4.2.1. However, the load cycle may comprise loads other than the rated load based on duty type S1. A load cycle comprising four discrete constant load/speed combinations is shown in Figure 10.

A.2 Depending on the value and duration of the different loads within one cycle, the relative life expectancy of the machine based on the thermal ageing of the insulation system can be calculated by the following formula:

$$\frac{1}{TL} = \sum_{i=1}^{n} \Delta t_i \times 2^{\frac{\Delta\Theta_i}{k}}$$

where

- TL is the relative thermal life expectancy related to the thermal life expectancy in case of duty type S1 with rated output;
- $\Delta\Theta_i$ is the difference between the temperature rise of the winding at each of the various loads within one cycle and the temperature rise based upon duty type S1 with reference load;
- Δt_i is the p.u. time of a constant load within a load cycle;
- k is the increase in temperature rise in K, which leads to a shortening of the thermal life expectancy of the insulation system by 50 %;
- n is the number of discrete values of load.

A.3 The quantity TL is an integral part of the unambiguous identification of the class of rating.

A.4 The value of the quantity TL can be determined only when, in addition to information concerning the load cycle according to Figure 10, the value k for the insulation system is known. This value k has to be determined by experiments in conformity with IEC 60034-18 for the whole temperature range within which the load cycle takes place according to Figure 10.

A.5 TL can be stated sensibly as a relative value only. This value can be used by approximation to assess the real change in the machine thermal life expectancy as compared to duty type S1 with rated output, because it may be assumed that in consideration of the varying loads existing within a cycle the remaining influences over the lifetime of the machine (e.g. dielectric stress, environmental influences) are approximately the same as in the case of duty type S1 with rated output.

A.6 The manufacturer of the machine is responsible for the correct compilation of the various parameters for determining the value of TL.

Annex B
(informative)

Electromagnetic compatibility (EMC) limits

Table B.1 – Electromagnetic emission limits per CISPR 11 Class B Group 1

	Frequency range	Limits
Radiated emission	30 MHz to 230 MHz	30 dB(µV/m) quasi peak, measured at 10 m distance (Note)
	230 MHz to 1 000 MHz	37 dB(µV/m) quasi peak, measured at 10 m distance (Note)
Conducted emission on AC or DC power supply terminals	0,15 MHz to 0,50 MHz Limits decrease linearly with logarithm frequency	66 dB(µV) to 56 dB(µV) quasi peak 56 dB(µV) to 46 dB(µV) average
	0,50 MHz to 5 MHz	56 dB(µV) quasi peak 46 dB(µV) average
	5 MHz to 30 MHz	60 dB(µV) quasi peak 50 dB(µV) average

NOTE May be measured at 3 m distance using the limits increased by 10 dB.

Table B.2 – Electromagnetic emission limits per CISPR 11 Class A Group 1

	Frequency range	Limits
Radiated emission	30 MHz to 230 MHz	30 dB(µV/m) quasi peak, measured at 30 m distance (Note)
	230 MHz to 1 000 MHz	37 dB(µV/m) quasi peak, measured at 30 m distance (Note)
Conducted emission on AC or DC power supply terminals	0,15 MHz to 0,50 MHz	79 dB(µV) quasi peak 66 dB(µV) average
	0,50 MHz to 30 MHz	73 dB(µV) quasi peak 60 dB(µV) average

NOTE May be measured at 10 m distance using the limits increased by 10 dB or measured at 3 m distance using the limits increased by 20 dB.

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IEC 60034-1

Edition 14.0 2022-02

INTERNATIONAL STANDARD

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Rotating electrical machines –
Part 1: Rating and performance

Machines électriques tournantes –
Partie 1: Caractéristiques assignées et caractéristiques de fonctionnement

IEC 60034-1:2022-02(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ROTATING ELECTRICAL MACHINES –

Part 1: Rating and performance

FOREWORD

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 Clarification on the capability to withstand impulse voltages
7.3	New subclause on voltage deviation during starting
7.4	Extended variation of supply frequency Note added on design for operation with extended voltage and frequency 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 Test voltage for variable speed AC machines added 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 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 Note on measurement uncertainty added
12.2	Change in the tolerance on efficiency Clarification on the tolerance on locked-rotor current 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. The main document types developed by IEC are described in greater detail at 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 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 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 60050-411:1996, *International Electrotechnical Vocabulary (IEV) – Part 411: Rotating* 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 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 equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV*

IEC 60335-1:2020, *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*

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, 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
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 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>
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 $I_{rms,maxN}$ to its average value I_{avN} (mean value integrated over one period) at rated conditions:

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

3.29
current ripple factor
ratio of the difference between the maximum value I_{max} and the minimum value I_{min} of an undulating current to two times the average value I_{av} (mean value integrated over one period):

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

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

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

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_{max}) and minimum (I_{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 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, 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 60034-24:2009, 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.

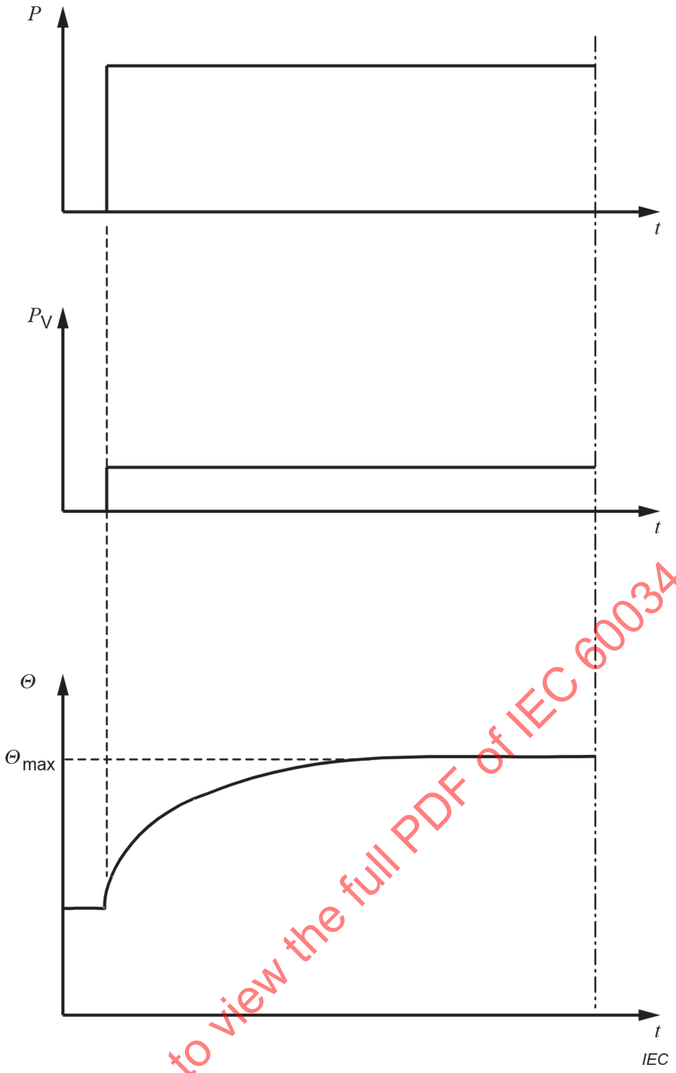
Where the purchaser does not declare a duty, the manufacturer shall assume that duty type S1 (continuous running duty) applies.

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
Θ	temperature
$Θ_{max}$	maximum temperature attained
t	time

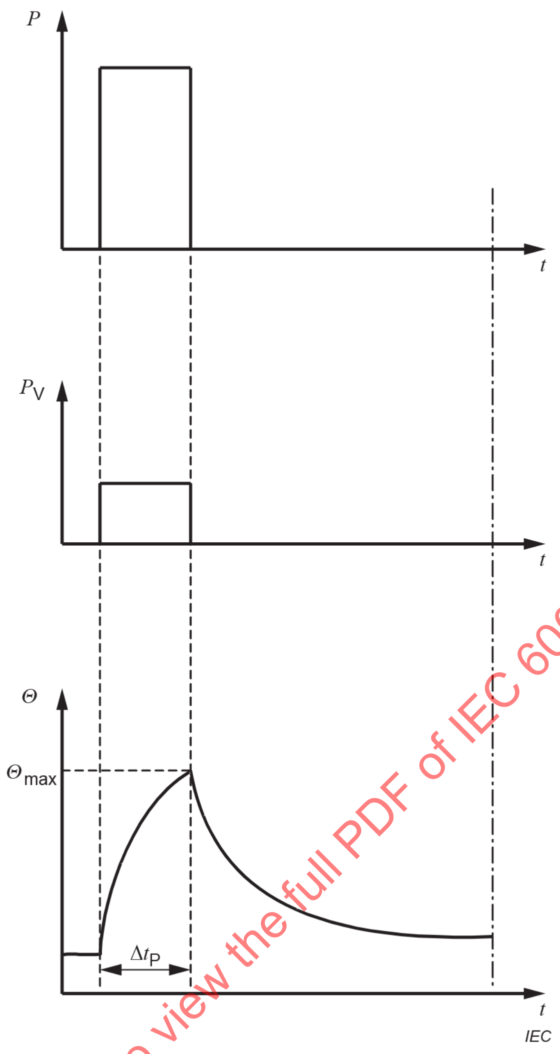
Figure 1 – Continuous running duty – Duty type S1

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
Θ	temperature
Θ_{max}	maximum temperature attained
t	time
Δt_P	operation time at constant load, e. g. Δt_P = 60 min for S2 60 min

Figure 2 – Short-time duty – Duty type S2

4.2.3 Duty type S3 – Intermittent periodic duty

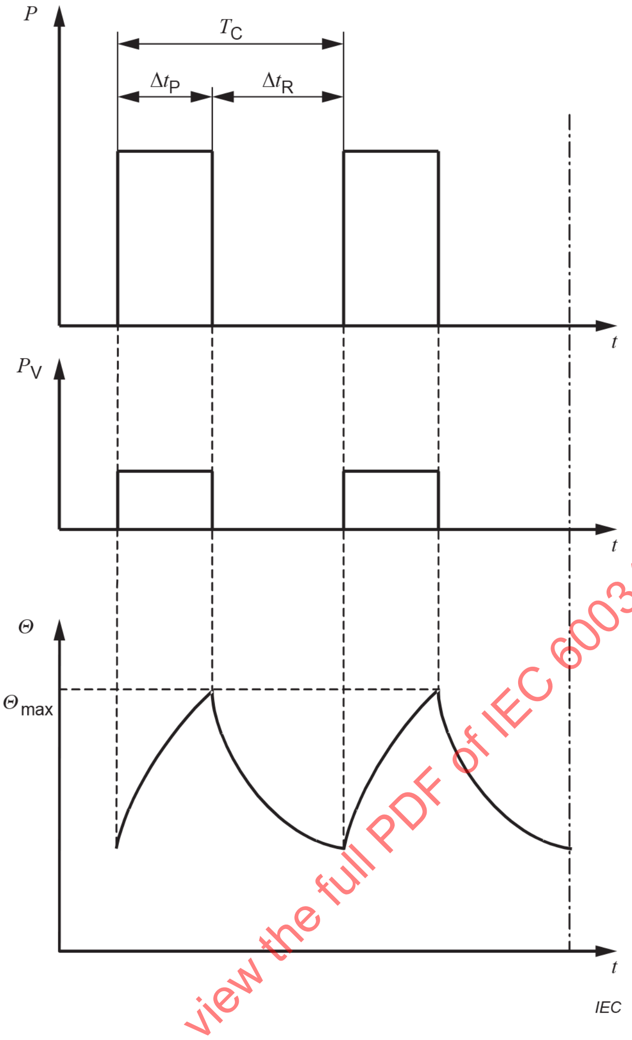
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

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
Θ	temperature
Θ_{max}	maximum temperature attained
t	time
T_C	time of one load cycle
Δt_P	operation time at constant load
Δt_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

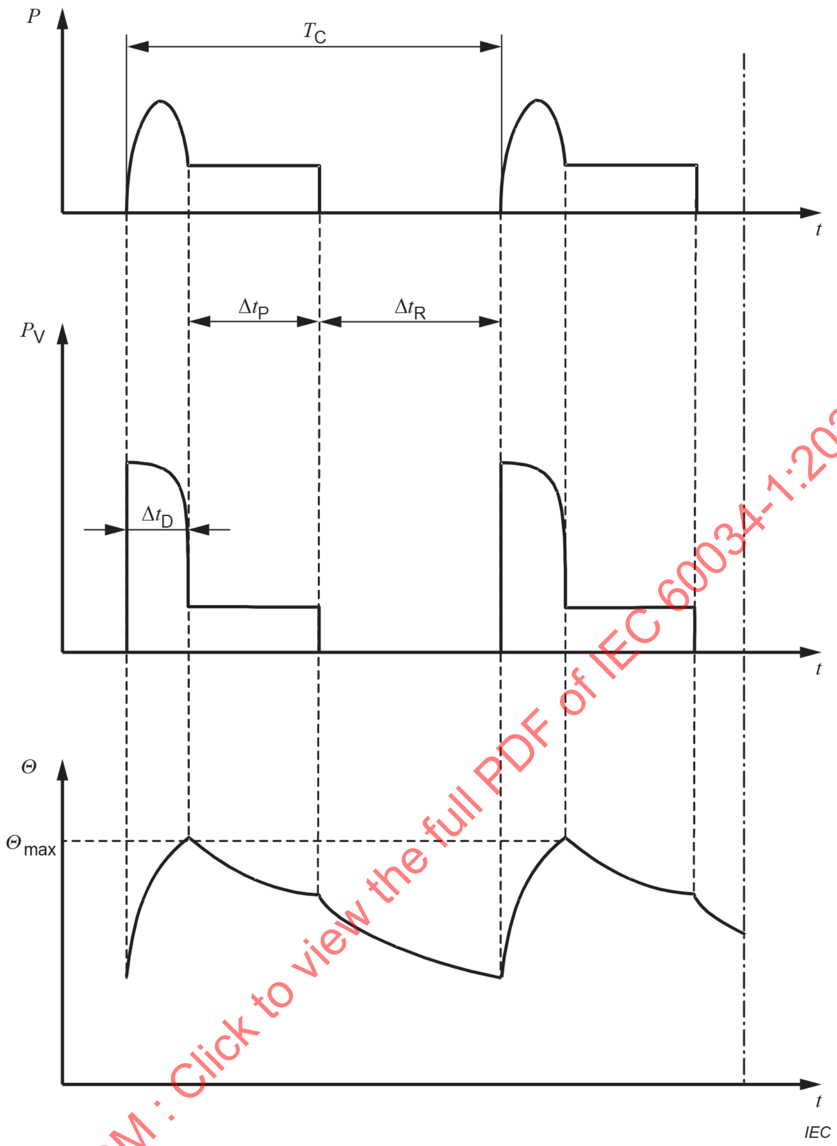
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

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_{ext}), both referred to the motor shaft.

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



Key

P	load	t	time
P_V	electrical losses	T_C	time of one load cycle
Θ	temperature	Δt_D	starting/accelerating time
Θ_{max}	maximum temperature attained	Δt_P	operation time at constant load
		Δt_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

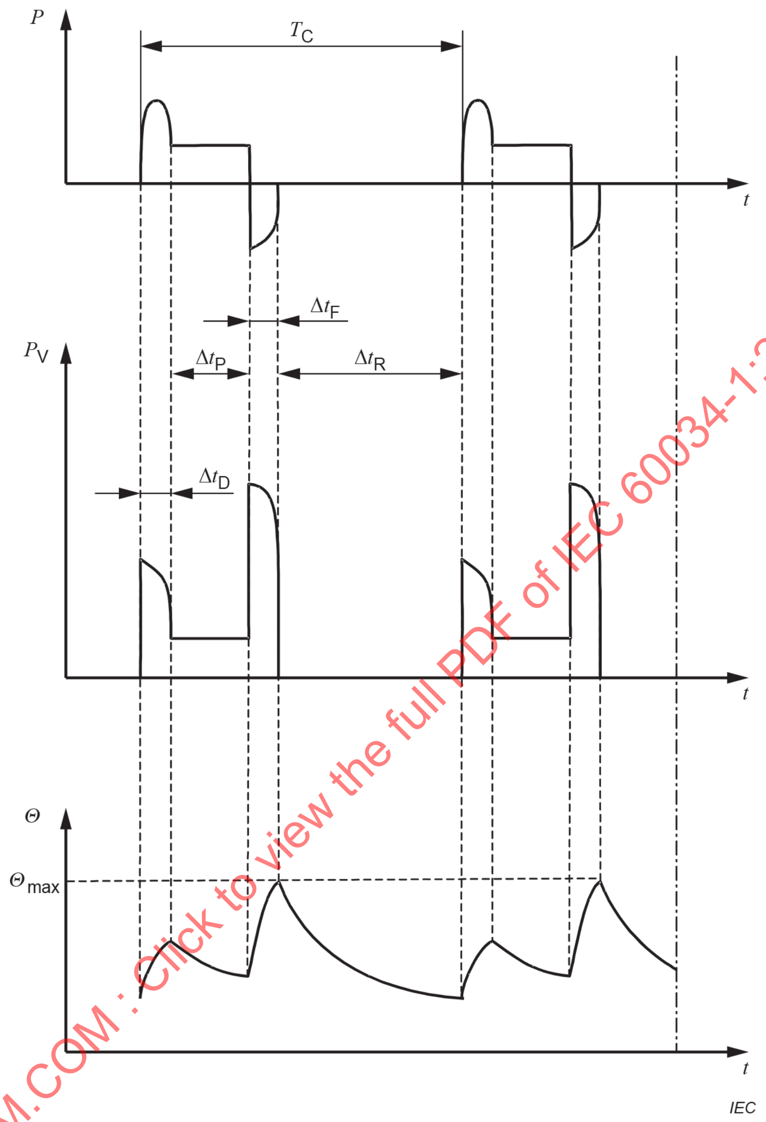
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

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 kg × m² J_{ext} = 0,7 kg × m².



Key

P	load	T_C	time of one load cycle
P_V	electrical losses	Δt_D	starting/accelerating time
Θ	temperature	Δt_P	operation time at constant load
Θ_{max}	maximum temperature attained	Δt_F	time of electric braking
t	time	Δt_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

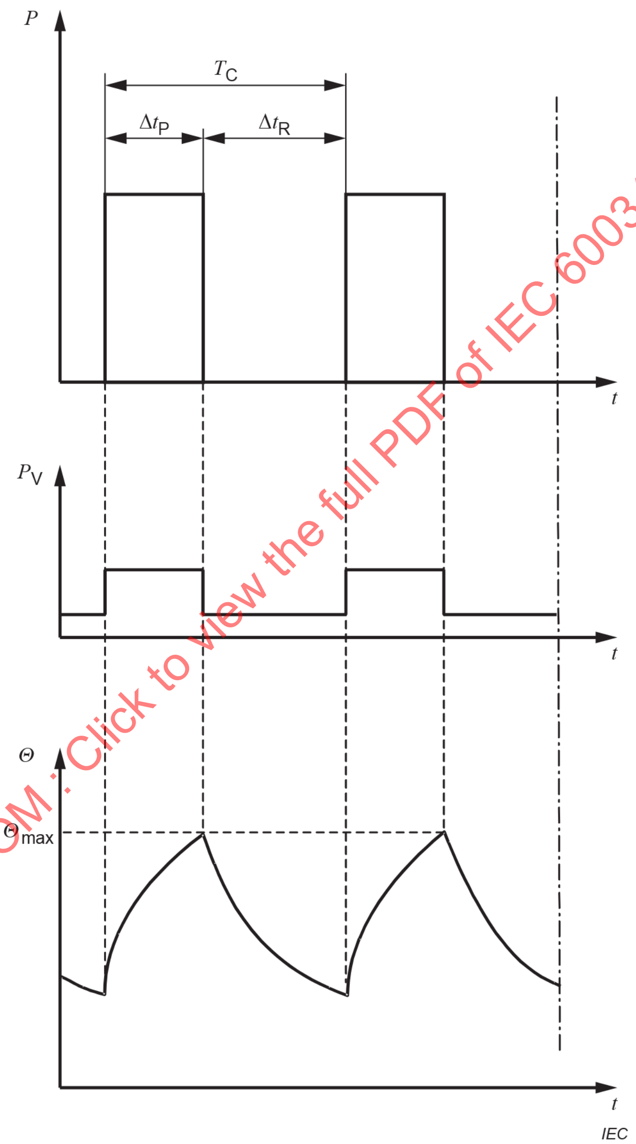
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

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
Θ	temperature	Δt_P	operation time at constant load
Θ_{max}	maximum temperature attained	Δt_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

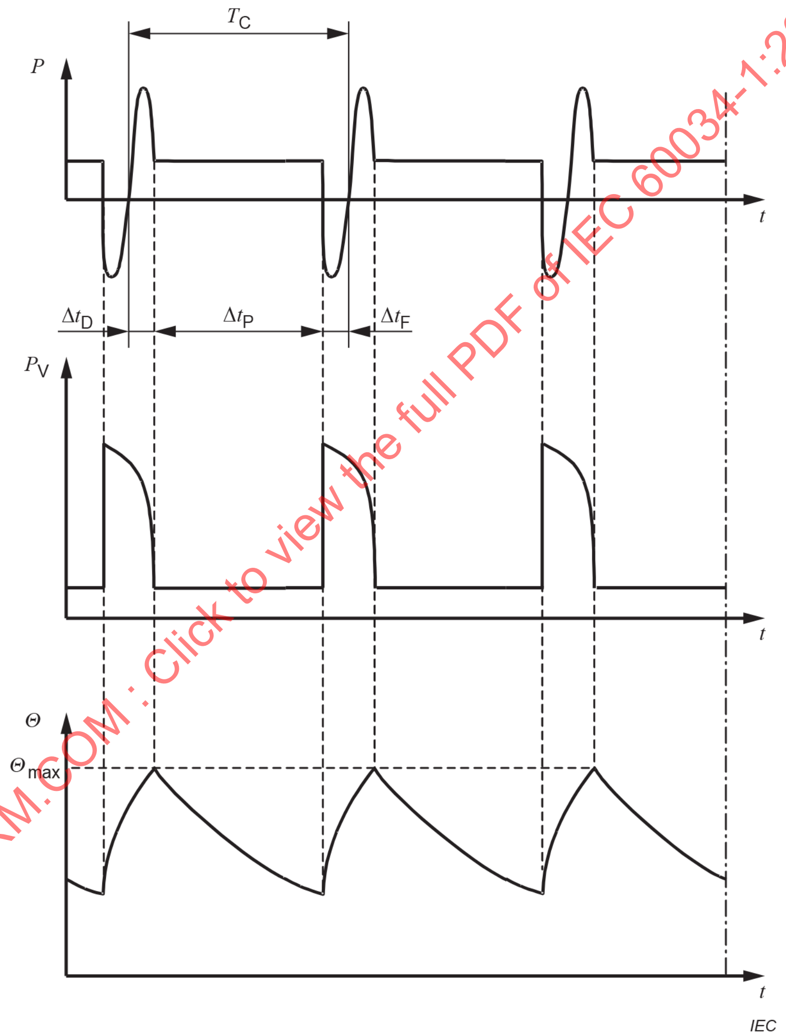
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

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 kg × m^2 J_{ext} = 7,5 kg × m^2



Key

P	load	t	time
P_V	electrical losses	T_C	time of one load cycle
Θ	temperature	Δt_D	starting/accelerating time
Θ_{max}	maximum temperature attained	Δt_P	operation time at constant load
Cyclic duration factor = 1		Δt_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

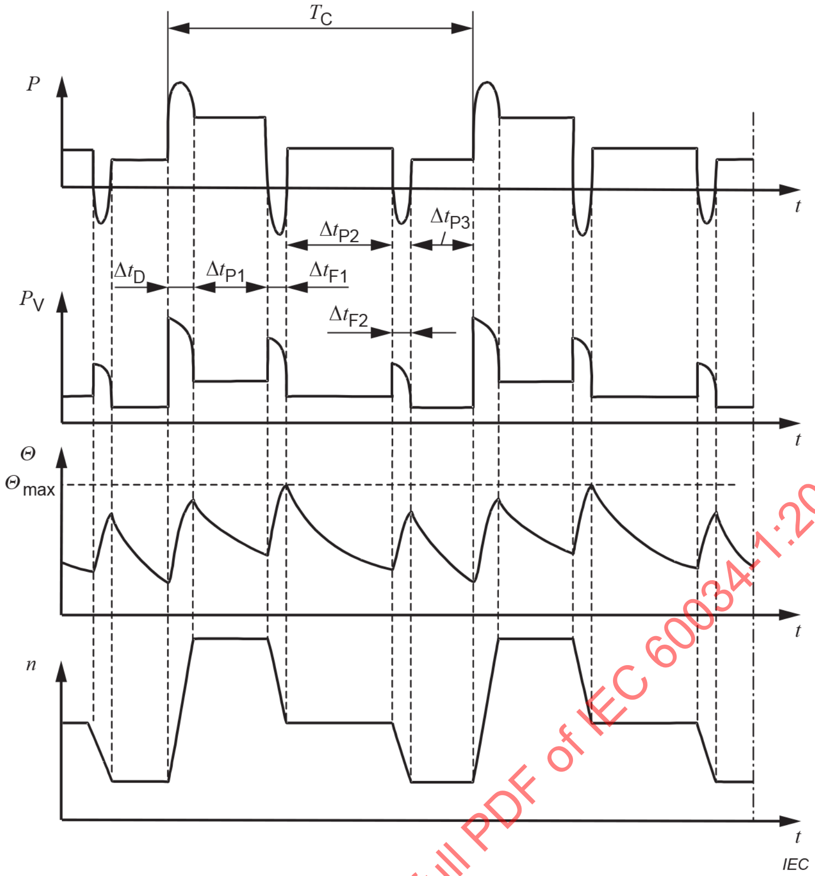
NOTE 1 Periodic duty implies that thermal equilibrium is not reached during the time on load.

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 kg × m^2	J_{ext} = 6 kg × m^2	16 kW	740 min^{-1}	30 %
			40 kW	1 460 min^{-1}	30 %
			25 kW	980 min^{-1}	40 %.



Key

P	load	t	time
P_V	electrical losses	T_C	time of one load cycle
Θ	temperature	Δt_D	starting/accelerating time
Θ_{max}	maximum temperature attained	Δt_P	operation time at constant load (P1, P2, P3)
n	speed	Δt_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

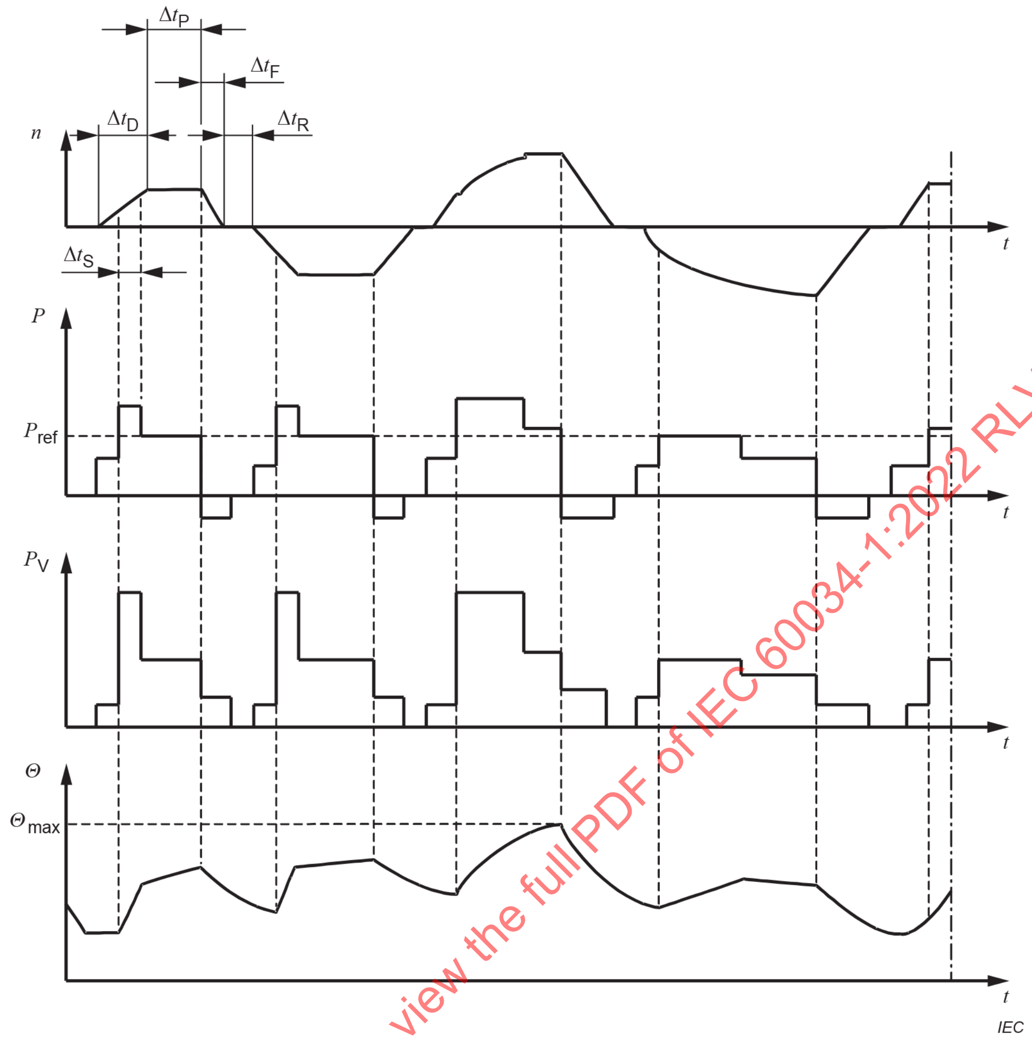
4.2.9 Duty type S9 – Duty with non-periodic load and speed variations

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_{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	Δt_D	starting/accelerating time
P_V	electrical losses	Δt_P	operation time at constant load
Θ	temperature	Δt_F	time of electric braking
Θ_{max}	maximum temperature attained	Δt_R	time at rest and de-energized
n	speed	Δt_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.

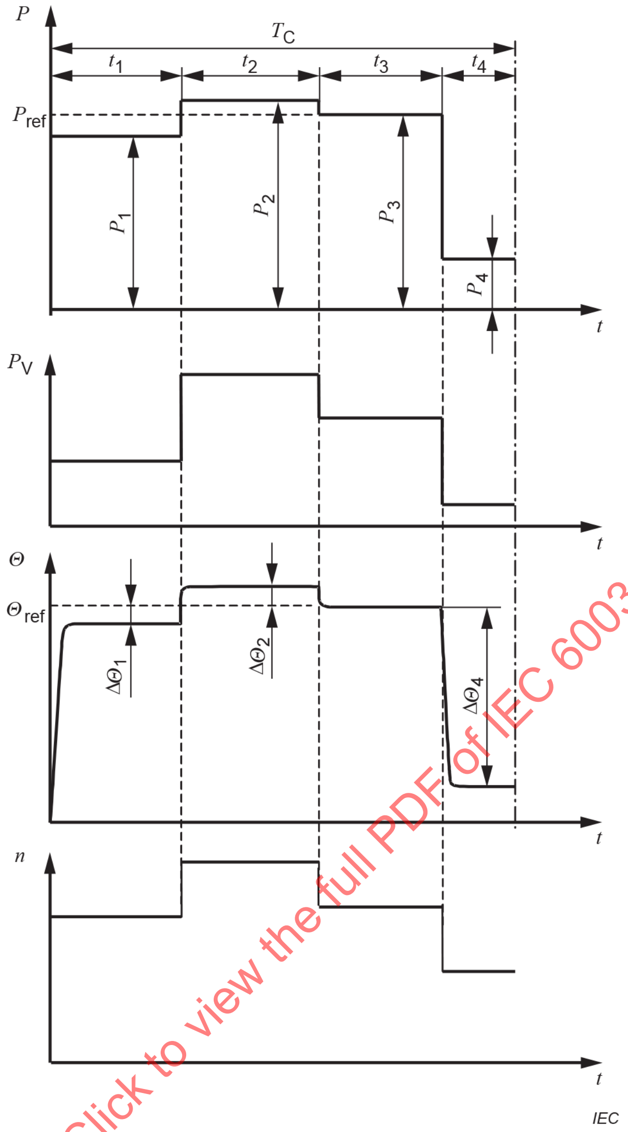
Example: S10 $p/\Delta t$ = 1,1/0,4; 1/0,3; 0,9/0,2; r/0,1 TL = 0,60.

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
Θ	temperature	n	speed
Θ_{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 compensators

The rated output is the reactive power at the terminals and shall be expressed in volt-amperes (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 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

Rated voltage kV	Minimum rated output kW (or kVA)
1,0 < U_N ≤ 3,0	100
3,0 < U_N ≤ 6,0	150
6,0 < U_N ≤ 11,0	800
11,0 < U_N ≤ 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 ºC:

a) rated output greater than 3 300 kW (or kVA) per 1 000 min^{-1};

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.

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.

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 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 ≤ 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 ≤ 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.

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:

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

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 $(I_{(2)}/I_{\mathrm{N}})^2$ 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 compensators	0,1	20
2	Direct cooled (inner cooled) stator and/or field windings		
	motors	0,08	15
	generators	0,05	15
	synchronous 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

[a] For these machines, the value of $I_{(2)}/I_N$ is calculated as follows:

$$\frac{I_{(2)}}{I_N} = 0{,}08 - \frac{S_N - 350}{3 \times 10^4}$$

[b] For these machines, the value of $(I_{(2)}/I_N)^2 \times t$, in seconds, is calculated as follows:
$(I_{(2)}/I_N)^2 \times t = 8 - 0{,}005\,45\,(S_N - 350)$
where in the two footnotes, S_N is the rated apparent power in MVA.

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 *CCC*	1-pair configuration (configuration name)	Pair number "m" for arms in IEC 61148	Clause No. and title in IEC 61148
A-Type	Thyristor + Thyristor (Full bridge)	m = 3	5.1.3.2 Bridge connection
B-Type	Thyristor + Diode (Mixed bridge)	m = 3	Same as above
C-Type	Thyristor + Thyristor (Full bridge)	m = 2	Same as above
D-Type	Thyristor + Diode (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 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 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:

$$|\Delta\emptyset| = \left|\frac{U-U_\mathrm{N}}{U_\mathrm{N}} - \frac{f-f_\mathrm{N}}{f_\mathrm{N}}\right|$$

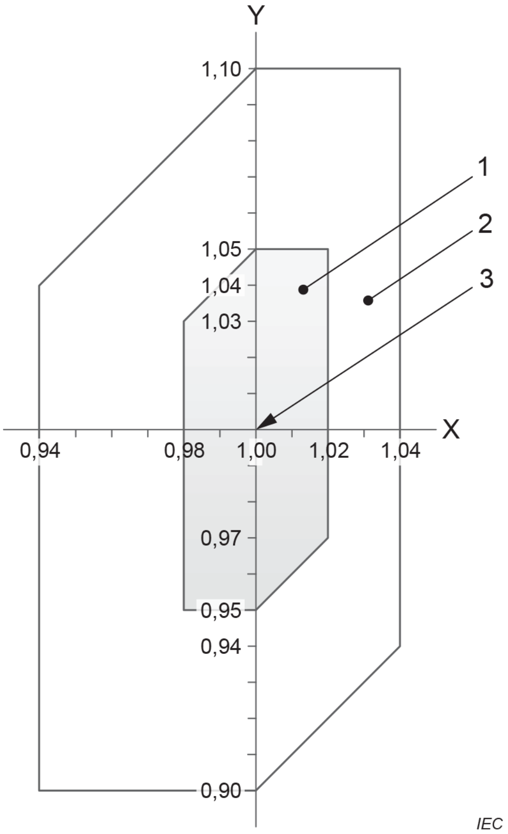
Operating outside zone A may also have significant effects on the acoustic noise, the vibration and the magnetic pull.

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 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.

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 compensator, excluding item 5	Rated reactive power (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 ≥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 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

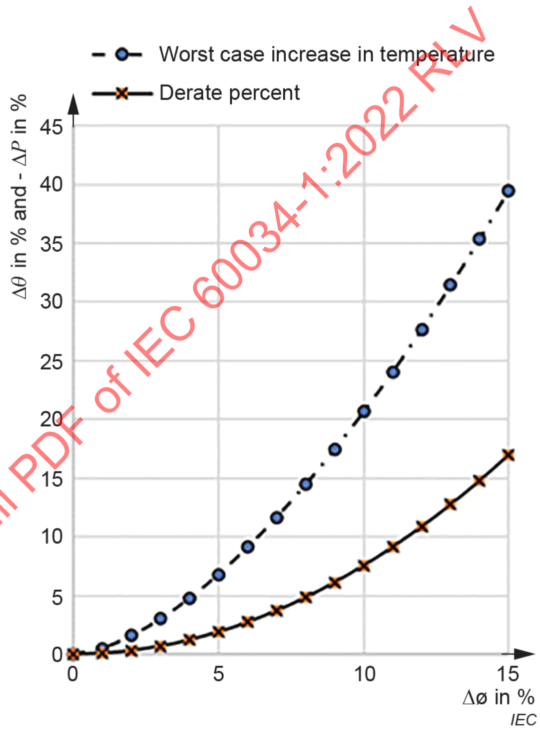


Figure 12 – Worst case increase in temperature rise ($\Delta\theta$) and recommended reduction of output power (ΔP) of motors as a function of the combined change of voltage and frequency $|\Delta\varnothing|$ (indicative guideline to users of motors and generators only)

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 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 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	8	Temperature rise	Ambient air Reference temperature: 40 °C
2	Air	Indirect	Air	8		
3	Air	Indirect	Water	8		Reference temperature of primary coolant at inlet to machine: 40 °C Reference temperature of ambient water: 25 °C
4	Hydrogen	Indirect	Water	9		
5	Air	Direct	None	13	Temperature	Ambient air Reference temperature: 40 °C
6	Air	Direct	Air	13		
7	Air	Direct	Water	13		Gas at entry to machine or liquid at entry to the windings Reference temperature: 40 °C
8	Hydrogen or liquid	Direct	Water	13		

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 ±0,1 % of the rated frequency, the average supply voltages shall be within ±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 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.

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

θ_1 is the temperature (°C) of the winding (cold) at the moment of the initial resistance measurement;

θ_2 is the temperature (°C) of the winding at the end of the thermal test;

θ_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 θ_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.

8.6.2.3.4 Windings with one coil-side per slot

For machines with one coil-side per slot, the resistance method by direct measurement may be used if the machine comes to rest within the time interval specified in Table 6. If the machine takes more than 90 s to come to rest after switching off the power, the superposition method (see 8.6.2.1) may be used if previously agreed.

8.6.3 Determination by ETD method

8.6.3.1 General

The detectors shall be suitably distributed throughout the winding and the number of detectors installed shall be not less than six.

All reasonable efforts, consistent with safety, shall be made to place the detectors at the points where the highest temperatures are likely to occur, in such a manner that they are effectively protected against contact with the primary coolant.

The highest reading from the ETD elements shall be used to determine the temperature of the winding.

ETD elements or their connections may fail and give incorrect readings. Therefore, if one or more readings are shown to be erratic, after investigation they should be eliminated.

8.6.3.2 Two or more coil-sides per slot

The detectors shall be located between the insulated coil-sides within the slot in positions at which the highest temperatures are likely to occur.

8.6.3.3 One coil-side per slot

The detectors shall be located between the wedge and the outside of the winding insulation in positions at which the highest temperatures are likely to occur, but see also 8.6.1.

8.6.3.4 End windings

The temperature detectors shall be located between two adjacent coil-sides within the end windings in positions where the highest temperatures are likely to occur. The sensing point of each detector shall be in close contact with the surface of a coil-side and be adequately protected against the influence of the coolant, but see also 8.6.1.

When placing a temperature detector in the end windings of high voltage machines, care shall be taken that the stress grading of the insulation is not compromised and that the difference of potential along the winding overhang does not cause problems. In addition, the ground of the measuring system is thus directly capacitive coupled to the HV-system. Disconnection of the measurement ground will in this case immediately lead to over voltages on the measuring system. Measures have to be taken to prevent consequential damage up to lethal injuries.

NOTE If the stator winding is a direct liquid cooled bar type, a temperature detector installed in the nozzle area of each bar monitoring water outlet temperature can give an indication of conductor strand cooling passage blocking.

8.6.4 Determination by thermometer method

All reasonable efforts, consistent with safety, shall be made to place thermometers at the point, or points where the highest temperatures are likely to occur (e.g. in the end windings close to the core iron) in such a manner that they are effectively protected against contact with the primary coolant and are in good thermal contact with the winding or other part of the machine.

The highest reading from any thermometer shall be taken to be the temperature of the winding or other part of the machine.

8.7 Duration of thermal tests

8.7.1 Rating for continuous running duty

The test shall be continued until thermal equilibrium has been reached.

8.7.2 Rating for short-time duty

The duration of the test shall be the time given in the rating.

8.7.3 Rating for periodic duty

Normally the rating for equivalent loading assigned by the manufacturer (see 5.2.6) shall be applied until thermal equilibrium has been reached. If a test on the actual duty is agreed, the load cycle specified shall be applied and continued until practically identical temperature cycles are obtained. The criterion for this shall be that a straight line between the corresponding points of successive duty cycles on a temperature plot has a gradient of less than 1 K per half hour. If necessary, measurements shall be taken at reasonable intervals over a period of time (see 3.25).

8.7.4 Ratings for non-periodic duty and for duty with discrete constant loads

The rating for equivalent loading assigned by the manufacturer (see 5.2.6) shall be applied until thermal equilibrium has been reached.

8.8 Determination of the thermal equivalent time constant for machines of duty type S9

The thermal equivalent time constant with ventilation as in normal operating conditions, suitable for approximate determination of the temperature course, can be determined from the cooling curve plotted in the same manner as in 8.6.2.3. The value of the time constant is 1,44 times (that is to say, 1/ln(2) times) the time taken by the machine to cool to one-half of the full load temperature rise, after its disconnection from the supply.

8.9 Measurement of bearing temperature

Either the thermometer method or the ETD method may be used.

The measuring point shall be as near as possible to one of the two locations specified in Table 7.

Table 7 – Measuring points

Type of bearing	Measuring point	Location of measuring point
Ball or roller	A	In the bearing housing preferably in contact with the outer ring of the bearing, but not more than 10 mm[a] from it[b]
	B	Outer surface of the bearing housing as close as possible to the outer ring of the bearing
Sleeve or tilting pad	A	In the pressure zone of the bearing shell[c] and not more than 10 mm[a] from the oil-film gap[b].
	B	Elsewhere in the bearing shell

[a] The distance is measured to the nearest point of the ETD or thermometer bulb.

[b] In the case of an 'inside out' machine, point A will be in the stationary part not more than 10 mm from the inner ring and point B on the outer surface of the stationary part as close as possible to the inner ring.

[c] The bearing shell is the part supporting the bearing material and which is secured in the housing. The pressure zone is the portion of the circumference which supports the combination of rotor weight and radial loads.

The thermal resistance between the temperature detector and the object whose temperature is to be measured shall be minimized; for example, air gaps shall be packed with thermally conducting paste.

NOTE Between the measuring points A and B, as well as between these points and the hottest point of the bearing, there are temperature differences which depend, among other things, on the bearing size. For sleeve bearings with pressed-in bushings and for ball and roller bearings with an inside diameter of up to 150 mm, the temperature difference between points A and B may be assumed to be negligible. In the case of larger bearings, the temperature difference between measuring points A and B is approximately 15 K.

8.10 Limits of temperature and of temperature rise

8.10.1 General

Limits are given for operation under site operating conditions specified in Clause 6 and at rating for continuous running duty (reference conditions), followed by rules for the adjustment of those limits when operating at site under other conditions and on other ratings. Further rules give adjustments to the limits during thermal testing when conditions at the test site differ from those at the operating site.

It is understood that the temperature of the hottest point of each winding under reference conditions, i.e. the rated conditions, generally does not exceed the agreed thermal class temperature of the insulation system.

The limits are stated relative to the reference coolant specified in Table 5.

A rule is given to allow for the purity of hydrogen coolant.

8.10.2 Indirect cooled windings

Temperature rises under reference conditions shall not exceed the limits given in Table 8 (air coolant) or Table 9 (hydrogen coolant) as appropriate for both, ETD and R method if applicable.

NOTE The measured temperature differences between method ETD and method R may be significantly higher or lower than the temperature limits specified in Table 8 or Table 9, depending on the machine design and the cooling system. It is not intended to compare ETD and R method against each other.

For other operating site conditions, for ratings other than continuous running duty, and for rated voltages greater than 12 000 V, the limits shall be adjusted according to Table 10. (See also Table 11 for limit on coolant temperature which is assumed in Table 10.)

In the case of thermometer readings made in accordance with 8.6.1, the limit of temperature rise shall be according to Table 8.

If, for windings indirectly cooled by air, conditions at the test site differ from those at the operating site, the adjusted limits given in Table 12 shall apply at the test site.

If the adjusted limits given in Table 12 lead to permissible temperatures at the test site which the manufacturer considers to be excessive, the testing procedure and the limits shall be agreed.

If temperature rise is to be measured above the temperature of the water where it enters the cooler, the effect of altitude on the temperature difference between air and water should strictly be allowed for. However, for most cooler designs, the effect will be small, the difference increasing with increasing altitude at the rate of roughly 2 K per 1 000 m. If an adjustment is necessary, it should be by agreement.

No adjustments at the test site are given for windings indirectly cooled by hydrogen, because it is very unlikely that they will be tested at rated load anywhere other than at the operating site.

Table 8 – Limits of temperature rise of windings indirectly cooled by air

Thermal class		130 (B)			155 (F)			180 (H)			200 (N)		
Method of measurement	Th = Thermometer, R = Resistance, ETD = Embedded temperature detector	**Th** K	**R** K	**ETD** K	**Th** K	**R** K	**ETD** K	**Th** K	**R** K	**ETD** K	**Th** K	**R** K	**ETD** K
Item	**Part of machine**												
1a)	AC windings of machines having outputs of 5 000 kW (or kVA) or more	–	80	85 [a]	–	105	110 [a]	–	125	130 [a]	–	145	150 [a]
1b)	AC windings of machines having outputs above 200 kW (or kVA), but less than 5 000 kW (or kVA)	–	80	90 [a]	–	105	115 [a]	–	125	140 [a]	–	145	160 [a]
1c)	AC windings of machines having outputs of 200 kW (or kVA) or less, other than those in items 1d) or 1e) [b]	–	80	–	–	105	–	–	125	–	–	145	–
1d)	AC windings of machines having rated outputs of less than 600 W (or VA) [b]	–	85	–	–	110	–	–	130	–	–	150	–
1e)	AC windings which are self-cooled without a fan (IC 40) and/or with encapsulated windings [b]	–	85	–	–	110	–	–	130	–	–	150	–
2	Windings of armatures having commutators	70	80	–	85	105	–	105	125	–	125	145	–
3	Field windings of AC and DC machines other than those in item 4	70	80	–	85	105	–	105	125	–	125	145	–
4a)	Field windings of synchronous machines with cylindrical rotors having a DC excitation winding embedded in slots, except synchronous induction motors	–	90	–	–	115	–	–	135	–	–	155	–
4b)	Insulated stationary field windings of DC machines having more than one layer	70	80	90	85	105	115	105	125	140	125	145	160
4c)	Low-resistance field windings of DC machines having more than one layer and compensating windings of DC machines	80	80	–	100	105	–	125	125	–	145	145	–
4d)	Single-layer windings of AC and DC machines with exposed bare or varnished metal surfaces [c]	90	90	–	110	115	–	135	135	–	155	155	–

[a] For adjustment for high-voltage AC windings, see item 4 of Table 10.

[b] With the application of the superposition test method to windings of machines rated at 200 kW (or kVA) or less with thermal classes 130 (B) and 155 (F), the limits of temperature rise given for the resistance method may be exceeded by 5 K.

[c] Also includes multiple layer windings, provided that the under layers are each in contact with the circulating primary coolant.

Table 9 – Limits of temperature rise of windings indirectly cooled by hydrogen

	Thermal class	130 (B)		155 (F)	
	Method of measurement ETD = Embedded temperature detector	**Resistance** K	**ETD** K	**Resistance** K	**ETD** K
Item					
1	AC windings of machines having outputs of 5 000 kW (or kVA) or more or having a core length of 1 m or more				
	Absolute hydrogen pressure [b] ≤ 150 kPa (1,5 bar)	–	85 [a]	–	105 [a]
	> 150 kPa ≤ 200 kPa (2,0 bar)	–	80 [a]	–	100 [a]
	> 200 kPa ≤ 300 kPa (3,0 bar)	–	78 [a]	–	98 [a]
	> 300 kPa ≤ 400 kPa (4,0 bar)	–	73 [a]	–	93 [a]
	> 400 kPa	–	70 [a]	–	90 [a]
2a	AC windings of machines having outputs of less than 5 000 kW (or kVA), or having a core length of less than 1 m	80	85 [a]	100	110 [a]
2b	DC field windings of AC and DC machines other than those in items 3 and 4	80	–	105	–
3	DC field windings of machines having cylindrical rotors	85	–	105	–
4a	Low-resistance field windings of more than one layer and compensating windings	80	–	100	–
4b	Single-layer windings with exposed bare or varnished metal surfaces [c]	90	–	110	–

[a] For adjustment for high-voltage AC windings, see item 4 of Table 10.

[b] This is the only item where the limit of temperature rise is dependent on hydrogen pressure.

[c] Also includes multi-layer field windings provided that the under layers are each in contact with the circulating primary coolant.

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

Item	Operation conditions or rating	Adjustment to limit of temperature rise ($\Delta\theta$) in Table 8 and Table 9	Item
1a	Maximum temperature of ambient air or of the cooling gas at inlet to the machine (θ_c) and for altitudes of up to 1 000 m. If the difference between the thermal class and the observable limit of temperature, consisting of the sum of the reference cold coolant inlet temperature of 40 °C and the limit of temperature rise according to Table 8 and Table 9 is less or equal to 5 K: For a higher altitude replace 40 °C with the value given in Table 11.	0 °C ≤ θ_c ≤ 40 °C	Increased by the amount by which the coolant temperature is less than 40 °C.
1b	Maximum temperature of ambient air or of the cooling gas at the inlet to the machine (θ_c) and for altitudes of up to 1 000 m. If the difference between the thermal class and the observable limit of the temperature, consisting of the sum of the reference cold coolant inlet temperature of 40 °C and the limit of temperature rise according to Table 8 and Table 9 is larger than 5 K: For a higher altitude replace 40 °C with the value given in Table 11.	0 °C ≤ θ_c ≤ 40 °C	The limit of temperature rise $\Delta\theta$ for cold gas temperature θ_c shall be $$\Delta\theta = \Delta\theta_{ref} \frac{\theta_{ThCl} - \theta_C}{\theta_{ThCl} - \theta_{C\cdot ref}}$$ where $\Delta\theta_{ref}$ is the limit of temperature rise according to Table 8 or Table 9 at 40 °C; θ_{ThCl} is the temperature of the thermal class (for example 130 °C or 155 °C); θ_{Cref} is the reference cold coolant temperature (40 °C).
1c		40 °C < θ_c ≤ 60 °C	Reduced by the amount by which the coolant temperature exceeds 40 °C
1d		θ_c < 0 °C or θ_c > 60 °C	By agreement

Item	Operation conditions or rating	Adjustment to limit of temperature rise ($\Delta\theta$) in Table 8 and Table 9	Item
2	Maximum temperature of the water at the inlet to water-cooled heat exchangers or maximum temperature of the ambient water for submersible machines with surface cooling or machines with water jacket cooling (θ_w)	5 °C ≤ θ_w ≤ 25 °C	Increased by 15 K and by the difference between 25 °C and θ_w
		θ_w > 25 °C	Increased by 15 K and reduced by the difference between θ_w and 25 °C
3a	Altitude (H) – general rule	1 000 m < H ≤ 4 000 m and maximum ambient air temperature not specified	No adjustment. It shall be assumed that the reduced cooling resulting from altitude is compensated by a reduction of maximum ambient temperature below 40 °C and that the total temperature will therefore not exceed 40 °C plus the Table 8 and Table 9 temperature rises [a]
		H > 4 000 m	By agreement
3b	Altitude (H) – power plant generator specific	according specification of the purchaser	The capability of power plant generators should be adjusted and is a function of the altitude (air pressure). No adjustment of the capability is needed for power plant generators if the absolute coolant pressure is maintained constant regardless of the altitude.
4	Rated stator winding voltage (U_N)	12 kV < U_N ≤ 24 kV	$\Delta\theta$ for embedded temperature detectors (ETD) shall be reduced by 1 K for each 1 kV (or part thereof) from 12 kV up to and including 24 kV
		U_N > 24 kV	By agreement
5 [b]	Rating for short-time duty (S2), with rated output less than 5 000 kW (kVA)		Increased by 10 K
6 [b]	Rating for non-periodic duty (S9)		$\Delta\theta$ may be exceeded for short periods during the operation of the machine
7 [b]	Rating for duty with discrete loads (S10)		$\Delta\theta$ may be exceeded for discrete periods during the operation of the machine

[a] Assuming the decrease in ambient temperature is 1 % of the limiting rises for every 100 m of altitude above 1 000 m, the maximum ambient air temperature at the operating site can be as shown in Table 11.

[b] For air-cooled windings only.

Table 11 – Assumed maximum ambient temperature

Altitude m	Thermal class			
	130 (B)	155 (F)	180 (H)	200 (N)
	Temperature °C			
1 000	40	40	40	40
2 000	32	30	28	26
3 000	24	19	15	12
4 000	16	9	3	0

8.10.3 Direct cooled windings

Temperatures under reference conditions shall not exceed the limits given in Table 13.

For other operating site conditions the limits shall be adjusted according to Table 14.

If conditions at the test site differ from those at the operating site, the adjusted limits given in Table 15 shall apply at the test site.

If the adjusted limits given in Table 15 lead to temperatures at the test site which the manufacturer considers to be excessive, the testing procedure and the limits shall be agreed.

8.10.4 Adjustments to take account of hydrogen purity on test

For windings directly or indirectly cooled by hydrogen, no adjustment shall be made to limits of temperature rise or of total temperature if the proportion of hydrogen in the coolant is between 95 % and 100 %.

8.10.5 Permanently short-circuited windings, magnetic cores and all structural components (other than bearings) whether or not in contact with insulation

The temperature rise or the temperature shall not be detrimental to the insulation of that part or to any other part adjacent to it.

8.10.6 Commutators and sliprings, open or enclosed and their brushes and brushgear

The temperature rise or temperature of any commutator, slipring, brush or brushgear shall not be detrimental to the insulation of that part or any adjacent part.

The temperature rise or temperature of a commutator or slipring shall not exceed that at which the combination of brush grade and commutator or slipring material can handle the current over the full operating range.

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

Item	Test condition		Adjusted limit at test site $\Delta\theta_T$
1	Temperature difference of reference coolant at test site (θ_{cT}) and operating site (θ_c)	Absolute value of $(\theta_c - \theta_{cT}) \le 30$ K	$\Delta\theta_T = \Delta\theta$
		Absolute value of $(\theta_c - \theta_{cT}) > 30$ K	By agreement
2	Difference of altitudes of test site (H_T) and operating site (H)	1 000 m < $H \le$ 4 000 m $H_T \le$ 1 000 m	$\Delta\theta_T = \Delta\theta\left(1 - \frac{H - 1\,000\text{ m}}{10\,000\text{ m}}\right)$
		$H \le$ 1 000 m 1 000 m < $H_T \le$ 4 000 m	$\Delta\theta_T = \Delta\theta\left(1 + \frac{H_T - 1\,000\text{ m}}{10\,000\text{ m}}\right)$
		1 000 m < $H \le$ 4 000 m 1 000 m < $H_T \le$ 4 000 m	$\Delta\theta_T = \Delta\theta\left(1 + \frac{H_T - H}{10\,000\text{ m}}\right)$
		$H >$ 4 000 m or $H_T >$ 4 000 m	By agreement

NOTE $\Delta\theta$ is given in Table 8 and adjusted if necessary in accordance with Table 10.

Table 13 – Limits of temperature of directly cooled windings and their coolants

Thermal class		130 (B)			155 (F)		
Method of measurement		Thermo-meter °C	Resistance °C	ETD °C	Thermo-meter °C	Resistance °C	ETD °C
Item	Part of the machine						
1	Coolant at the outlet of direct-cooled AC windings. These temperatures are preferred to the values given in item 2 as the basis of rating.						
1a)	Gas (air, hydrogen, helium, etc.)	110	–	–	130	–	–
1b)	Liquid (water, oil, etc.)	90	–	–	90	–	–
2	AC windings						
2a) 2b)	Gas cooled Liquid or evaporative cooled	–	–	120 [a]	–	–	145 [a]
3	Field windings of turbine type machines						
3a)	Cooled by gas leaving the rotor through the following number of outlet regions [b]						
	1 and 2	–	100	–	–	115	–
	3 and 4	–	105	–	–	120	–
	5 and 6	–	110	–	–	125	–
	7 to 14	–	115	–	–	130	–
	above 14	–	120	–	–	135	–
3b)	Liquid or evaporative cooled	Observance of the maximum coolant temperature given in item 1b) will ensure that the hotspot temperature of the winding is not excessive					
4	Field windings of AC and DC machines having DC excitation other than in item 3.						
4a)	Gas cooled	–	130	–	–	150	–
4b)	Liquid or evaporative cooled	Observance of the maximum coolant temperature given in item 1b) will ensure that the hotspot temperature of the winding is not excessive					

[a] No adjustment in the case of high-voltage AC windings is applicable to these items, see Table 14, item 2.

[b] The rotor ventilation is classified by the number of radial outlet regions on the total length of the rotor. Special outlet regions for the coolant of the end windings are included as one outlet for each end. The common outlet region of two axially opposed flows is to be counted as two regions.

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

Item	Operating condition or rating		Adjustment to limit of temperature in Table 13
1	Temperature θ_c of reference coolant	0 °C ≤ θ_c ≤ 40 °C	Reduction by the amount of the difference between 40 °C and θ_c. However, by agreement, a smaller reduction may be applied, provided that for θ_c < 10 °C the reduction is made at least equal to the difference between 10 °C and θ_c.
		40 °C < θ_c ≤ 60 °C	No adjustment
		θ_c < 0 °C or θ_c > 60 °C	By agreement
2	Rated stator winding voltage (U_N)	U_N > 11 kV	No adjustment The heat flow is mainly towards the coolant inside the conductors and not through the main insulation of the winding.

Table 15 – Adjusted limits of temperature at the test site θ_T for windings directly cooled by air to take account of test site operating conditions

Item	Test condition		Adjusted limit of temperature at test site θ_T
1	Difference of reference coolant temperatures of test site (θ_{cT}) and operating site (θ_c)	Absolute value of $(\theta_c - \theta_{cT}) \leq 30$ K	$\theta_T = \theta$
		Absolute value of $(\theta_c - \theta_{cT}) > 30$ K	By agreement
2	Difference of altitudes of test site (H_T) and operating site (H)	1 000 m < $H \leq$ 4 000 m $H_T \leq$ 1 000 m	$\theta_T = (\theta - \theta_c)\left(1 - \frac{H - 1000\text{ m}}{10\,000\text{ m}}\right) + \theta_{cT}$
		$H \leq$ 1 000 m 1 000 m < $H_T \leq$ 4 000 m	$\theta_T = (\theta - \theta_c)\left(1 + \frac{H_T - 1000\text{ m}}{10\,000\text{ m}}\right) + \theta_{cT}$
		1 000 m < $H \leq$ 4 000 m 1 000 m < $H_T \leq$ 4 000 m	$\theta_T = (\theta - \theta_c)\left(1 + \frac{H_T - H}{10\,000\text{ m}}\right) + \theta_{cT}$
		H > 4 000 m or H_T > 4 000 m	By agreement
NOTE θ is given in Table 13 and adjusted if necessary in accordance with Table 14.			

9 Other performance and tests

9.1 Routine tests

Routine tests are always factory tests. They shall be performed on all machines which are assembled at the factory of the manufacturer. The machines need not be completely assembled. They can lack components which are not significant for the testing. Routine tests do not need the machines to be coupled except for the open-circuit test on synchronous machines.

The minimum test schedule is listed in Table 16 and is applicable for machines with rated output ≤ 20 MW (MVA) that are assembled and tested in the factory. Additional routine tests may be performed especially on machines with ratings above 200 kW (kVA). The term synchronous machines includes brushless permanent magnet machines.

For DC machines, depending on size and design, a commutation test under load may be performed as a routine test.

Table 16 – Minimum routine tests for machines assembled and tested in the factory of the manufacturer

Item	Test	Induction machines (including synchronous induction machines) [a]	Electrically excited synchronous machines	Synchronous reluctance machines and PM excited synchronous machines	DC machines with separate or shunt excitation
1	Resistance of windings (cold)	Yes	Yes	Yes	Yes
2	No-load losses and current [d]	Yes	–	Yes	–
3a	No-load losses at unity power factor [c]	–	Yes [c]	–	–
3b	No-load excitation current at rated voltage by open-circuit test [c]	–	Yes [c]	–	–
4	Excitation current at rated speed and rated armature voltage	–	–	–	Yes
5	Open circuit secondary induced voltage at standstill (wound rotor)[b]	Yes	–	–	–
6	Direction of rotation (motors) or phase sequence (generators)	Yes	Yes	Yes	Yes
7	Withstand voltage test according to 9.2	Yes	Yes	Yes	Yes

[a] IEC 60050-411:1996, 411-33-04.

[b] For safety considerations this test may be performed at reduced voltage.

[c] Only one of the tests 3a or 3b is required.

[d] No stabilization of temperature required for measurement of no-load losses.

9.2 Withstand voltage test

A test voltage, as specified below, shall be applied between the windings under test and the frame of the machine, with the core and the windings not under test connected to the frame. It shall be applied only to a new and completed machine with all its parts in place under conditions equivalent to normal working conditions and shall be carried out at the manufacturer's factory or after erection on site. A withstand voltage test shall be carried out after the completion of the full test sequence.

For equipment manufactured for stock holding, the withstand voltage test carried out for acceptance on completion of manufacture remains valid and shall not be repeated provided the test voltage is equal to, or greater than, the test voltage given in Table 17 based on the rated voltage noted on the rating plate.

NOTE 1 For high voltage machines, additional methods as described in the parts of IEC 60034-27 can be used to prove the suitability of the machine winding insulation system.

Except as stated below, the frequency of the test voltage shall be the power frequency at the factory of the manufacturer, and the voltage waveform shall be as near as possible to a sine wave form. The final value of the voltage shall be in accordance with Table 17. However, for machines with a rated voltage 6 kV or greater, when power frequency equipment is not available, then by agreement a DC test may be carried out at a voltage 1,7 times the r.m.s. value given in Table 17.

NOTE 2 It is recognized that, during a DC test, the surface potential distribution along the end winding insulation and the ageing mechanisms are different from those occurring during an AC test.

In the case of polyphase machines with rated voltage above 1 kV having both ends of each phase individually accessible, the test voltage shall be applied between each phase and the frame, with the core and the other phases and windings not under test connected to the frame. The test shall be commenced at a voltage not exceeding half of the full test voltage. The voltage shall then be increased to the full value, steadily or in steps of not more than 5 % of the full value, the time allowed for the voltage increase from half to full value being not less than 10 s. The full test voltage shall then be maintained for 1 min in accordance with the value as specified in Table 17. The voltage test equipment shall be capable of maintaining the test voltage throughout the test within ±5 % of the specified value. There shall be no failure (see IEC 60060-1) during this period.

During the routine testing of quantity produced machines up to 200 kW (or kVA) and rated for U_N ≤ 1 kV, the 1 min test may be replaced by a test of 1 s at 120 % of the test voltage specified in Table 17. In the case applying this for very small sized machines rated up to 1 kW (or kVA) with IVIC C or D assigned (item 2b in Table 17), 120 % of the test voltage according to item 2b in Table 17 (i. e. including the test voltage factor according to Table 18) for 1s may be too excessive. In this case, 100 % of the test voltage specified in Table 17 can be used for 1 s test.

The withstand voltage test at full voltage made on the windings on acceptance shall not be repeated. If, however, a second test is made at the request of the purchaser, after further drying if considered necessary, the test voltage shall be 80 % of the voltage specified in Table 17.

To determine the test voltage from Table 17 for DC motors supplied by static power converters, the direct voltage of the motor or the r.m.s. phase-to-phase value of the rated alternating voltage at the input terminals of the static power converter shall be used, whichever is the greater.

Voltage variation according to 7.3 should not be considered when determining the test voltage.

For variable speed AC machines that are subjected to impulse voltages during operation having assigned an Impulse Voltage Insulation Class (IVIC) according to IEC 60034-18-41 or IEC60034-18-42, the test voltage shall be chosen according to the IVIC of its insulation system as defined in IEC 60034-18-41 or IEC 60034-18-42, respectively (see item 2b in Table 17).

Completely rewound windings shall be tested at the full test voltage for new machines.

When a user and a repair contractor have agreed to carry out withstand voltage tests in cases where windings have been partially rewound or in the case of an overhauled machine, the following procedure is recommended:

a) Partially rewound windings are tested at 75 % of the test voltage for a new machine. Before the test, the old part of the winding shall be carefully cleaned and dried.
b) Overhauled machines, after cleaning and drying, are subjected to a test at a voltage equal to 1,5 times the rated voltage, with a minimum of 1 000 V if the rated voltage is equal to or greater than 100 V and a minimum of 500 V if the rated voltage is less than 100 V.

Table 17 – Withstand voltage tests

Item	Machine or part	Test voltage [e] (r.m.s.)
1	Insulated windings of rotating machines of rated output less than 1 kW (or kVA) and of rated voltage less than 100 V with the exception of those in items 4 to 8	500 V + twice the rated voltage
2	Insulated windings of rotating machines of rated output less than 10 000 kW (or kVA) with the exception of those in item 1 and items 4 to 8 [b]	
2a)	for sinusoidal supply or for frequency converter supply with the exception of those in item 2b	1 000 V + twice the rated voltage with a minimum of 1 500 V [a]
2b)	with an IVIC assigned according to IEC 60034-18-41 or IEC 60034-18-42, i.e. subjected to repetitive impulse voltages, such as those generated by pulse width modulation (PWM) voltage-source converters [f]	1 000 V + twice the rated voltage multiplied with the test voltage factor (TVF) according to Table 18, i.e. 1 000 V + (2 × U_N × *TVF*)
3	Insulated windings of rotating machines of rated output 10 000 kW (or kVA) or more with the exception of those in items 4 to 8 [b] Rated voltage [a]: - up to and including 24 000 V - above 24 000 V	 1 000 V + twice the rated voltage Subject to agreement
4	Separately excited field windings of DC machines	1 000 V + twice the maximum rated circuit voltage with a minimum of 1 500 V
5	Field windings of synchronous generators, synchronous motors and synchronous compensators.	
5a)	Rated field voltage: - up to, and including 500 V, - above 500 V.	 Ten times the rated field voltage with a minimum of 1 500 V 4 000 V + twice the rated field voltage
5b)	When a machine is intended to be started with the field winding short-circuited or connected across a resistance of value less than ten times the resistance of the winding	Ten times the rated field voltage with a minimum of 1 500 V and a maximum of 3 500 V.
5c)	When the machine is intended to be started either with the field winding connected across a resistance of value equal to, or more than, ten times the resistance of the winding, or with the field windings on open circuit with or without a field-dividing switch	1 000 V + twice the maximum value of the r.m.s. voltage, which can occur under the specified starting conditions, between the terminals of the field winding, or in the case of a sectionalized field winding between the terminals of any section, with a minimum of 1 500 V [c]
6	Secondary (usually rotor) windings of induction machines or synchronous induction motors if not permanently short-circuited (e.g. if intended for rheostatic starting)	
6a)	For non-reversing motors or motors reversible from standstill only	1 000 V + twice the open-circuit standstill voltage as measured between slip-rings or secondary terminals with rated voltage applied to the primary windings
6b)	For motors to be reversed or braked by reversing the primary supply while the motor is running	1 000 V + four times the open-circuit standstill secondary voltage as defined in item 6a)
7	Exciters (except as below) Exception 1: exciters of synchronous motors (including synchronous induction motors) if connected to earth or disconnected from the field windings during starting Exception 2: separately excited field windings of exciters (see item 4)	As for the windings to which they are connected 1 000 V + twice the rated exciter voltage, with a minimum of 1 500 V

Item	Machine or part	Test voltage [e] (r.m.s.)
8	Electrically interconnected machines and apparatus	A repetition of the tests in items 1 to 7 above should be avoided if possible, but if a test is performed on a group of machines and apparatus, each having previously passed its withstand voltage test, the test voltage to be applied to such an electrically connected arrangement shall be 80 % of the lowest test voltage appropriate for any individual piece of the arrangement [d]
9	Devices that are in physical contact with windings, for example, temperature detectors, shall be tested to the machine frame. During the withstand voltage test on the machine winding, all devices in physical contact with the winding shall be connected to the machine frame.	1 500 V
10	For devices used on extra-low voltage circuits with protective-separation, which are not used in explosive atmospheres, it is sufficient to connect them to the frame when performing the tests according to the previous items.	no test required

[a] For two-phase windings having one terminal in common, the voltage in the formula shall be the highest r.m.s. voltage arising between any two terminals during operation.

[b] Withstand tests on machines having graded insulation should be the subject of agreement.

[c] The voltage occurring between the terminals of the field windings, or sections thereof, under the specified starting conditions, may be measured at any convenient reduced supply voltage, and the voltage so measured shall be increased in the ratio of the specified starting supply voltage to the test supply voltage.

[d] For windings of one or more machines connected together electrically, the voltage to be considered is the maximum voltage that occurs in relation to earth.

[e] The leakage current drawn by the machine during withstand voltage test will vary according to the size of the machine.

[f] In case of an IVIC assigned, it is sufficient to test the phase-to-ground insulation only.

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

Windings within the scope of IEC 60034-18-41		Windings within the scope of IEC 60034-18-42	
IVIC phase-to-ground	Test voltage factor	IVIC phase-to-ground	Test voltage factor
A	1,0	1 to 4	1,0
B	1,0	5	1,2
C	1,3	6	1,3
D	1,7	7	1,5
S [a]	$\frac{Y}{2\sqrt{2}}$	S [a]	$\frac{Y}{2\sqrt{2}}$

[a] In case of the manufacturer specified Impulse Voltage Insulation Class (IVIC) S, Y is the maximum allowable peak to peak operating value of the phase-to-ground voltage in units of the rated voltage U_N.

9.3 Occasional excess current

9.3.1 General

The excess current capability of rotating machines is given for the purpose of co-ordinating these machines with control and protective devices. Tests to demonstrate these capabilities are not a requirement of this document. The heating effect in the machine windings varies approximately as the product of the time and the square of the current. A current in excess of the rated current will result in increased temperature. Unless otherwise agreed, it can be assumed that the machine will not be operated at the excess currents specified for more than a few short periods during the lifetime of the machine. When an AC machine is to be used as both a generator and a motor, the excess current capability should be the subject of agreement.

NOTE For the capability of synchronous machines concerning the occasional negative-sequence component of current under fault conditions, see 7.2.3.

9.3.2 Generators

AC generators having rated outputs not exceeding 1 200 MVA shall be capable of withstanding a current equal to 1,5 times the rated current for not less than 30 s.

AC generators having rated outputs above 1 200 MVA shall be capable of withstanding a current equal to 1,5 times the rated current for a period which shall be agreed, but this period shall be not less than 15 s.

9.3.3 Motors (except commutator motors and permanent magnet motors)

Polyphase motors having rated outputs not exceeding 315 kW and rated voltages not exceeding 1 kV shall be capable of withstanding:

– a current equal to 1,5 times the rated current for not less than 2 min.

NOTE For polyphase motors having rated outputs above 315 kW and all single-phase motors, no occasional excess current is specified.

9.3.4 Commutator machines

A commutator machine shall be capable of withstanding, for 60 s, 1,5 times rated current under the appropriate combination of conditions as follows:

a) speed:
   1) DC motor: highest full-field speed;
   2) DC generator: rated speed;
   3) AC commutator motor: highest full-field speed;
b) armature voltage: that corresponding to the specified speed.

Attention should be given to the limits of commutation capability. The limits of commutation of a given DC machine are defined in IEC 60034-19.

9.4 Momentary excess torque for motors

9.4.1 Polyphase induction motors and DC motors

Motors, whatever their duty and construction, shall be capable of withstanding an excess torque of at least 60 % of their rated torque for 15 s without either stalling or exhibiting an abrupt change of speed (under gradual increase of torque). The voltage and frequency (for induction motors) shall be maintained at their rated values.

Higher torques are required for some motors manufactured according to IEC 60034-12.

For DC motors, the excess torque shall be expressed in terms of overload current.

Motors for duty type S9 shall be capable of withstanding momentarily an excess torque determined according to the duty specified.

For an approximate determination of the change in temperature due to the current-related losses, the thermal equivalent time constant determined according to 8.8 may be used.

Motors intended for specific applications that require a high torque (for example for hoisting) shall be the subject of agreement.

For cage-type induction motors specially designed to ensure a starting current of less than 4,5 times the rated current, the excess torque can be below the value of 60 % given in paragraph 1, but not less than 50 %, or the value of the excess torque shall be the subject of agreement.

In the case of special types of induction motors with special inherent starting properties, for example motors intended for use at variable frequency or induction motors supplied from static converters, the value of the excess torque shall be the subject of agreement.

9.4.2 Polyphase synchronous motors

Unless otherwise agreed, a polyphase synchronous motor, irrespective of the duty, shall be capable of withstanding an excess torque as specified below for 15 s without falling out of synchronism, the excitation being maintained at the value corresponding to rated load. When automatic excitation is used, the limits of torque shall be the same values with the excitation equipment operating under normal conditions:

– synchronous (wound rotor) induction motors: 35 % excess torque;
– synchronous (cylindrical rotor) motors: 35 % excess torque;
– synchronous (salient pole) motors: 50 % excess torque.

9.4.3 Other motors

The momentary excess torque and time for single-phase, commutator and other motors shall be the subject of agreement.

9.5 Pull-up torque and locked-rotor torque for cage induction motors with direct online starting

Unless otherwise specified (for example machines according to IEC 60034-12), the pull-up torque of cage induction motors under full voltage shall be not less than 0,3 times the rated torque. The locked rotor torque shall also not be less than 0,3 times the rated torque.

9.6 Safe operating speed of cage induction motors

All three-phase single-speed cage induction motors of frame number up to and including 315 and for voltages up to and including 1 000 V shall be capable of safe continuous operation at speeds up to the appropriate speed given in Table 19 unless otherwise stated on the rating plate.

Table 19 – Maximum safe operating speed (min^{-1}) of three-phase single-speed cage induction motors for voltages up to and including 1 000 V

Frame number	2 pole	4 pole	6 pole
≤ 100	5 200	3 600	2 400
112	5 200	3 600	2 400
132	4 500	2 700	2 400
160	4 500	2 700	2 400
180	4 500	2 700	2 400
200	4 500	2 300	1 800
225	3 600	2 300	1 800
250	3 600	2 300	1 800
280	3 600	2 300	1 800
315	3 600	2 300	1 800
NOTE The above values may have to be reduced to meet the requirements of IEC 60079.			

When operating at speeds above rated speed, for example, when used with adjustable speed controls, noise and vibration levels will increase. The user may require the manufacturer to fine balance the motor rotor for acceptable operation above rated speed. Bearing life may be reduced. Attention should be paid to the re-greasing intervals and the grease service life.

9.7 Overspeed

Machines shall be designed to withstand the speeds specified in Table 20.

An overspeed test is not normally considered necessary, but can be performed when this is specified and has been agreed. (For turbine-type AC generators, see also IEC 60034-3.) An overspeed test shall be considered as satisfactory if no permanent abnormal deformation is apparent subsequently, and no other weakness is detected which would prevent the machine from operating normally, and provided the rotor windings after the test comply with the required dielectric tests. The duration of any overspeed test shall be 2 min.

Due to settling of laminated rotor rims, laminated poles held by wedges or by bolts, etc., a minute permanent increase in the diameter is natural, and not to be considered as an abnormal deformation indicating that the machine is not suitable for normal operation.

During commissioning of a hydraulic-turbine driven synchronous generator, the machine shall be driven at the speed it can reach with the overspeed protection operating, so as to ascertain that the balance is satisfactory up to that speed.

Table 20 – Overspeeds

Item	Machine type	Overspeed
1	AC machines All machines other than those specified below:	1,2 times the maximum rated speed
1a)	Water-turbine driven generators, and any auxiliary machines connected directly (electrically or mechanically) to the main machine	Unless otherwise specified, the runaway speed of the set but not less than 1,2 times the maximum rated speed
1b)	Machines which may under certain circumstances be driven by the load	The specified runaway speed of the set but not less than 1,2 times the maximum rated speed.
1c)	Series and universal motors	1,1 times the no-load speed at rated voltage. For motors integrally attached to loads that cannot become accidentally disconnected, the words 'no-load speed' shall be interpreted to mean the lightest load condition possible with the load
1d)	Three-phase single-speed cage induction motors according to 9.6	1,2 times the maximum safe operating speed
2	DC machines	
2a)	Shunt and separately excited motor	1,2 times the highest rated speed or 1,15 times the corresponding no-load speed, whichever is greater
2b)	Compound excited motors having speed regulation of 35 % or less	1,2 times the higher rated speed or 1,15 times the corresponding no-load speed, whichever is greater but not exceeding 1,5 times the highest rated speed
2c)	Compound excited motors having speed regulation greater than 35 % and series motors	The manufacturer shall assign a maximum safe operating speed which shall be marked on the rating plate. The overspeed for these motors shall be 1,1 times the maximum safe operating speed. The safe operating speed marking is not required on motors that are capable of an overspeed of 1,1 times the no-load speed at rated voltage
2d)	Permanent-magnet excited motors	Overspeed as specified in item 2a) unless the motor has a series winding and, in such a case, they shall withstand the overspeeds specified in items 2b) or 2c) as appropriate
2e)	Generators	1,2 times the rated speed

9.8 Short-circuit current for synchronous machines

Unless otherwise specified, the peak value of the short-circuit current for synchronous machines, including turbine-type machines not covered by IEC 60034-3, in the case of short circuit on all phases during operation at rated voltage, shall not exceed 15 times the peak value or 21 times the r.m.s. value of the rated current.

Verification may be carried out by calculation or by means of a test at a voltage of 0,5 times the rated voltage or above.

9.9 Short-circuit withstand test for synchronous machines

The three-phase short-circuit test for synchronous machines shall be carried out only at the request of the purchaser. In this case, the test shall be carried out on the machine running on no-load with an excitation corresponding to the rated voltage unless otherwise agreed. The test shall not be carried out with an excitation greater than that corresponding to 1,05 times the rated voltage at no load.

The excitation for the test, as determined, may be reduced by agreement, in order to take into account the impedance of the transformer which may be placed between the machines and the system. In this latter case, it may also be agreed that the test be made at the operating site with the over-excitation device in operation. The short circuit shall be maintained for 3 s.

The test is considered satisfactory if no harmful deformation occurs and if the requirements of the applied voltage dielectric test (see Table 17) are met after the short-circuit test. For three-phase turbine-type machines, see IEC 60034-3.

9.10 Commutation test for commutator machines

A DC or AC commutator machine shall be capable of operating from no-load to operation with the excess current or excess torque, specified in 9.3 and 9.4 respectively, without permanent damage to the surface of the commutator or brushes and without injurious sparking, the brushes remaining in the same set position. If possible, the commutation test shall be performed in warm conditions.

NOTE Annex A of IEC 60276:2018 gives clarification on how to assess these criteria. In 8.3.2 of IEC 60034-19:2014, it is further specified that "Commutation is assessed by any means that the manufacturer considers reliable".

9.11 Total harmonic distortion (*THD*) for synchronous machines

9.11.1 General

The requirements of this subclause apply only to synchronous machines having rated outputs of 300 kW (or kVA) or more, intended for connection to power networks operating at nominal frequencies of 16 $^{2/3}$ Hz to 100 Hz inclusive, with a view to minimizing interference caused by the machines.

9.11.2 Limits

When tested on open-circuit and at rated speed and voltage, the total harmonic distortion (*THD*) of the line-to-line terminal voltage, as measured according to the methods laid down in 9.11.3, shall not exceed 5 %.

NOTE Limiting values of individual harmonics are not specified as it is considered that machines which meet the above requirements will operate satisfactory.

9.11.3 Tests

Type tests shall be carried out on AC machines to verify compliance with 9.11.2. The range of frequencies measured shall cover all harmonics from rated frequency up to the 100$^{\text{th}}$ harmonic. Synchronous motors do not need to be measured.

Either the *THD* may be measured directly by means of a meter and associated network specially designed for the purpose, or each individual harmonic shall be measured and from the measured values the *THD* shall be computed using the following formula:

$$THD = \sqrt{\sum_{n=2}^{k} u_{\text{n}}^2}$$

where

u_n is the ratio of the line-to-line terminal voltage U_n of the harmonic n of the machine to the line-to-line terminal fundamental voltage U_1 of the machine;

n is the order of harmonic;

k = 100.

9.12 Protective earth test

In a type test of a machine with rated voltage not exceeding AC 1 000 V or DC 1 500 V, respectively, a protective earth test shall be performed in addition.

Machines with rated voltage not exceeding AC 1 000 V or DC 1 500 V, respectively, and with an earthing terminal require a protective earth type test to ensure sufficiently small internal resistances. If not defined by a different product standard, the type test can be done by determining the possible voltage drop between any point of the machine, which has the risk of coming into contact with live parts, and the earthing terminal. The test is considered successful, when the measured value of the resistance $R_{PE,M}$ between these two points does not exceed:

$$R_{PE,M} \leq 0{,}8 \cdot 30\ V / (K \cdot I_N) \text{ for AC circuits,}$$

$$R_{PE,M} \leq 0{,}8 \cdot 60\ V / (K \cdot I_N) \text{ for DC circuits,}$$

where

I_N is the rated current of the machine,

0,8 is a safety factor, and

K is a factor as shown in Figure 13.

The factor K is derived from the typical fuse size assigned to motors for direct online starting with a ratio of starting current to rated current of 10, multiplied by 2. This approach is valid for generators as well. For power ratings above 1 000 kW, K = 3,4 applies.

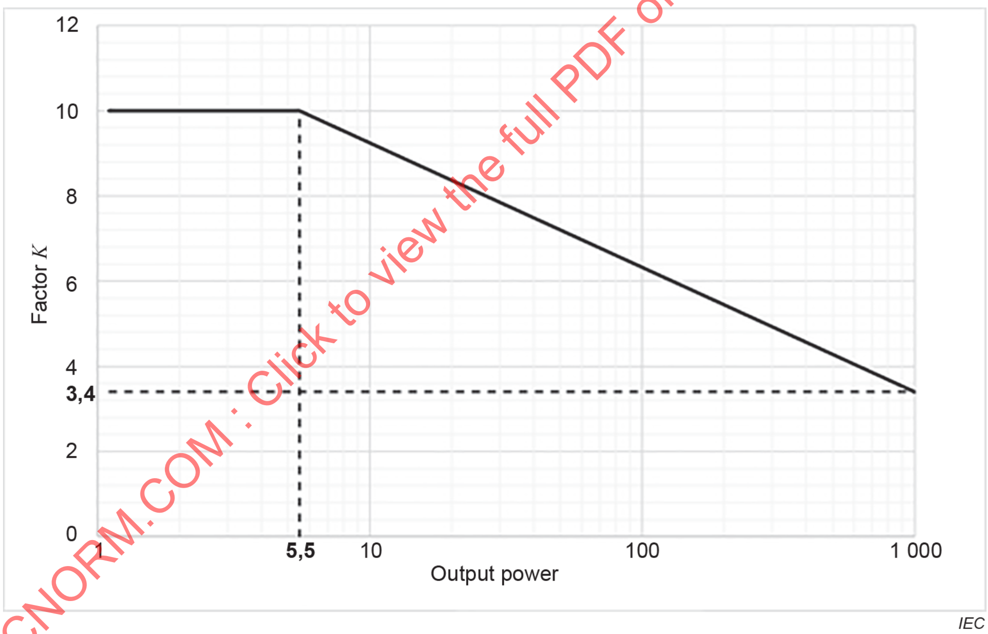


Figure 13 – Factor K for determining $R_{PE,M}$

The current used to determine the resistance $R_{PE,M}$ shall be at least 3 A.

NOTE The method is based on the protective equipotential bonding impedance type test described in IEC 62477-1.

9.13 Measurement of insulation resistance and polarization index of winding insulation

For measurement of insulation resistance and polarization index of a winding insulation, see IEC 60034-27-4.

9.14 Shaft-voltage test

A shaft-voltage test shall not be made in case of insulated bearings (1 MΩ or higher for sinusoidal or DC power supply) or in case safety aspects are concerned. The shaft voltage of (mainly) supply frequency (not to be mixed-up with a HF shaft voltage, see 3.37) shall be measured directly between the two shaft ends of an electrical machine being operated at rated voltage and rated frequency at no load and preferably uncoupled. It is not permitted to determine the shaft voltage by measuring the shaft-to-ground voltages across the two bearings and subtracting the values, as this may lead to false results. The shaft voltage has to be evaluated as RMS value. As long as no other limitation is agreed on between manufacturer and customer, the RMS value of the shaft voltage in case of non-insulated ball or roller bearings (or similar) should not exceed 350 mV.

10 Information requirements

10.1 General

Each electrical machine shall be delivered with appropriate documentation comprising the minimally required information (see 10.4) and a rating plate or rating plates (see 10.3).

10.2 Product documentation

The product documentation shall be delivered by the manufacturer including the data sheets and/or operating manual. This documentation can be supplied with the motor physically or in a digital form. For series production of standardized machines, this information can also be directly accessible in the manufacturer's website, which should be easily available. The minimum content of the product document is given in 10.4.

10.3 Rating plate

The plates shall be made of durable material and be securely mounted. The writing has to be made with durable marking (e.g. print, engraving).

The rating plate(s) shall preferably be mounted on the frame of the machine and be located so as to be easily legible in the position of use determined by the type of construction and mounting arrangement of the machine. If the electrical machine is so enclosed or incorporated in the equipment that its rating plate is not easily legible, the manufacturer shall, on request, supply a second plate to be mounted on the equipment.

Rating plate(s) shall be durably marked with the items in 10.4, as far as they apply. The items need not all be on the same plate. Letter symbols for units and quantities shall be in accordance with IEC 60027-1 and IEC 60027-4.

As an option, the rating plate or another part of the machine (e.g. inside the machine's terminal box) may carry an electronic identification symbol, e.g. a QR code, including a direct link to the product documentation at the manufacturer's website.

NOTE QR code according to ISO/IEC 18004:2015.

Except for normal maintenance (lubrification, cleaning, bearing replacement), when a machine is repaired or refurbished, an additional plate shall be provided to indicate the name of the company undertaking the work, the year of repair. In case of modification, the changes affecting the original rating plate data shall be displayed on this additional plate, as well. Additional information on the modifications and its influence to technical data not being displayed on the rating plate can be received from the company undertaking the work.

10.4 Information content

10.4.1 General

The items in 10.4.2 to 10.4.5 shall be given, when applicable, in the product documentation as well as on the rating plate(s). If the manufacturer gives more information in the product documentation, this need not necessarily be marked on the rating plate(s). The items in 10.4.6 are optional, but recommended at least for machines over 5 kW (or 5 kVA) rated output.

The items are numbered a) to jj) for convenient reference, but the order in which they appear in the product documentation and on the rating plate(s) is not standardized. Items may be suitably combined.

10.4.2 Minimum information requirements

The minimum information requirements for machines with all rated output sizes, including special-purpose and built-in machines, are:

a) The manufacturer's name or mark.

b) The manufacturer's serial number or identification mark.

NOTE 1 A single identification mark may be used to identify each member of a group of machines which are made to the same electrical and mechanical design and are produced in one batch using the same technology.

c) The manufacturer's machine code.

d) Information to identify the year of manufacture.

e) The rated voltage(s) or range of rated voltage;
two different rated values shall be indicated by "/" (e.g. 400V/230 V) while a range of rated values shall be indicated by "-" (e.g. 380V-440 V).

NOTE 2 In all these cases, voltage (and frequency) variations according to 7.4 are valid and will not be indicated separately.

f) The rated current(s) or range of rated current.

g) The connecting instructions in accordance with IEC 60034-8 by means of a diagram (or text located near the terminals).

h) The rated output(s) or range of rated output power and the class(es) of rating of the machine if designed for other than rating for continuous running duty S1, see 5.2.

i) The rated speed(s) or range of rated speed and the permissible overspeed if other than specified in 9.7 or the maximum safe operating speed if less than in 9.6 or in case of a converter duty machine, given in the unit min^{-1} or 1/min. In case of a converter duty machine, the range of speed can also be given in per unit or percent of the rated speed.

j) For motors within the scope of IEC 60034-30-1 and IEC 60034-30-2, the efficiency class (IE code) and for motors within the scope of IEC 60034-30-1 also the rated efficiency.

k) When specified, the approximate total mass of the machine, if exceeding 30 kg.

l) The degree of protection provided by the integral design of the rotating electrical machine (IP code) in accordance with IEC 60034-5.

m) The thermal class and the limit of temperature or of temperature rise (when lower than that of the thermal class) in accordance with IEC 60085 and, if necessary, the method of measurement, followed in the case of a machine with a water-cooled heat exchanger by 'P' or 'S', depending on whether the temperature rise is measured above the primary or secondary coolant respectively (see 8.2). This information shall be given for both stator and rotor (separated by a slash) when their thermal class differ.

n) For motors within the scope of IEC 60034-12, the design letter(s) as specified in Clause 5 of IEC 60034-12: 2016 indicating the starting requirements in case it is not design N.

o) For machines suitable for operation in only one direction of rotation, the direction of rotation, indicated either by indicating cw (clockwise) or ccw (counter clockwise) on the rating plate or by an arrow. This arrow need not be on the rating plate, but it shall be easily visible.

p) The altitude for which the machine is designed if exceeding 1 000 m above sea level.

10.4.3 All AC machines

10.4.3.1

q) For AC machines, the number of phases.

r) For AC machines the rated frequency and in case of converter duty machines the term 'converter duty'.
For universal motors, the rated frequency shall be followed by the appropriate symbol, for example, ~ 50 Hz / ⎓ (IEC 60417-5031) or AC 50 Hz / DC.

10.4.3.2 All synchronous machines

s) In case of machines excited by permanent magnets, the open circuit voltage at rated speed.

t) In case of electrical excitation, the rated field voltage and the rated field current.

u) In case of electrical excitation, the rated power factor.

10.4.3.3 All wound-rotor induction machines

v) The rated open-circuit voltage between slip-rings and the rated slip-ring current.

10.4.4 All DC machines

w) For machines with separate excitation or with shunt excitation, the rated field voltage and the rated field current.

x) The rated form factor and the rated alternating voltage at the input terminals of the static power converter, when this exceeds the rated direct voltage of the motor armature circuit.

10.4.5 Machines over 5 kW (or 5 kVA) rated output

y) The number(s) of the rating and performance standard(s) which are applicable (IEC 60034-x and/or equivalent national standard(s)). If IEC 60034 is marked, this implies compliance with all the other relevant standards of the IEC 60034 series. If IEC 60034-1 is marked, this implies compliance with the standard itself, not with the references.

z) The maximum ambient air temperature if other than 40 °C.

aa) The minimum ambient air temperature if other than specified in 6.4.

bb) The maximum water coolant temperature if other than 25 °C.

cc) For hydrogen-cooled machines, the hydrogen pressure at rated output.

10.4.6 Optional information

dd) The method of cooling (IC code) in accordance with IEC 60034-6 in case it is not IC411.

ee) For AC machines, the rated power factor(s).

ff) For induction machines, the locked rotor apparent power.

gg) The types of the bearings, the type of grease or oil and the lubrication interval in case of roller or ball bearings.

hh) For motors with duty type S9, the momentary excess torque capability at rated speed in percent of the rated torque, in case the value exceeds 160 %.

ii) For machines with an IVIC assigned, the IVIC level in accordance with IEC 60034-18-41 or IEC 60034-18-42, respectively.

jj) For converter capable machines (see 3.35), the term 'converter capable'.

11 Miscellaneous requirements

11.1 Protective earthing of machines

Machines shall be provided with an earthing terminal or another device to permit the connection of a protective conductor or an earthing conductor.

The symbol  (IEC 60417-5019) or legend shall identify this device. However, machines shall neither be earthed nor be provided with an earthing terminal when:

a) they are fitted with supplementary insulation, or;

b) they are intended for assembly in apparatus having supplementary insulation, or;

c) they have rated voltages up to AC 50 V or DC 120 V and are intended for use on SELV circuits.

NOTE 1 The term SELV is defined in IEC 60884-2-4.

In the case of machines having rated voltages greater than AC 50 V or DC 120 V, but not exceeding AC 1 000 V or DC 1 500 V, the terminal for the earthing conductor shall be situated in the vicinity of the terminals for the line conductors, being placed in the terminal box, if one is provided. Machines having rated outputs in excess of 100 kW (or kVA) shall have in addition an earthing terminal fitted on the frame.

Machines for rated voltages greater than AC 1 000 V or DC 1 500 V shall have an earthing terminal on the frame, for example an iron strap, and in addition, a means inside the terminal box for connecting a conducting cable sheath, if any.

The earthing terminal shall be designed to ensure a good connection with the earthing conductor without any damage to the conductor or terminal. Accessible conducting parts which are not part of the operating circuit shall have good electrical contact with each other and with the earthing terminal if there is a risk that they will come into contact with live parts. When all bearings and the rotor winding of a machine are insulated, the shaft shall be electrically connected to the earthing terminal, unless the manufacturer and the purchaser agree to alternative means of protection.

When an earthing terminal is provided in the terminal box, it shall be assumed that the earthing conductor is made of the same metal as the lead conductors.

When an earthing terminal is provided on the frame, the earthing conductor may, by agreement, be made of another metal (for example, steel). In this case, in designing the terminal, proper consideration shall be given to the conductivity of the conductor.

The earthing terminal shall be designed to accommodate an earthing conductor of cross-sectional area in accordance with Table 21. If an earthing conductor larger than the size given in Table 21 is used, it is recommended that it should correspond as nearly as possible to one of the other sizes listed.

For other cross-sectional areas of phase conductors, the earthing or protective conductor shall have a cross-sectional area at least equivalent to:

– that of the phase conductor for cross-sectional areas less than 25 mm^2;

– 25 mm^2 for cross-sectional areas between 25 mm^2 and 50 mm^2;

– 50 % of that of the phase conductor for cross-sectional areas exceeding 50 mm^2.

For generators ≥ 20 MVA the earthing conductor cross-sectional area outside the machine should be calculated by the system integrator and the neutral point bus-bar cross-sectional area by the manufacturer to safely meet the short circuit current at double earth fault during the time needed until the machine has been disconnected by the protective system and is deexcited. The earthing terminal shall be identified in accordance with IEC 60445.

In the documentation of each machine with rated voltage not exceeding AC 1 000 V or DC 1 500 V, respectively, it shall be clearly stated that a protective earth test as required by IEC 60364, if applicable, or as stated by specific customer requirements shall be made after the installation of the machine. The responsibility for conducting this test is not with the machine manufacturer, but with the end-user or the system integrator.

NOTE 2 For small machines with frame sizes below 63 mm, proper earthing may be provided by the flange alone.

Table 21 – Cross-sectional areas of earthing conductors

Cross-sectional area of the phase conductor mm^2	**Cross-sectional area of the earthing or protective conductor** mm^2
4	4
6	6
10	10
16	16
25	25
35	25
50	25
70	35
95	50
120	70
150	70
185	95
240	120
300	150
400	185

11.2 Shaft-end key(s)

When a machine shaft end is provided with one or more keyways, each shall be provided with a full key of normal shape and length.

12 Tolerances

12.1 General

Tolerance is the maximum allowed deviation between the test result of a quantity from Table 22 and the declared value on the rating plate or in the catalogue. As long as test procedures and test equipment according to IEC standards are used, the test result shall not exceed the allowed deviation independent of test laboratory or equipment. Tolerance does not cover the uncertainty of a test procedure, i.e. the deviation between the test result and the true value. The tolerances of the test equipment itself are included in the tolerances specified in Table 22.

NOTE 1 In case of a series production the tolerance applies to any selected sample, i.e. tolerance covers variations in raw material properties and manufacturing procedures.

NOTE 2 Detailed information on the influence of measurement uncertainty can be found in IEC Guide 115:2021.

12.2 Tolerances on values of quantities

Unless stated otherwise, tolerances on declared values shall be as specified in Table 22.

Table 22 – Schedule of tolerances on values of quantities

Item	Quantity	Tolerance
1	Efficiency η [c]	–15 % of $(1 - \eta)$
2	Rated field current of synchronous machines	+15 % of the value
3	Power-factor, cos ϕ, for induction machines and permanent magnet synchronous machines operating direct on-line	–1/6 (1 – cos ϕ) Minimum absolute value 0,02 Maximum absolute value 0,07
4	Speed of DC motors (at full load and at working temperature) [a]	
4a)	Shunt and separately excited motors	1 000 P_N/n_N < 0,67 ± 15 % 0,67 ≤ 1 000 P_N/n_N < 2,5 ± 10 % 2,5 ≤ 1 000 P_N/n_N < 10 ± 7,5 % 10 ≤ 1 000 P_N/n_N ± 5 %
4b)	Series motors	1 000 P_N/n_N < 0,67 ± 20 % 0,67 ≤ 1 000 P_N/n_N < 2,5 ± 15 % 2,5 ≤ 1 000 P_N/n_N < 10 ± 10 % 10 ≤ 1 000 P_N/n_N ± 7,5 %
4c)	Compound excited motors	Tolerances as for item 4b) unless otherwise agreed
5	Variation of speed of DC shunt and compound excited motors (from no-load to full load)	±20 % of the variation with a minimum of ±2 % of the rated speed
6	Inherent voltage regulation of DC generators, shunt or separately excited at any point on the characteristic	±20 % of the regulation at that point
7	Inherent voltage regulation of compound excited generators (at the rated power-factor in the case of alternating current)	±20 % of the regulation, with a minimum of ±3 % of the rated voltage. (This tolerance applies to the maximum deviation at any load between the observed voltage at that load and a straight line drawn between the points of no-load and full-load voltage.)
8 a)	Slip of induction machines (at full load and at working temperature) P_N < 1 kW P_N ≥ 1 kW	 ±30 % of the slip ±20 % of the slip
8 b)	Speed of AC (commutator) motors with shunt characteristics (at full load and at working temperature)	– on the highest speed: –3 % of the synchronous speed – on the lowest speed: +3 % of the synchronous speed
9	Locked rotor current of cage induction motors with any specified starting apparatus	+20 % of the current; for motors within the scope of IEC 60034-12, the limit specified in IEC 60034-12 for the locked rotor apparent power shall not be exceeded.
10	Locked rotor torque of cage induction motors	$^{+25}_{-15}$ % of the torque. (+25 % may be exceeded by agreement)

Item	Quantity	Tolerance
11	Pull-up torque of cage induction motors	−15 % of the value
12	Breakdown torque of induction motors	−10 % of the torque except that after allowing for this tolerance the torque shall be not less than 1,6 or 1,5 times the rated torque, see 9.4.1
13	Locked rotor current of synchronous motors	+ 20 % of the value
14	Locked rotor torque of synchronous motors	$^{+25}_{-15}$ % of the value (+25 % may be exceeded by agreement)
15	Pull-out torque of synchronous motors	−10 % of the value except that after allowing for this tolerance, the torque shall be not less than 1,35 or 1,5 times the rated torque, see 9.4.2
16	Peak value of short-circuit current of an AC generator under specified conditions	±30 % of the value[b]
17	Steady short-circuit current of an AC generator at specified excitation	±15 % of the value
18	Moment of inertia	±10 % of the value
19	Average A-weighted sound pressure level or sound power level at no-load and sinusoidal supply	+ 3 dB(A)

NOTE When a tolerance is stated in only one direction, the value is not limited in the other direction.

[a] Tolerances in item 4 depend on the ratio of rated output P_N in kW, to rated speed in min^{-1}.

[b] For some simulations, tolerances in item 16 are too wide. Manufacturer and customer may agree on higher accuracy.

[c] The tolerance on efficiency implies a tolerance on the total losses of +15 % of the total losses.

13 Electromagnetic compatibility (EMC)

13.1 General

The EMC requirements specified in this clause apply to rotating electrical machines with rated voltages not exceeding AC 1 000 V or DC 1 500 V intended for operation and use in residential, commercial or industrial environments.

Electronic components mounted inside a rotating electrical machine and which are essential for its operation (for example rotating excitation devices) are part of the machine.

Requirements which apply to the final drive system and its components, for example power and control electronic equipment, coupled machines, monitoring devices, etc., whether mounted inside or outside the machine, are outside the scope of this document.

The requirements of this clause apply to machines that are supplied directly to the end-user.

NOTE 1 The purpose of this clause is to give advice for contractual agreements between supplier and end-user.

NOTE 2 Machines that are intended for incorporation as components in an apparatus, where the enclosure and assembly will affect the EMC emissions, are covered by the EMC standard that relates to the final product.

In synchronous machines, electronic power supplies of the exciter machine's stator being part of the synchronous machine shall comply with the EMC requirements of this document.

NOTE 3 As the generator in a power plant is often a very large machine having some higher magnetic fields outside the housing, it is possible to define boundaries around the generator in the machine hall, inside of which fields may be higher than according to CISPR requirements and access is forbidden for electronic devices and restricted to allowed staff only.

Transients (such as starting) are not covered by this clause.

13.2 Immunity

13.2.1 Machines not incorporating electronic circuits

Machines without electronic circuits are not sensitive to electromagnetic emissions under normal service conditions and, therefore, no immunity tests are required.

13.2.2 Machines incorporating electronic circuits

As electronic circuits which are incorporated in machines generally utilize components that are passive (for example diodes, resistors, varistors, capacitors, surge suppressors, inductors), immunity tests are not required.

13.3 Emission

For machines intended for use in residential environments, radiated and conducted emissions shall comply with the requirements of CISPR 11 for class B group 1 equipment, see Table B.1, in Annex B.

For machines intended for use in industrial environments, radiated and conducted emissions shall comply with the requirements of CISPR 11 for class A group 1 equipment with a rated input power of ≤ 20 kVA , independently from their actual rated input power. These limits are also found in Table B.2.

13.4 Immunity tests

Immunity tests are not required.

13.5 Emission measurements

For general purpose rotating electrical machines, type tests shall be carried out in accordance with CISPR 11 and the respective parts of the CISPR 16 standards series as applicable. Type tests on rotating electrical machines intended for assembly into final products in the scope of CISPR 14 shall be carried out also observing the advice found in CISPR 14.

For the measurements, the requirements specified in 13.3 apply.

Machines without brushes shall comply with the emission limits of 13.3 with any load condition.

Machines with brushes shall at least comply with the emission limits of CISPR 11 for class A group 1 equipment with a rated input power of ≤ 20 kVA , independently from their actual rated input power, when tested without a load. Such machines need to be denoted as class A components.

Cage induction machines do not need to be measured.

Emissions at terminals intended for earthing or grounding do not need to be measured.

14 Application requirements

Rotating machines in accordance with this document shall comply with the requirements of IEC 60204-1 or IEC 60204-11 or, in the case of rotating machines incorporated in household and similar electrical appliances, IEC 60335-1, as appropriate unless otherwise specified in this document, and be designed and constructed as far as possible in accordance with internationally accepted best design practice, appropriate to the application.

NOTE It is the responsibility of the manufacturer or assembler of equipment incorporating electrical machines as components to ensure that the overall equipment is safe.

This may involve consideration of relevant product standards such as:

IEC 60079 (all parts),and other parts of IEC 60034 including:

IEC 60034-5, IEC 60034-6, IEC 60034-7, IEC 60034-8, IEC 60034-9, IEC 60034-11, IEC 60034-12 and IEC 60034-14.

In addition, it may be necessary to consider limitation of the surface temperature and similar characteristics; see for example IEC 60335-1:2020, Clause 11: Heating.

Annex A
(informative)

Guidance for the application of duty type S10 and for establishing the value of relative thermal life expectancy *TL*

A.1 The load of the machine at any moment is equivalent to duty type S1 corresponding to 4.2.1. However, the load cycle may comprise loads other than the rated load based on duty type S1. A load cycle comprising four discrete constant load/speed combinations is shown in Figure 10.

A.2 Depending on the value and duration of the different loads within one cycle, the relative life expectancy of the machine based on the thermal ageing of the insulation system can be calculated by the following formula:

$$\frac{1}{TL} = \sum_{i=1}^{n} \Delta t_i \times 2^{\frac{\Delta\Theta_i}{k}}$$

where

TL is the relative thermal life expectancy related to the thermal life expectancy in case of duty type S1 with rated output;

$\Delta\Theta_i$ is the difference between the temperature rise of the winding at each of the various loads within one cycle and the temperature rise based upon duty type S1 with reference load;

Δt_i is the p.u. time of a constant load within a load cycle;

k is the increase in temperature rise in K, which leads to a shortening of the thermal life expectancy of the insulation system by 50 %;

n is the number of discrete values of load.

A.3 The quantity TL is an integral part of the unambiguous identification of the class of rating.

A.4 The value of the quantity TL can be determined only when, in addition to information concerning the load cycle according to Figure 10, the value k for the insulation system is known. This value k has to be determined by experiments in conformity with IEC 60034-18 for the whole temperature range within which the load cycle takes place according to Figure 10.

A.5 TL can be stated sensibly as a relative value only. This value can be used by approximation to assess the real change in the machine thermal life expectancy as compared to duty type S1 with rated output, because it may be assumed that in consideration of the varying loads existing within a cycle the remaining influences over the lifetime of the machine (e.g. dielectric stress, environmental influences) are approximately the same as in the case of duty type S1 with rated output.

A.6 The manufacturer of the machine is responsible for the correct compilation of the various parameters for determining the value of TL.

Annex B
(informative)

Electromagnetic compatibility (EMC) limits

Table B.1 – Electromagnetic emission limits per CISPR 11 Class B Group 1

	Frequency range	Limits
Radiated emission	30 MHz to 230 MHz	30 dB(µV/m) quasi peak, measured at 10 m distance (Note)
	230 MHz to 1 000 MHz	37 dB(µV/m) quasi peak, measured at 10 m distance (Note)
Conducted emission on AC or DC power supply terminals	0,15 MHz to 0,50 MHz Limits decrease linearly with logarithm frequency	66 dB(µV) to 56 dB(µV) quasi peak 56 dB(µV) to 46 dB(µV) average
	0,50 MHz to 5 MHz	56 dB(µV) quasi peak 46 dB(µV) average
	5 MHz to 30 MHz	60 dB(µV) quasi peak 50 dB(µV) average

NOTE May be measured at 3 m distance using the limits increased by 10 dB.

Table B.2 – Electromagnetic emission limits per CISPR 11 Class A Group 1

	Frequency range	Limits
Radiated emission	30 MHz to 230 MHz	30 dB(µV/m) quasi peak, measured at 30 m distance (Note)
	230 MHz to 1 000 MHz	37 dB(µV/m) quasi peak, measured at 30 m distance (Note)
Conducted emission on AC or DC power supply terminals	0,15 MHz to 0,50 MHz	79 dB(µV) quasi peak 66 dB(µV) average
	0,50 MHz to 30 MHz	73 dB(µV) quasi peak 60 dB(µV) average

NOTE May be measured at 10 m distance using the limits increased by 10 dB or measured at 3 m distance using the limits increased by 20 dB.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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MACHINES ÉLECTRIQUES TOURNANTES –

Partie 1: Caractéristiques assignées et caractéristiques de fonctionnement

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L’IEC 60034-1 a été établie par le comité d’études 2 de l'IEC: Machines tournantes. Il s'agit d'une Norme internationale.

Cette quatorzième édition annule et remplace la treizième édition parue en 2017. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

Article ou paragraphe	Modifications
1	Clarification du domaine d'application
2	Généralités sur l'utilisation des références datées
3.29	Clarification relative à l'identification de l'intensité maximale et minimale
3.34	Définition de l'isolation principale
3.35	Définition d'une machine apte à fonctionner sur convertisseur
3.36	Définition d'une machine fonctionnant exclusivement sur convertisseur
3.37	Définition de la tension d'arbre
4.2	Explications relatives à l'utilisation des services types S9 et S10 pour les machines fonctionnant exclusivement sur convertisseur
5.6.3	Nouveau paragraphe de clarification des termes plage de tensions assignées et variations de tension
6.2	Exigence relative à la prise en considération d'une distance de claquage réduite dans la conception des machines pour les altitudes > 1 000 m
7.1	Clarification sur le transfert par bus ou le réenclenchement rapide Clarification sur la capacité de tenue aux chocs électriques
7.3	Nouveau paragraphe sur l'écart de tension pendant le démarrage
7.4	Extension de la variation de la fréquence de l'alimentation Ajout d'une note relative à la conception pour un fonctionnement avec une tension et une fréquence étendues Ajout d'un déclassement recommandé pour les variations importantes de tension et de fréquence
7.6	Clarification du fait que les fils émaillés ne constituent pas un matériau actif nu
8.3.1	Ajout d'une clarification concernant l'alimentation électrique pendant les essais thermiques
9.1	Modifications du Tableau 16, en particulier l'inclusion des aimants permanents (PM - *permanent magnets*) et des machines à réluctance synchrone
9.2	Ajout d'une exigence relative à l'équipement d'essai pour l'essai de tension de tenue Ajout d'une tension d'essai pour les machines à courant alternatif à vitesse variable Clarification apportée aux essais de tension de tenue pour les machines après stockage
9.5	Paragraphe étendu aux exigences relatives au couple à rotor bloqué minimal
9.10	Ajout d'une note sur les critères relatifs à l'essai de commutation
9.11.3	Ajout d'une clarification concernant le fait que les moteurs synchrones ne nécessitent pas un essai de distorsion harmonique totale (THD - *total harmonic distortion*)
9.12	Nouveau paragraphe relatif à l'essai de mise à la terre
9.13	Nouveau paragraphe relatif au mesurage de la résistance d'isolation et l'indice de polarisation
9.14	Nouveau paragraphe relatif au mesurage de la tension d'arbre
10	Cet article a été entièrement réorganisé Ajout d'une clarification sur le symbole d'unité pour la vitesse
11.1	Ajout d'une clarification concernant l'essai de mise à la terre après l'installation
12.1	Clarification concernant les tolérances en raison de l'exactitude de l'équipement d'essai Ajout d'une note concernant l'incertitude de mesure
12.2	Modification de la tolérance relative au rendement Clarification concernant la tolérance relative au courant à rotor bloqué Nouvelle tolérance concernant le niveau de pression acoustique
14	Amélioration du titre de l'article

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
2/2084/FDIS	2/2090/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Le présent document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

Une liste de toutes les parties de la série IEC 60034, publiée sous le titre général *Machines électriques tournantes*, se trouve sur le site web de l'IEC.

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MACHINES ÉLECTRIQUES TOURNANTES –

Partie 1: Caractéristiques assignées et caractéristiques de fonctionnement

1 Domaine d'application

La présente partie de l'IEC 60034 s'applique à toutes les machines électriques tournantes à l'exception des machines destinées aux véhicules ferroviaires et routiers, qui sont couvertes par la série de normes IEC 60349.

Les machines comprises dans le domaine d'application du présent document peuvent également être soumises à des exigences nouvelles, modifiées ou complémentaires figurant dans d'autres normes, par exemple, les séries IEC 60079 et IEC 60092.

NOTE Si certains articles du présent document sont modifiés afin de permettre des applications spéciales, par exemple pour les machines soumises à la radioactivité ou les machines aérospatiales, tous les autres articles s'appliquent dans la mesure où ils sont compatibles.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60027-1:1992, *Symboles littéraux à utiliser en électrotechnique – Partie 1: Généralités*
IEC 60027-1:1992/AMD1:1997
IEC 60027-1:1992/AMD2:2005

IEC 60027-4:2006, *Symboles littéraux à utiliser en électrotechnique – Partie 4: Machines électriques tournantes*

IEC 60034-2 (toutes les parties), *Machines électriques tournantes – Partie 2: Méthodes normalisées pour la détermination des pertes et du rendement à partir d'essais (à l'exclusion des machines pour véhicules de traction)*

IEC 60034-3:2020, *Machines électriques tournantes – Partie 3: Exigences spécifiques pour les alternateurs synchrones entraînés par des turbines à vapeur ou par des turbines à gaz et pour les compensateurs synchrones*

IEC 60034-5:2020, *Machines électriques tournantes – Partie 5: Degrés de protection procurés par la conception intégrale de machines électriques tournantes (code IP) – Classification*

IEC 60034-6:1991, *Machines électriques tournantes – Partie 6: Modes de refroidissement (code IC)*

IEC 60034-8:2007, *Machines électriques tournantes – Partie 8: Marques d'extrémité et sens de rotation*
IEC 60034-8:2007/AMD1:2014

IEC 60034-12:2016, *Machines électriques tournantes – Partie 12: Caractéristiques de démarrage des moteurs triphasés à induction à cage à une seule vitesse*

IEC 60034-15:2009, *Machines électriques tournantes – Partie 15: Niveaux de tenue au choc électrique des bobines de stator préformées des machines tournantes à courant alternatif*

IEC 60034-18 (toutes les parties), *Machines électriques tournantes – Partie 18: Évaluation fonctionnelle des systèmes d'isolation*

IEC 60034-18-41:2014, *Machines électriques tournantes – Partie 18-41: Systèmes d'isolation électrique sans décharge partielle (Type I) utilisés dans des machines électriques tournantes alimentées par des convertisseurs de tension – Essais de qualification et de contrôle qualité*
IEC 60034-18-41:2014/AMD1:2019

IEC 60034-18-42:2017, *Machines électriques tournantes – Partie 18-42: Systèmes d'isolation électrique résistants aux décharges partielles (Type II) utilisés dans des machines électriques tournantes alimentées par convertisseurs de tension – Essais de qualification*
IEC 60034-18-42:2017/AMD1:2020

IEC 60034-19:2014, *Machines électriques tournantes – Partie 19: Méthodes spécifiques d'essai pour machines à courant continu à alimentation conventionnelle ou redressée*

IEC TS 60034-25:2014, *Machines électriques tournantes – Partie 25: Machines électriques à courant alternatif utilisées dans les entraînements électriques de puissance – Guide d'application*

IEC 60034-27-4, *Machines électriques tournantes – Partie 27-4: Mesure de la résistance d'isolement et de l'index de polarisation sur le système d'isolation des enroulements des machines électriques tournantes*

IEC 60034-29:2008, *Machines électriques tournantes – Partie 29: Techniques par charge équivalente et par superposition – Essais indirects pour déterminer l'échauffement*

IEC 60034-30-1:2014, *Machines électriques tournantes – Partie 30-1: Classes de rendement pour les moteurs à courant alternatif alimentés par le réseau (code IE)*

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

IEC 60034-33: *Rotating electrical machines – Part 33: Specific technical requirements for hydro generators* (disponible en anglais seulement)

IEC 60050-411:1996, *Vocabulaire électrotechnique international – Chapitre 411: Machines tournantes*
IEC 60050-411:1996/AMD1:2007
IEC 60050-411:1996/AMD2:2021

IEC 60060-1:2010, *Technique des essais à haute tension – Partie 1: Définitions et exigences générales*

IEC 60085:2007, *Isolation électrique – Évaluation et désignation thermiques*

IEC 60204-1:2016, *Sécurité des machines – Équipement électrique des machines – Partie 1: Exigences générales*

IEC 60204-11:2018, *Sécurité des machines – Équipement électrique des machines – Partie 11: Exigences pour les équipements fonctionnant à des tensions supérieures à 1 000 V en courant alternatif ou 1 500 V en courant continu et ne dépassant pas 36 kV*

IEC 60335-1:2020, *Household and similar electrical appliances – Safety – Part 1: General requirements* (disponible en anglais seulement)

IEC 60364 (toutes les parties), *Installations électriques à basse tension*

IEC 60417, *Symboles graphiques utilisables sur le matériel*

IEC 60445:2017, *Principes fondamentaux et de sécurité pour les interfaces homme-machine, le marquage et l'identification – Identification des bornes de matériels, des extrémités de conducteurs et des conducteurs*

IEC 60664-1:2020, *Coordination de l'isolement des matériels dans les réseaux d'énergie électrique à basse tension – Partie 1: Principes, exigences et essais*

IEC 61148:2011, *Marquage des bornes de blocs et d'ensembles d'éléments de valve et d'équipement de conversion de puissance*

IEC TS 61800-8, *Adjustable speed electrical power drive systems – Part 8: Specification of voltage on the power interface* (disponible en anglais seulement)

CISPR 11:2015, *Appareils industriels, scientifiques et médicaux – Caractéristiques de perturbations radioélectriques – Limites et méthodes de mesure*
CISPR 11:2015/AMD1:2016
CISPR 11:2015/AMD2:2019

CISPR 14 (toutes les parties), *Compatibilité électromagnétique – Exigences relatives aux appareils électrodomestiques, aux outils électriques et aux appareils analogues*

CISPR 16 (toutes les parties), *Spécifications des méthodes et des appareils de mesure des perturbations radioélectriques et de l'immunité aux perturbations radioélectriques*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions de l'IEC 60050-411, ainsi que les suivants s'appliquent.

NOTE 1 Pour des définitions autres que celles en 3.17 à 3.22 concernant le refroidissement et les fluides de refroidissement, voir l'IEC 60034-6.

NOTE 2 Pour les besoins du présent document, le terme "accord" signifie "accord entre le constructeur et l'acheteur".

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1
valeur assignée
valeur d'une grandeur fixée, généralement par le constructeur, pour un fonctionnement spécifié d'une machine

Note 1 à l'article: La tension assignée ou plage de tensions assignées est la tension assignée ou plage de tensions assignées entre phases aux bornes.

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

3.2
caractéristiques assignées
ensemble des valeurs assignées et des conditions de fonctionnement

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

3.3
puissance (utile) assignée
valeur de la puissance (utile) incluse dans les caractéristiques assignées

3.4
charge
ensemble des valeurs des grandeurs électriques, *dans le cas d'un générateur*, et mécaniques, *dans le cas d'un moteur*, qui caractérisent les exigences imposées à une machine tournante par un circuit électrique ou un dispositif mécanique à un instant donné

[SOURCE: IEC 60050-411:1996, 411-51-01, modifié: modification indiquée en italique]

3.5
fonctionnement à vide
état de fonctionnement d'une machine tournant à puissance nulle *(mais en conditions normales de fonctionnement par ailleurs)*

[SOURCE: IEC 60050-411:1996, 411-51-02, modifié: modification indiquée en italique]

3.6
pleine charge
charge amenant une machine à fonctionner à ses caractéristiques assignées

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

3.7
valeur de pleine charge
valeur d'une grandeur pour une machine fonctionnant à pleine charge

Note 1 à l'article: Cette notion est applicable à la puissance, au couple, au courant, à la vitesse, etc.

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

3.8
repos
absence complète de tout mouvement et de toute alimentation électrique ou de tout entraînement mécanique

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

3.9
service
stipulation de la charge (des charges) à laquelle (auxquelles) la machine est soumise, y compris, le cas échéant, les périodes de démarrage, de freinage électrique, de fonctionnement à vide et de repos, ainsi que leurs durées et leur ordre de succession dans le temps

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

3.10
service type
service continu, temporaire ou périodique comprenant une ou plusieurs charges qui restent constantes pendant la durée spécifiée ou service non périodique pendant lequel généralement la charge et la vitesse varient dans la plage de fonctionnement admissible

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

3.11
facteur de marche
rapport de la période de fonctionnement en charge, y compris le démarrage et le freinage électrique, à la durée du cycle de service, exprimé en pourcentage

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

3.12
couple à rotor bloqué
couple mesuré le plus faible que développe le moteur sur son bout d'arbre d'entraînement, quand son rotor est maintenu bloqué, quelle que soit sa position angulaire, et qu'il est alimenté à tension et fréquence assignées

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

3.13
courant à rotor bloqué
valeur efficace la plus élevée du courant en régime établi, absorbé par le moteur, lorsqu'il est alimenté aux tension et fréquence assignées et que son rotor est maintenu bloqué quelle que soit sa position angulaire

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

3.14
creux de couple <d'un moteur à courant alternatif>
valeur minimale du couple asynchrone en régime établi, que le moteur développe entre la vitesse nulle et la vitesse qui correspond au couple maximal (couple de décrochage) lorsque le moteur est alimenté à la tension et à la fréquence assignées

Note 1 à l'article: Cette définition ne s'applique pas au cas de moteurs asynchrones dont le couple décroît continuellement lorsque la vitesse augmente.

Note 2 à l'article: En plus des couples asynchrones en régime établi, il existe, à des vitesses spécifiques, des couples harmoniques synchrones qui dépendent de l'angle de charge du rotor.

À de telles vitesses, le couple d'accélération peut être négatif pour certains angles de charge du rotor.

L'expérience et le calcul démontrent que c'est une condition de fonctionnement instable et qu'en conséquence les couples harmoniques synchrones n'empêchent pas l'accélération du moteur et sont exclus de cette définition.

3.15
couple maximal <d'un moteur à courant alternatif> couple de décrochage
valeur maximale du couple asynchrone en régime établi développé par le moteur sans chute brutale de la vitesse lorsque le moteur est alimenté à la tension et à la fréquence assignées

Note 1 à l'article: Cette définition ne s'applique pas aux moteurs dont le couple diminue de manière continue quand la vitesse augmente.

3.16
couple de fonctionnement <d'un moteur synchrone>
couple maximal développé par un moteur synchrone à la vitesse synchrone et tension, fréquence et courant d'excitation assignés

3.17
refroidissement
opération par laquelle de la chaleur provenant des pertes produites dans une machine est cédée à un fluide de refroidissement primaire qui peut être continûment remplacé ou être lui-même refroidi dans un échangeur de chaleur par un fluide de refroidissement secondaire

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

3.18
fluide de refroidissement
fluide, liquide ou gaz, par l'intermédiaire duquel la chaleur est transférée

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

3.19
fluide de refroidissement primaire
fluide, liquide ou gaz, qui, se trouvant à une température inférieure à celle des pièces de la machine et en contact avec celles-ci, transporte la chaleur cédée par ces pièces

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

3.20
fluide de refroidissement secondaire
fluide, liquide ou gaz, qui, se trouvant à une température inférieure à celle du fluide de refroidissement primaire, transporte la chaleur cédée par ce fluide primaire au moyen d'un échangeur de chaleur ou à travers la surface extérieure de la machine

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

3.21
enroulement à refroidissement direct
enroulement à refroidissement interne
enroulement refroidi principalement par un fluide de refroidissement s'écoulant en contact direct avec la partie refroidie à travers des passages creux, tubes, conduits ou canaux qui, quelle que soit leur orientation, forment partie intégrante de l'enroulement à l'intérieur de l'isolation principale

Note 1 à l'article: Dans tous les cas où "indirect" ou "direct" n'est pas précisé, cela implique un enroulement à refroidissement indirect.

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

3.22
enroulement à refroidissement indirect
tout enroulement autre qu'un enroulement à refroidissement direct

Note 1 à l'article: Dans tous les cas où "indirect" ou "direct" n'est pas précisé, cela implique un enroulement à refroidissement indirect.

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

3.23
isolation supplémentaire
isolation indépendante prévue en plus de l'isolation principale, en vue d'assurer la protection contre les chocs électriques en cas de défaut survenant dans l'isolation principale

3.24
moment d'inertie
somme (intégrale) des produits des masses élémentaires d'un corps par le carré de leurs distances (radiales) par rapport à un axe donné

3.25
équilibre thermique
état atteint lorsque les échauffements des diverses parties de la machine ne varient pas de plus d'un gradient de *1 K par demi-heure*

Note 1 à l'article: L'équilibre thermique peut être déterminé à partir d'un tracé de l'échauffement en fonction du temps, lorsque les droites entre points pris en début et fin de chacun de deux intervalles de temps successifs d'au moins une demi-heure chacun ont une pente de 1 K ou moins par demi-heure ou de 2 K ou moins par heure.

[SOURCE: IEC 60050-411:1996, 411-51-08, modifié: modification indiquée en italique]

3.26
constante de temps thermique équivalente
constante de temps qui, en remplaçant plusieurs constantes de temps individuelles, détermine approximativement l'évolution de la température dans un enroulement après une variation de courant en échelon

3.27
enroulement enrobé
enroulement complètement enfermé ou noyé dans un isolant moulé

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

3.28
valeur assignée du facteur de forme du courant continu fourni à l'induit d'un moteur à courant continu par un convertisseur statique de puissance
rapport de la valeur efficace maximale admissible du courant $I_{\text{rms,maxN}}$ à sa valeur moyenne I_{avN} (valeur moyenne intégrée sur une période) dans les conditions assignées:

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

3.29
facteur d'ondulation du courant
rapport de la différence entre la valeur maximale I_{max} et la valeur minimale I_{min} d'un courant ondulé au double de sa valeur moyenne I_{av} (valeur moyenne intégrée sur une période):

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

Note 1 à l'article: Pour de faibles valeurs d'ondulation du courant, le facteur d'ondulation peut être approché par la formule suivante:

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

Note 2 à l'article: La formule ci-dessus peut être utilisée en tant qu'approximation si la valeur calculée résultante de q_{i} est inférieure ou égale à 0,4.

Il convient que la base pour déterminer cette variation soit un mesurage effectué par oscilloscope (ou un dispositif comparable) et non un relevé d'ampèremètre. Il convient de tracer une ligne qui passe par les crêtes consécutives de l'onde de courant sur l'oscillogramme. Cette ligne constitue l'enveloppe de l'onde de courant. La variation est la différence entre les ordonnées maximale (I_{max}) et minimale (I_{min}) de cette enveloppe.

3.30
tolérance
écart permis entre la valeur déclarée et la valeur mesurée

3.31
essai de type
essai effectué sur une ou plusieurs machines réalisées selon une conception donnée pour vérifier que cette conception répond à certaines spécifications

Note 1 à l'article: L'essai de type peut être aussi considéré comme valide s'il a été réalisé sur une machine ayant des déviations mineures en caractéristiques assignées ou autres. Il convient que ces déviations fassent l'objet d'un accord.

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

3.32
essai individuel de série
essai auquel est soumise chaque machine en cours ou en fin de fabrication pour vérifier qu'elle satisfait à des critères définis

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

3.33
vitesse d'emballement
vitesse maximale atteinte par le groupe convertisseur, en cas de disparition de la pleine charge de la génératrice et de non-fonctionnement du régulateur de vitesse

Note 1 à l'article: Le moteur peut également être une turbine ou un moteur à explosion.

Note 2 à l'article: Pour les moteurs, la survitesse maximale à la perte de l'alimentation est celle qu'un moteur peut atteindre lorsqu'il est entraîné par l'équipement couplé.

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

3.34
isolation principale
isolation principale (voir l'IEC 60034-1) d'une machine électrique tournante

3.35
machine apte à fonctionner sur convertisseur
machine électrique conçue pour un démarrage direct en ligne et qui convient pour un fonctionnement sur convertisseur électronique de fréquence sans filtre spécifique

Note 1 à l'article: Ces moteurs comprennent, entre autres, les conceptions IEC N, NE, H ou HE ou les conceptions NEMA A, B ou C qui peuvent être soumises à des réglementations relatives au rendement énergétique dans l'UE, en Amérique du Nord ou d'autres localisations.

Note 2 à l'article: Le but d'un moteur apte à fonctionner sur convertisseur est de fonctionner dans la classe thermique du système d'isolement, mais comme le contenu harmonique de la tension de sortie du convertisseur varie en fonction des différentes typologies d'entraînement, l'utilisateur final peut exiger de se coordonner avec le constructeur.

Note 3 à l'article: Voir l'IEC TS 60034-25 pour les variations de performance de toutes les caractéristiques telles que le rendement et le bruit acoustique lors du fonctionnement sur un convertisseur de fréquence d'un moteur apte à fonctionner sur convertisseur.

3.36
machine fonctionnant exclusivement sur convertisseur
machine électrique conçue pour fonctionner spécifiquement lorsqu'elle est alimentée par un convertisseur électronique de fréquence avec un échauffement compris dans la classe thermique d'isolation spécifiée ou la classe thermique

Note 1 à l'article: De tels moteurs ne comprennent aucune lettre de conception IEC ou de conception NEMA et peuvent être exemptés des réglementations relatives au rendement énergétique dans l'UE, en Amérique du Nord ou d'autres localisations.

3.37
tension d'arbre
tension de la fréquence d'alimentation principale mesurée entre les extrémités de l'arbre d'une machine électrique, qui peut se produire en raison d'asymétries magnétiques

Note 1 à l'article: Pour plus d'informations relatives à la cause fondamentale de la tension d'arbre, voir 5.5 et l'Article 6 de l'IEC TS 60034-24:2009.

Note 2 à l'article: Il convient que la tension d'arbre (principalement) de la fréquence d'alimentation ne soit pas confondue avec la tension d'arbre à haute fréquence qui peut être causée dans les machines alimentées par convertisseur par un courant d'impulsion de mode commun à haute fréquence.

4 Services

4.1 Spécification du service

C'est à l'acheteur qu'incombe la responsabilité de spécifier le service. L'acheteur peut décrire le service par l'une des méthodes suivantes:

a) numériquement, si la charge ne varie pas ou varie de façon connue;

b) graphiquement, par une représentation des grandeurs variables en fonction du temps;

c) en choisissant l'un des services types S1 à S10 à condition que ce service soit au moins aussi sévère que le service prévu.

Le service type doit être désigné par l'abréviation appropriée, spécifiée en 4.2, à la suite de la valeur de la charge.

Une formulation du facteur de marche est indiquée sous chaque figure appropriée de service type.

Normalement, l'acheteur ne peut pas fournir une valeur pour le moment d'inertie de la machine (J_M) ni pour l'espérance de vie thermique en valeur relative (TL) (voir l'Annexe A). Ces valeurs sont fournies par le constructeur.

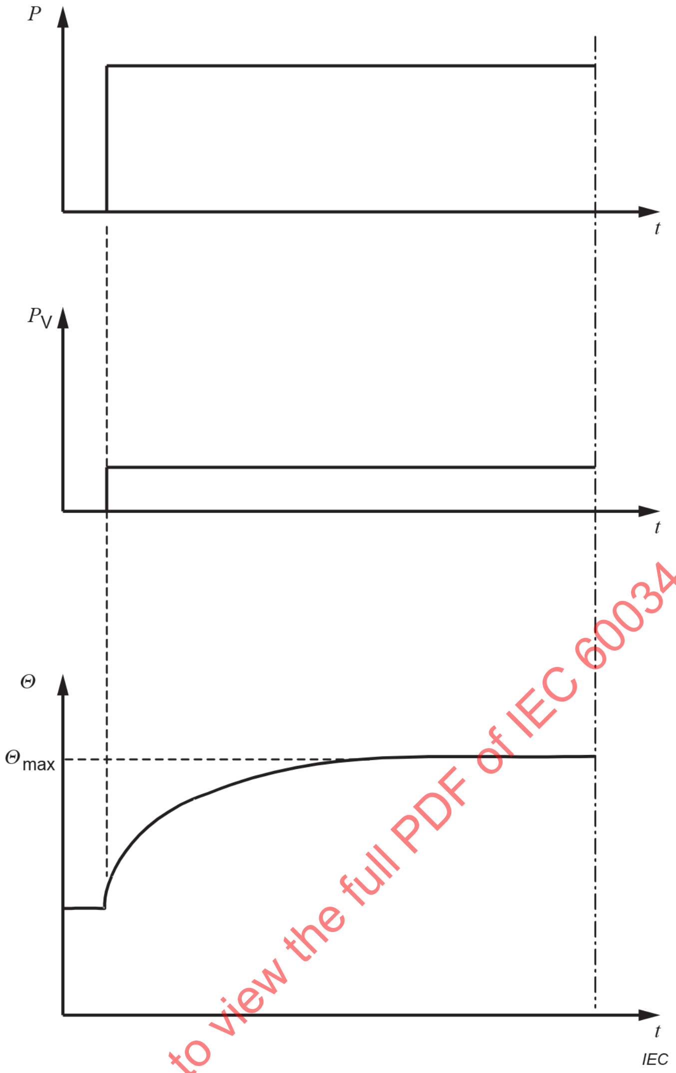
Lorsque l'acheteur ne stipule pas de service, le constructeur doit partir du principe que le service type S1 (service continu) s'applique.

4.2 Services types

4.2.1 Service type S1 – Service continu

Fonctionnement à charge constante maintenue pendant une durée suffisante pour que la machine atteigne l'équilibre thermique (voir la Figure 1).

L'abréviation appropriée est S1.



Légende

P	charge
P_V	pertes électriques
Θ	température
Θ_{max}	température maximale atteinte
t	temps

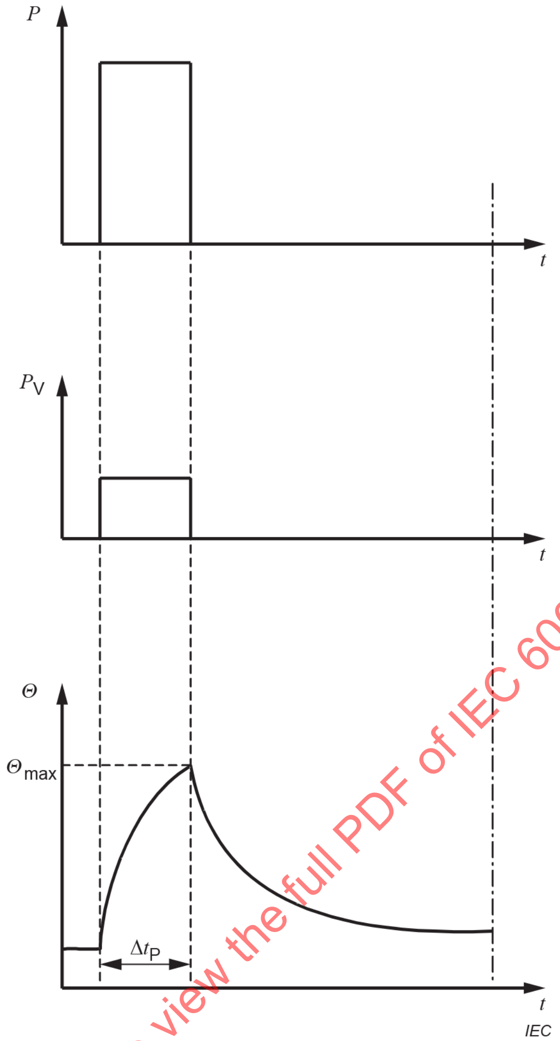
Figure 1 – Service continu – Service type S1

4.2.2 Service type S2 – Service temporaire

Fonctionnement à charge constante pendant un temps déterminé, inférieur à celui exigé pour atteindre l'équilibre thermique, suivi d'un temps d'arrêt d'une durée suffisante pour rétablir à 2 K près l'égalité de température entre la machine et le fluide de refroidissement, voir la Figure 2.

L'abréviation appropriée est S2, suivie de la valeur de la durée du service.

Exemple: S2 60 min.



Légende

P charge

P_V pertes électriques

Θ température

Θ_{max} température maximale atteinte

t temps

Δt_P durée de fonctionnement à charge constante, par exemple Δt_P = 60 min pour S2 60 min

Figure 2 – Service temporaire – Service type S2

4.2.3 Service type S3 – Service intermittent périodique

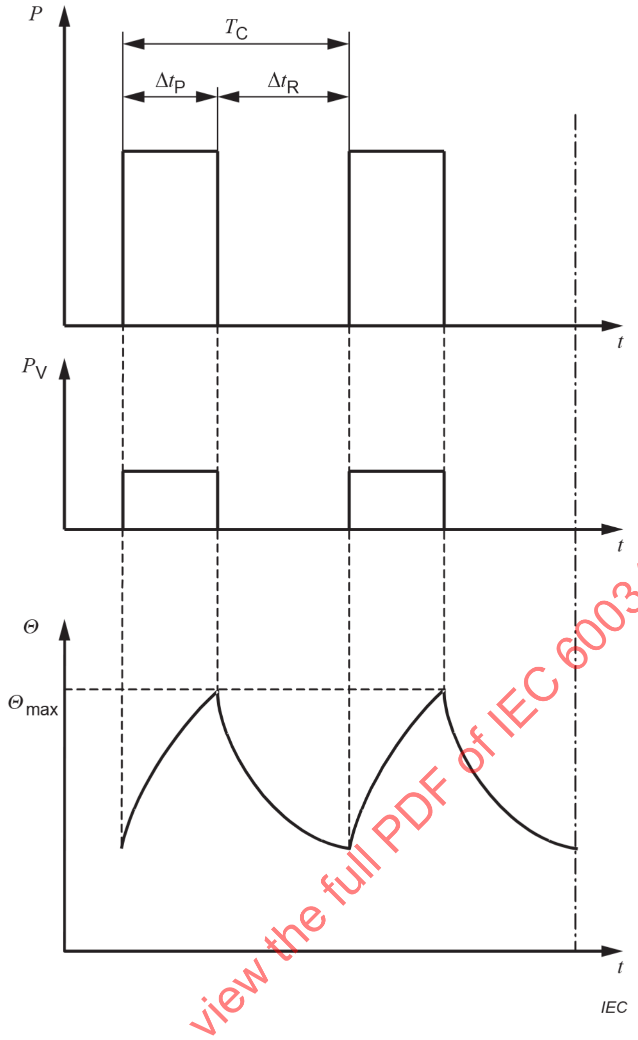
NOTE 1 Un service type périodique implique que l'équilibre thermique n'est pas atteint pendant la période de charge.

NOTE 2 Pour les cycles de service dont la durée de cycle T_c est différente de 10 min, voir 5.2.3.

Suite de cycles de service identiques comprenant chacun un temps de fonctionnement à charge constante et un temps de repos (voir la Figure 3). Dans ce service, le cycle est tel que le courant de démarrage n'affecte pas l'échauffement de façon significative.

L'abréviation appropriée est S3, suivie de la valeur du facteur de marche.

Exemple: S3 25 %.



Légende

P charge

P_V pertes électriques

Θ température

$Θ_{max}$ température maximale atteinte

t temps

T_C durée d'un cycle

Δt_P durée de fonctionnement à charge constante

Δt_R temps de repos

Facteur de marche = $\Delta t_P/T_C$

Figure 3 – Service intermittent périodique – Service type S3

4.2.4 Service type S4 – Service intermittent périodique à démarrage

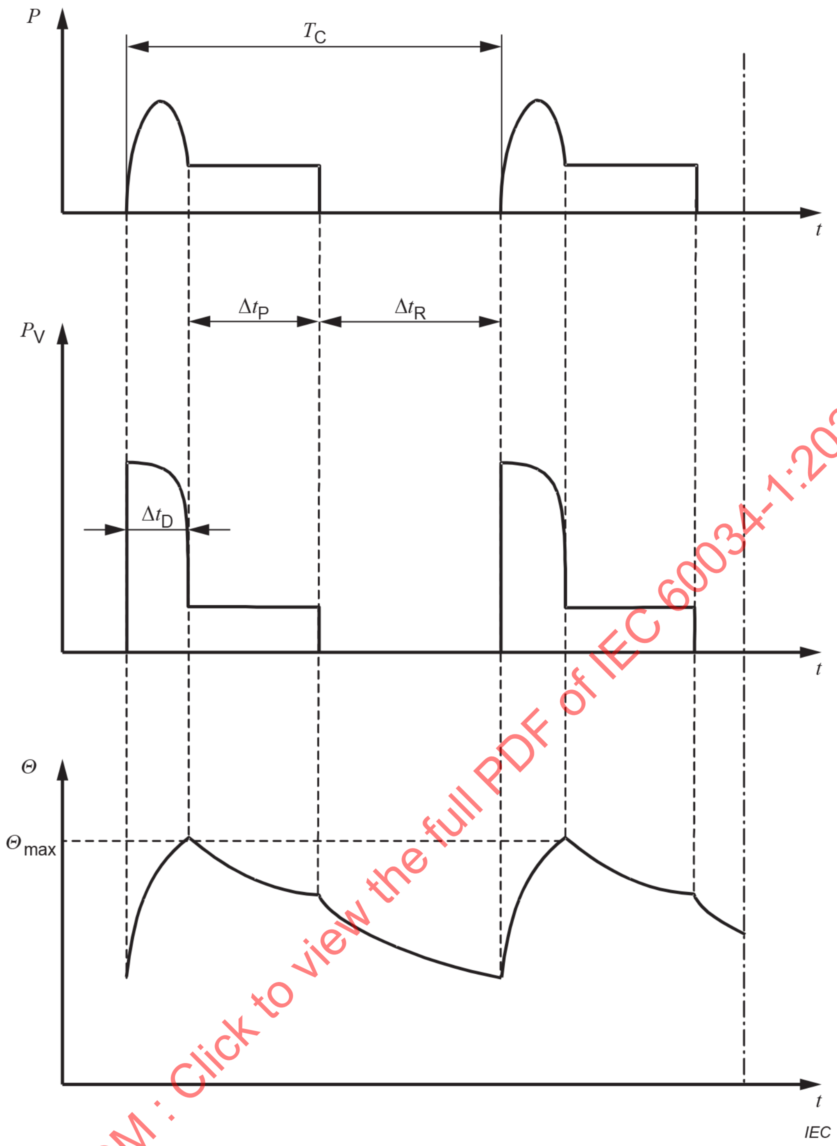
NOTE 1 Un service type périodique implique que l'équilibre thermique n'est pas atteint pendant la période de charge.

NOTE 2 Pour les cycles de service dont la durée de cycle T_c est différente de 10 min, voir 5.2.3.

Suite de cycles de service identiques comprenant chacun un temps de démarrage significatif, un temps de fonctionnement à charge constante et un temps de repos (voir la Figure 4).

L'abréviation appropriée est S4, suivie des valeurs du facteur de charge, du moment d'inertie du moteur (J_M) et du moment d'inertie de la charge (J_{ext}), tous deux rapportés à l'arbre du moteur.

Exemple: S4 25 % J_M = 0,15 kg × m² J_{ext} = 0,7 kg × m².



Légende

P	charge	t	temps
P_V	pertes électriques	T_C	durée d'un cycle
Θ	température	Δt_D	durée de démarrage/accélération
Θ_{max}	température maximale atteinte	Δt_P	durée de fonctionnement à charge constante
		Δt_R	temps de repos

Facteur de marche = $(\Delta t_D + \Delta t_P)/T_C$

Figure 4 – Service intermittent périodique à démarrage – Service type S4

4.2.5 Service type S5 – Service intermittent périodique à freinage électrique

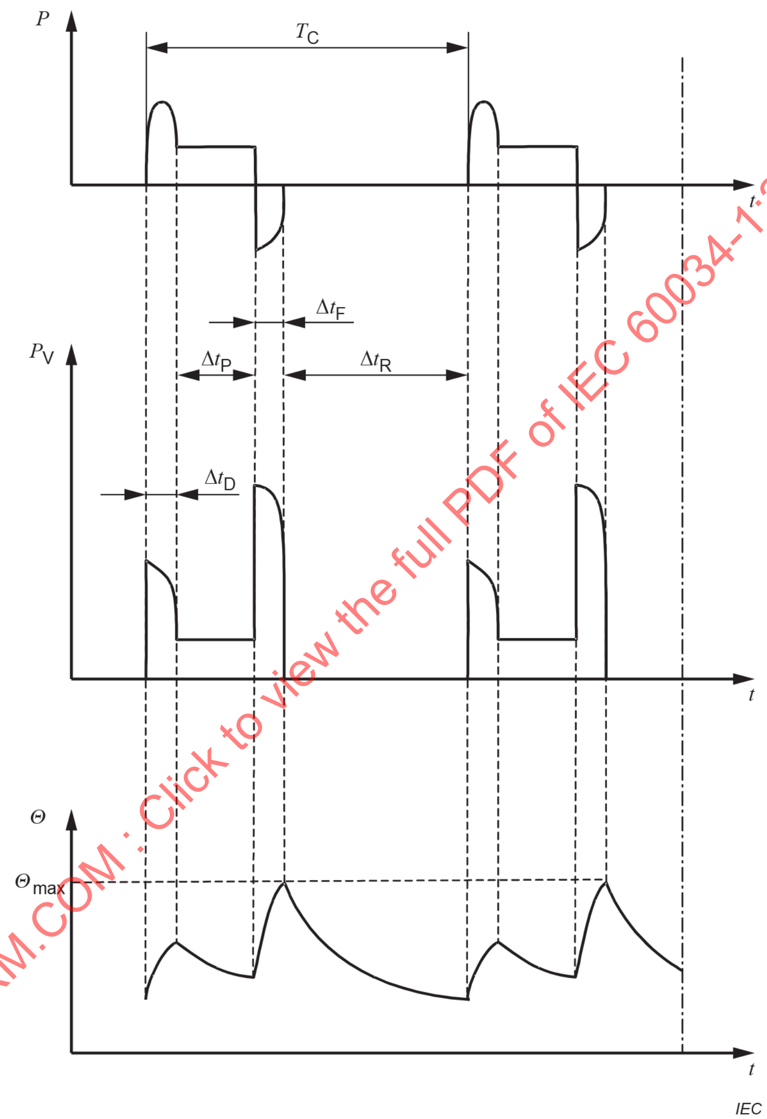
NOTE 1 Un service type périodique implique que l'équilibre thermique n'est pas atteint pendant la période de charge.

NOTE 2 Pour les cycles de service dont la durée de cycle T_c est différente de 10 min, voir 5.2.3.

Suite de cycles de service identiques comprenant chacun un temps de démarrage, un temps de fonctionnement à charge constante, un temps de freinage électrique et un temps de repos, voir la Figure 5.

L'abréviation appropriée est S5, suivie des valeurs du facteur de charge, du moment d'inertie du moteur (J_M) et du moment d'inertie de la charge (J_{ext}), tous deux rapportés à l'arbre du moteur.

Exemple: S5 25 % J_M = 0,15 kg × m² J_{ext} = 0,7 kg × m².



Légende

P	charge	T_C	durée d'un cycle
P_V	pertes électriques	Δt_D	durée de démarrage/accélération
Θ	température	Δt_P	durée de fonctionnement à charge constante
Θ_{max}	température maximale atteinte	Δt_F	durée de freinage électrique
t	temps	Δt_R	temps de repos

Facteur de marche = $(\Delta t_D + \Delta t_P + \Delta t_F)/T_C$

Figure 5 – Service intermittent périodique à freinage électrique – Service type S5

4.2.6 Service type S6 – Service ininterrompu périodique

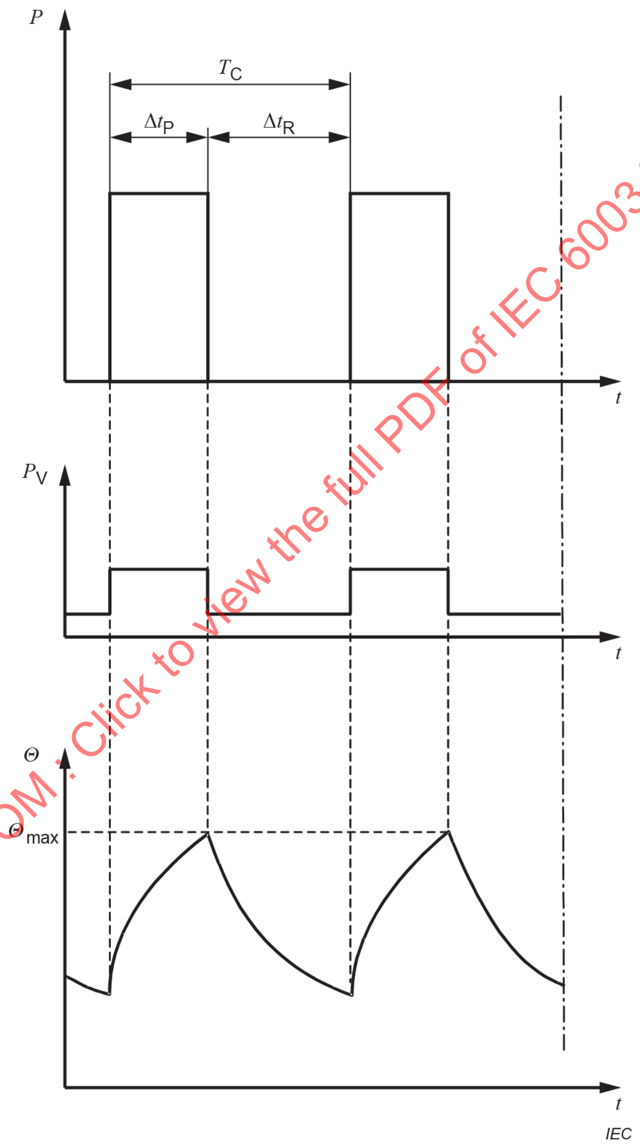
NOTE 1 Un service type périodique implique que l'équilibre thermique n'est pas atteint pendant la période de charge.

NOTE 2 Pour les cycles de service dont la durée de cycle T_c est différente de 10 min, voir 5.2.3.

Suite de cycles de service identiques comprenant chacun un temps de fonctionnement à charge constante et un temps de fonctionnement à vide. Il n'y a pas de temps de repos, voir la Figure 6.

L'abréviation appropriée est S6, suivie de la valeur du facteur de marche.

Exemple: S6 40 %.



Légende

P	charge	t	temps
P_V	pertes électriques	T_C	durée d'un cycle
Θ	température	Δt_P	durée de fonctionnement à charge constante
Θ_{max}	température maximale atteinte	Δt_V	durée de fonctionnement à vide

Facteur de marche = $\Delta t_P/T_C$

Figure 6 – Service ininterrompu périodique – Service type S6

4.2.7 Service type S7 – Service ininterrompu périodique à freinage électrique

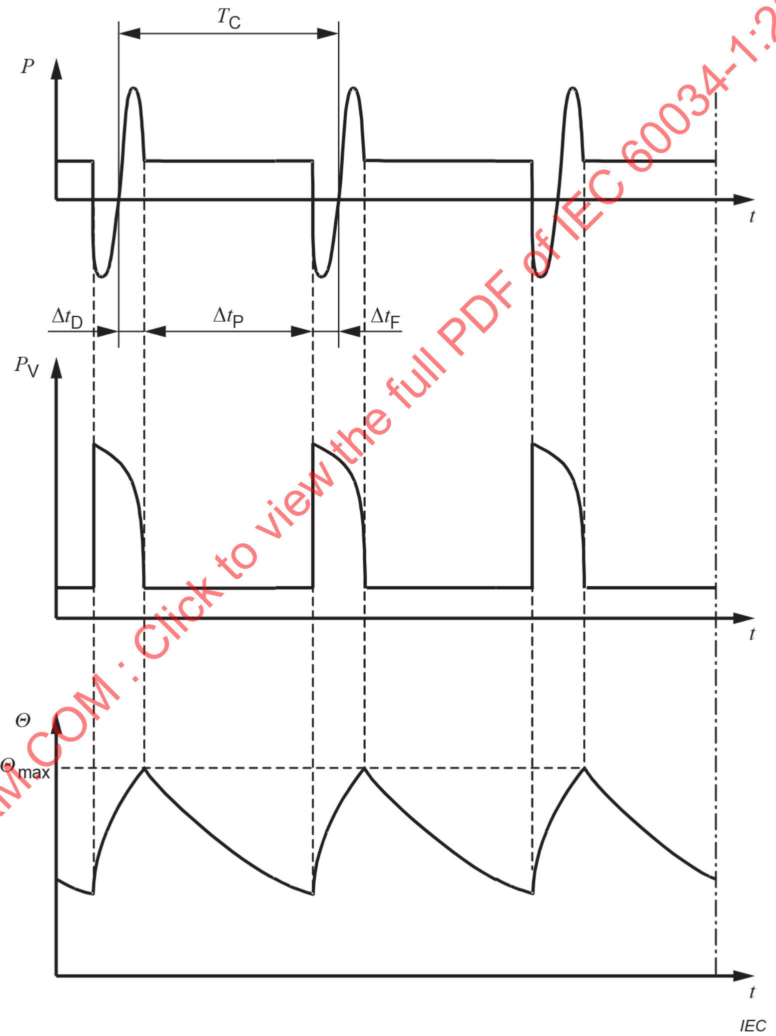
NOTE 1 Un service type périodique implique que l'équilibre thermique n'est pas atteint pendant la période de charge.

NOTE 2 Pour les cycles de service dont la durée de cycle T_c est différente de 10 min, voir 5.2.3.

Suite de cycles de service identiques comprenant chacun un temps de démarrage, un temps de fonctionnement à charge constante et un temps de freinage électrique. Il n'y a pas de temps de repos, voir la Figure 7.

L'abréviation appropriée est S7, suivie des valeurs du moment d'inertie du moteur (J_M) et du moment d'inertie de la charge (J_{ext}), tous deux rapportés à l'arbre du moteur.

Exemple: S7 J_M = 0,4 kg × m² J_{ext} = 7,5 kg × m²



Légende

P	charge	t	temps
P_V	pertes électriques	T_C	durée d'un cycle
Θ	température	Δt_D	durée de démarrage/accélération
Θ_{max}	température maximale atteinte	Δt_P	durée de fonctionnement à charge constante
Facteur de marche = 1		Δt_F	durée de freinage électrique

Figure 7 – Service ininterrompu périodique à freinage électrique – Service type S7

4.2.8 Service type S8 – Service ininterrompu périodique à changements liés de charge et de vitesse

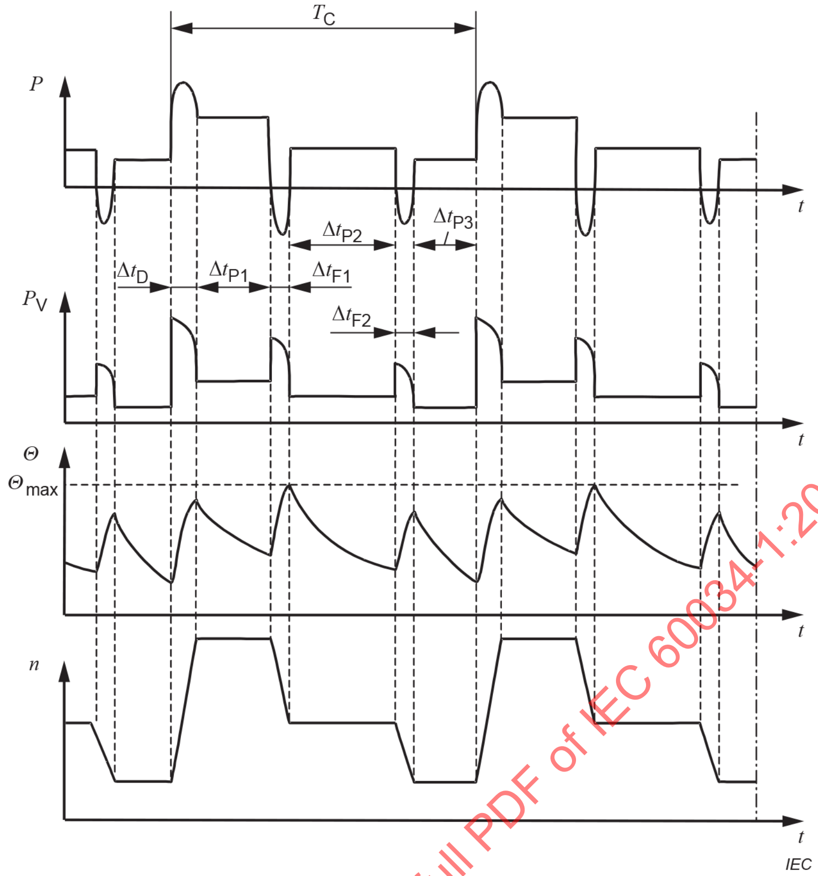
NOTE 1 Un service type périodique implique que l'équilibre thermique n'est pas atteint pendant la période de charge.

NOTE 2 Pour les cycles de service dont la durée de cycle T_c est différente de 10 min, voir 5.2.3.

Suite de cycles de service identiques comprenant chacun un temps de fonctionnement à charge constante correspondant à une vitesse de rotation prédéterminée, suivie d'un ou plusieurs temps de fonctionnement à d'autres charges constantes correspondant à différentes vitesses de rotation (réalisées par exemple par changement du nombre de pôles dans le cas des moteurs à induction). Il n'y a pas de temps de repos (voir la Figure 8).

L'abréviation appropriée est S8 suivie des valeurs du moment d'inertie du moteur (J_M) et du moment d'inertie de la charge (J_{ext}), tous deux rapportés à l'arbre du moteur, de même que de la charge, de la vitesse et du facteur de marche pour chacun des régimes caractérisés par une vitesse.

Exemple:	S8 J_M = 0,5 kg × m^2	J_{ext} = 6 kg × m^2	16 kW	740 min^{-1}	30 %
			40 kW	1 460 min^{-1}	30 %
			25 kW	980 min^{-1}	40 %.



Légende

P	charge	t	temps
P_V	pertes électriques	T_C	durée d'un cycle
$Θ$	température	$Δt_D$	durée de démarrage/accélération
$Θ_{max}$	température maximale atteinte	$Δt_P$	durée de fonctionnement à charge constante (P1, P2, P3)
n	vitesse	$Δt_F$	durée de freinage électrique (F1, F2)

Facteur de marche = $(Δt_D + Δt_{P1})/T_C$; $(Δt_{F1} + Δt_{P2})/T_C$; $(Δt_{F2} + Δt_{P3})/T_C$

Figure 8 – Service ininterrompu périodique à changements liés de charge et de vitesse – Service type S8

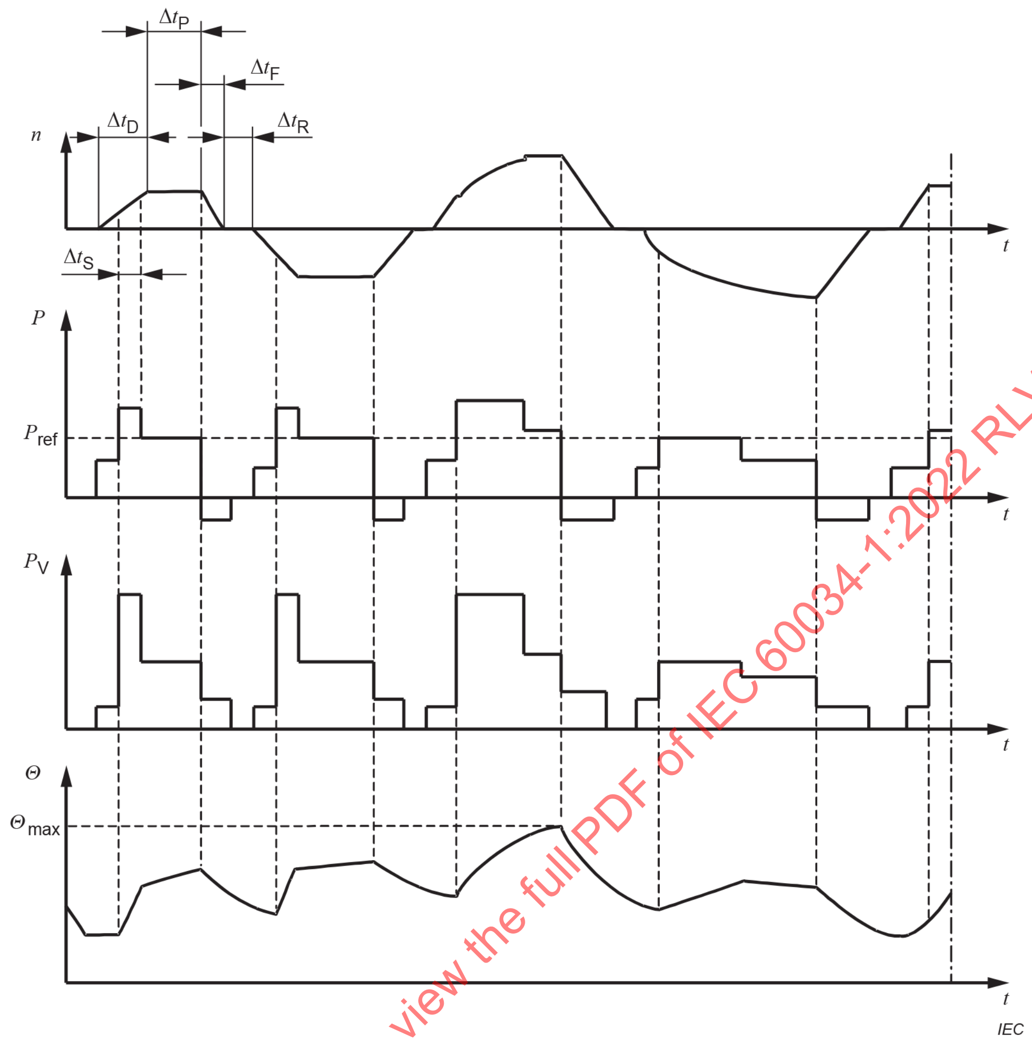
4.2.9 Service type S9 – Service à variations non périodiques de charge et de vitesse

Service dans lequel généralement la charge et la vitesse ont une variation non périodique dans la plage de fonctionnement admissible. Ce service inclut fréquemment des surcharges appliquées qui peuvent être largement supérieures à la charge de référence (voir la Figure 9).

L'abréviation appropriée est S9.

Pour ce service type, une charge constante, judicieusement choisie et fondée sur le service type S1, est prise comme valeur de référence (P_{ref} à la Figure 9) pour la notion de surcharge.

L'alimentation par convertisseur peut également être déterminée sous le service type S9 lorsque celui-ci fonctionne avec une charge dynamique non périodique et avec des variations de vitesse. Le paragraphe 4.2 de l'IEC TS 60034-25:2014 peut être pris comme référence pour déterminer le service pour l'alimentation par convertisseur.



Légende

P	charge	t	temps
P_{ref}	charge de référence	Δt_D	durée de démarrage/accélération
P_V	pertes électriques	Δt_P	durée de fonctionnement à charge constante
Θ	température	Δt_F	durée de freinage électrique
Θ_{max}	température maximale atteinte	Δt_R	temps de repos
n	vitesse	Δt_S	durée de fonctionnement en surcharge

Figure 9 – Service à variations non périodiques de charge et de vitesse – Service type S9

4.2.10 Service type S10 – Service avec charges et vitesses constantes discrètes

Service comprenant un nombre spécifique de valeurs discrètes de charge (ou charges équivalentes), et de vitesse si cela est applicable, chaque combinaison charge/vitesse étant maintenue pendant une durée suffisante pour permettre à la machine d'atteindre l'équilibre thermique (voir la Figure 10). La charge minimale pendant un cycle de service peut avoir la valeur zéro (à vide ou au repos).

L'abréviation appropriée est S10, suivie des valeurs réduites (p.u) $p/\Delta t$ pour les différentes charges et leurs durées respectives, et de la valeur réduite (p.u.) TL pour l'espérance de vie thermique relative du système d'isolation. La valeur de référence pour l'espérance de vie thermique est l'espérance de vie thermique aux caractéristiques assignées pour service continu et aux limites admissibles d’échauffement fondées sur le service type S1. Pour un temps de repos, la charge doit être indiquée par la lettre r.

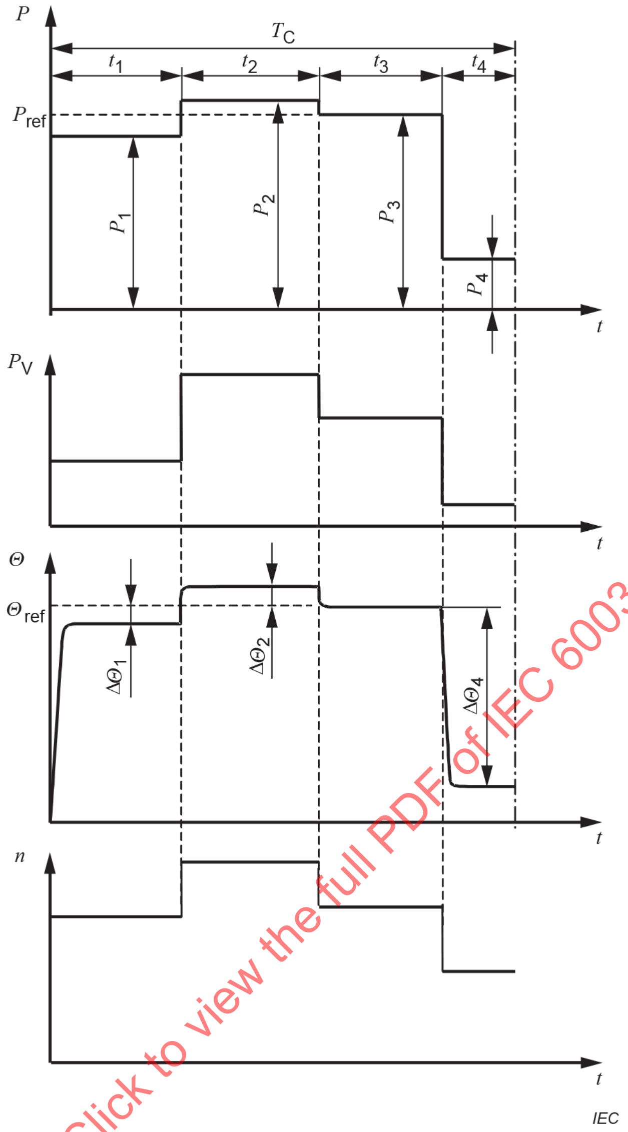
Exemple: S10 $p/\Delta t$ = 1,1/0,4; 1/0,3; 0,9/0,2; r/0,1 TL = 0,60.

Il convient d’arrondir la valeur de TL au plus proche multiple de 0,05. L’Annexe A donne des indications sur la signification de ce paramètre et la détermination de sa valeur.

Pour ce service type, une charge constante, judicieusement choisie et fondée sur le service type S1, doit être prise comme valeur de référence (P_{ref} à la Figure 10) pour les charges discrètes.

Les valeurs discrètes de charges sont habituellement des charges équivalentes obtenues par intégration en fonction du temps. Il n’est pas nécessaire que chaque cycle de charge soit exactement le même, à condition que chaque charge à l’intérieur d’un cycle soit appliquée pendant une durée suffisante pour que l’équilibre thermique soit atteint et que chaque cycle de charge puisse être intégré pour donner la même espérance de vie thermique relative.

L’alimentation par convertisseur peut également être déterminée sous le service type S10 lorsque celui-ci fonctionne avec une charge discrète, c’est-à-dire non dynamique, non périodique et avec des variations de vitesse. Le paragraphe 4.2 de l’IEC TS 60034-25:2014 peut être pris comme référence pour déterminer le service pour l’alimentation par convertisseur.



Légende

P	charge	t	temps
P_i	charge constante pendant un cycle	t_i	durée d'une charge constante pendant un cycle
P_{ref}	charge de référence fondée sur le service type S1	T_C	durée d'un cycle
P_V	pertes électriques	$\Delta\Theta_i$	différence entre l'échauffement de l'enroulement au cours de chacune des différentes charges pendant un cycle et l'échauffement fondé sur le service type S1 à la charge de référence
Θ	température	n	vitesse
Θ_{ref}	température à la charge de référence fondée sur le service type S1		

Figure 10 – Service avec charges constantes discrètes – Service type S10

5 Caractéristiques assignées

5.1 Attribution des caractéristiques assignées

Les caractéristiques assignées, définies en 3.2, doivent être attribuées par le constructeur. En attribuant les caractéristiques assignées, le constructeur doit choisir l'une des classes de caractéristiques assignées définies de 5.2.1 à 5.2.6. La désignation de la classe des caractéristiques assignées doit être écrite après la puissance (utile) assignée. Si aucune désignation n'est précisée, les caractéristiques assignées pour service continu s'appliquent.

Quand des composants auxiliaires (tels que des bobines d'inductance, des condensateurs, etc.) sont insérés par le constructeur en tant que partie intégrante de la machine, les valeurs assignées doivent se rapporter aux bornes d'alimentation de l'ensemble complet.

NOTE Cela ne s'applique pas aux transformateurs de puissance connectés entre la machine et l'alimentation.

Une attention spéciale est demandée lors de l'attribution de caractéristiques assignées à des machines alimentées par, ou alimentant, des convertisseurs statiques. L'IEC TS 60034-25 fournit des recommandations relatives à ce sujet.

5.2 Classes de caractéristiques assignées

5.2.1 Caractéristiques assignées pour service continu

Caractéristiques assignées auxquelles la machine peut fonctionner pendant une durée illimitée et conformément aux exigences du présent document.

Cette classe de caractéristiques assignées correspond au service type S1 et est désignée comme le service type S1.

5.2.2 Caractéristiques assignées pour service temporaire

Caractéristiques assignées auxquelles la machine peut fonctionner pendant une durée limitée, en démarrant à la température ambiante et conformément aux exigences du présent document.

Cette classe de caractéristiques assignées correspond au service type S2 et est désignée comme le service type S2.

5.2.3 Caractéristiques assignées pour service périodique

Caractéristiques assignées auxquelles la machine peut fonctionner suivant des cycles de service, conformément aux exigences du présent document.

Cette classe de caractéristiques assignées correspond à l'un des services types périodiques S3 à S8 et est désignée comme le service type correspondant.

Sauf spécifications contraires, la durée d'un cycle de service doit être de 10 min et le facteur de marche doit avoir l'une des valeurs suivantes:

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

5.2.4 Caractéristiques assignées pour service non périodique

Caractéristiques assignées auxquelles la machine peut fonctionner de façon non périodique, conformément aux exigences du présent document.

Cette classe de caractéristiques assignées correspond au service type non périodique S9 et est désignée comme le service type S9.

5.2.5 Caractéristiques assignées pour service avec charges et vitesses constantes discrètes

Caractéristiques assignées auxquelles la machine peut fonctionner avec l'association des charges et des vitesses du service type S10, pendant une durée illimitée tout en satisfaisant aux exigences du présent document. La charge maximale admissible dans un cycle doit prendre en considération tous les éléments de la machine, par exemple, le système d'isolation en ce qui concerne la validité de la loi exponentielle pour l'espérance de vie thermique relative, les roulements en ce qui concerne la température, d'autres éléments en ce qui concerne la dilatation thermique. Sauf spécifications dans d'autres normes applicables de l'IEC, la charge maximale ne doit pas dépasser 1,15 fois la valeur de la charge fondée sur le service type S1. La charge minimale peut avoir la valeur zéro quand la machine fonctionne à vide ou est au repos. Des informations relatives à l'application de cette classe de caractéristiques assignées sont données à l'Annexe A.

Cette classe de caractéristiques assignées correspond au service type S10 et est désignée comme le service type S10.

NOTE D'autres normes applicables de l'IEC peuvent spécifier la charge maximale en matière de limitation de la température (ou d'échauffement) d'enroulement au lieu d'une valeur relative de la charge fondée sur le service type S1.

5.2.6 Caractéristiques assignées pour charge équivalente

Caractéristiques assignées auxquelles, à des fins d'essais, la machine peut fonctionner à charge constante jusqu'à ce que l'équilibre thermique soit atteint et qui conduisent au même échauffement de l'enroulement statorique que l'échauffement moyen pendant un cycle en charge pour le service type spécifié.

Pour déterminer des caractéristiques assignées du type équivalent, il convient de prendre en compte les charge, vitesse et refroidissement variables du cycle de service.

Le cas échéant, cette classe de caractéristiques assignées est désignée par 'équ'.

5.3 Choix d'une classe de caractéristiques assignées

Une machine construite en vue d'un usage général doit avoir des caractéristiques assignées pour service continu et être capable de fonctionner en service type S1.

Si le service n'a pas été spécifié par l'acheteur, le service type S1 s'applique et les caractéristiques assignées doivent être des caractéristiques assignées pour service continu.

Lorsqu'une machine est prévue pour des caractéristiques assignées pour service temporaire, les caractéristiques assignées doivent être fondées sur le service type S2 (voir 4.2.2).

Lorsqu'une machine est prévue pour fonctionner à des charges variables ou des charges comprenant un temps de fonctionnement à vide ou des temps pendant lesquels la machine est à l'état de repos, les caractéristiques assignées doivent être des caractéristiques assignées pour service périodique fondées sur un service type choisi parmi les services types S3 à S8 (voir 4.2.3 à 4.2.8).

Lorsqu'une machine est prévue pour alimenter de façon non périodique des charges variables à des vitesses variables, y compris à des surcharges, les caractéristiques assignées doivent être des caractéristiques assignées pour service non périodique fondées sur le service type S9 (voir 4.2.9).

Lorsqu'une machine est prévue pour fonctionner à des charges constantes discrètes comprenant des temps de surcharge ou des temps de marche à vide (ou à l'état de repos), les caractéristiques assignées doivent être des caractéristiques assignées pour service avec charges constantes discrètes fondées sur le service type S10 (voir 4.2.10).

5.4 Attribution de la puissance (utile) à une classe de caractéristiques assignées

Dans la détermination des caractéristiques assignées:

Pour les services types S1 à S8, la ou les valeurs spécifiées de la ou des charges constantes doivent être les puissances (utiles) assignées (voir 4.2.1 à 4.2.8).

Pour les services types S9 et S10, la valeur de référence de la charge fondée sur le service type S1 doit être prise comme puissance (utile) assignée, (voir 4.2.9 et 4.2.10).

5.5 Puissance (utile) assignée

5.5.1 Génératrices de courant continu

La puissance (utile) assignée est la puissance (utile) aux bornes et elle doit être exprimée en watts (W).

5.5.2 Alternateurs

La puissance (utile) assignée est la puissance électrique apparente aux bornes et elle doit être exprimée en voltampères (VA), complétée par l'indication du facteur de puissance.

Le facteur de puissance assigné des alternateurs synchrones doit être de 0,8 inductif (surexcité), sauf spécification contraire de l'acheteur.

NOTE Un diagramme de capacité P-Q (graphique de puissance) indiquant les limites de fonctionnement fournit plus d'informations détaillées sur la performance du générateur.

5.5.3 Moteurs

La puissance (utile) assignée est la puissance mécanique disponible sur l'arbre et elle doit être exprimée en watts (W).

NOTE Il est d'usage dans un certain nombre de pays d'exprimer aussi la puissance mécanique disponible sur l'arbre en chevaux-vapeur (h.p. - *horsepower*) (1 h.p. équivaut à 745,7 W; 1 ch (cheval ou horsepower métrique) équivaut à 736 W).

5.5.4 Compensateurs synchrones

La puissance (utile) assignée est la puissance réactive aux bornes et elle doit être exprimée en voltampères (VA) en régime capacitif (sous-excité) et en régime inductif (surexcité).

5.6 Tension assignée

5.6.1 Génératrices de courant continu

Pour les génératrices de courant continu prévues pour fonctionner dans une plage de tensions d'étendue relativement faible, la puissance (utile) assignée et le courant assigné doivent, sauf spécification contraire, être applicables à la limite supérieure de la plage de tensions (voir également 7.3).

5.6.2 Alternateurs

Pour les alternateurs prévus pour fonctionner dans une plage de tensions d'étendue relativement faible, la puissance (utile) assignée et le facteur de puissance assigné doivent, sauf spécification contraire, être applicables à toute tension de la plage (voir également 7.3).

5.6.3 Moteurs à courant alternatif

Les moteurs à courant alternatif peuvent avoir deux tensions assignées ou plus, ou encore une plage de tension assignée, selon l'indication de la plaque signalétique (voir 10.4.2). Dans l'ensemble de ces cas, les variations de tension (et de fréquence) supplémentaires selon 7.4 sont valables et n'ont pas besoin d'être indiquées séparément.

5.7 Combinaison préférentielle des tensions et des puissances (utiles)

La pratique n'est pas de construire des machines de toutes caractéristiques assignées pour toutes les tensions assignées. En général, pour les machines à courant alternatif, en se fondant sur des considérations de conception et de fabrication, les tensions assignées préférentielles supérieures à 1 kV sont indiquées dans le Tableau 1, en fonction des puissances (utiles) assignées.

Tableau 1 – Tensions assignées préférentielles

Tension assignée kV	**Puissance (utile) assignée minimale** kW (ou kVA)
1,0 < U_N ≤ 3,0	100
3,0 < U_N ≤ 6,0	150
6,0 < U_N ≤ 11,0	800
11,0 < U_N ≤ 15,0	2 500

5.8 Machines ayant plus d'un ensemble de caractéristiques assignées

Pour les machines qui ont plus d'un ensemble de caractéristiques assignées, la machine doit être conforme, à tous points de vue, au présent document pour chaque ensemble de caractéristiques assignées.

Pour les machines à plusieurs vitesses, des caractéristiques assignées doivent être attribuées pour chaque vitesse.

Quand une grandeur assignée (puissance utile, tension, vitesse, etc.) peut avoir par hypothèse plusieurs valeurs ou varier constamment entre deux limites, les caractéristiques assignées doivent être précisées à ces valeurs ou limites. Cette disposition ne s'applique ni aux variations de tension et de fréquence en fonctionnement définies en 7.3, ni au montage étoile-triangle pour le démarrage.

6 Conditions de fonctionnement sur site

6.1 Généralités

Sauf spécification contraire, les machines doivent être appropriées aux conditions sur site ci-après à l'extérieur du carter pendant le fonctionnement, pour l'arrêt, le stockage et le transport. Les températures froides à l'entrée du fluide de refroidissement pour différents types de refroidissements sont spécifiées dans le Tableau 5. Pour des conditions de fonctionnement sur site différentes de ces valeurs, des corrections sont données dans l'Article 8.

Les machines fonctionnant à l'extérieur de la plage de conditions sur site normalisées doivent nécessiter une attention spéciale.

6.2 Altitude

L'altitude ne doit pas dépasser 1 000 m au-dessus du niveau de la mer. Pour les altitudes supérieures, le fait que la distance de claquage diminue en fonction de la diminution de la pression atmosphérique doit être pris en considération dans la conception de la machine.

6.3 Température maximale de l'air ambiant

La température de l'air ambiant ne doit pas dépasser 40 °C.

6.4 Température minimale de l'air ambiant

Sauf accord contraire conclu entre le constructeur et le client, la température de l'air ambiant ne doit pas être inférieure à -15 °C pour toutes les machines, excepté les machines équipées d'un ou plusieurs des éléments suivants; pour lesquelles la température de l'air ambiant ne doit pas être inférieure à 0 °C:

a) une puissance (utile) assignée supérieure à 3 300 kW (ou kVA) par 1 000 min^{-1};
b) une puissance (utile) assignée inférieure à 600 W (ou VA);
c) un collecteur;
d) un roulement à coussinet;
e) l'eau comme fluide de refroidissement primaire ou secondaire.

6.5 Température de l'eau de refroidissement

Pour la température de référence de l'eau de refroidissement, voir le Tableau 5. Pour d'autres températures de l'eau de refroidissement, voir le Tableau 10. La température de l'eau de refroidissement ne doit pas être inférieure à + 5 °C.

6.6 Arrêt, stockage et transport

Quand des températures inférieures à celles spécifiées en 6.4 sont susceptibles de se produire durant le transport, le stockage ou après installation à l'arrêt, l'acheteur doit informer le constructeur et spécifier la température minimale prévue.

Des mesures particulières peuvent être nécessaires avant d'alimenter la machine après de longues périodes d'arrêt, de stockage et de transport. Des mesures particulières peuvent également être nécessaires durant les périodes de non-fonctionnement. Se reporter aux instructions du constructeur.

6.7 Pureté de l'hydrogène de refroidissement

Les machines refroidies à l'hydrogène doivent être capables de fonctionner à la puissance (utile) assignée dans les conditions assignées avec un fluide de refroidissement contenant au moins 95 % d'hydrogène en volume.

Pour des raisons de sécurité, il convient de toujours maintenir la teneur en hydrogène à 90 % ou davantage, en admettant par hypothèse que l'autre gaz entrant dans le mélange est de l'air.

Pour calculer le rendement conformément à l'IEC 60034-2 (toutes les parties), la composition normalisée du mélange gazeux doit être de 98 % d'hydrogène et 2 % d'air en volume, à des valeurs spécifiées de pression et de température du gaz refroidi, sauf accord contraire. Les pertes par ventilation doivent être calculées à la densité correspondante.

7 Conditions de fonctionnement électriques

7.1 Alimentation électrique

Pour les machines triphasées à courant alternatif, 50 Hz ou 60 Hz, destinées à être directement reliées à un réseau de distribution ou d'utilisation, les tensions assignées doivent être dérivées des tensions nominales données dans l'IEC 60038.

NOTE Pour les machines à courant alternatif de forte puissance à haute tension, les tensions peuvent être choisies pour l'obtention de caractéristiques de fonctionnement optimales.

Pour les machines à courant alternatif connectées à des convertisseurs statiques, ces restrictions sur la tension, la fréquence et la forme d’onde ne s’appliquent pas. Dans ce cas, le choix des tensions assignées doit se faire par accord.

Pour les machines électriques aptes à fonctionner sur convertisseur ou conçues pour fonctionner sur convertisseur et équipées de systèmes d'isolation de Type I ou Type II selon l’IEC 60034-18-41 ou l’IEC 60034-18-42, le constructeur peut attribuer une classe d'isolation de la tension de choc (IVIC - *impulse voltage insulation class*) pour le système d’isolation.

Dans le cas d'une machine électrique apte à fonctionner sur convertisseur ou conçue pour fonctionner sur convertisseur dont la puissance assignée est supérieure à 1 kW avec un système d’isolation de Type I et une IVIC attribuée, il convient que le système d'isolation soit approprié à une IVIC C entre phases et une IVIC B entre phase et terre, ou comme l'utilisateur et le constructeur en ont convenu.

Dans le cas d'une machine électrique apte à fonctionner sur convertisseur ou conçue pour fonctionner sur convertisseur de tension assignée de $U_N \leq 1$ kV avec un système d’isolation de Type II et une IVIC attribuée, il convient que le système d'isolation soit approprié à une IVIC 5 entre phases et une IVIC 4 entre phase et terre, ou comme l'utilisateur et le constructeur en ont convenu.

Dans le cas d'une machine électrique apte à fonctionner sur convertisseur ou conçue pour fonctionner sur convertisseur de tension assignée de $U_N > 1$ kV avec un système d'isolation de Type II, il relève de la responsabilité du constructeur de la machine électrique de spécifier la capacité de tenue en impulsion de tension de l'isolation de l’enroulement. Comme les topologies d’entraînement varient de manière importante, et puisque les moteurs de forte puissance sont des machines fonctionnant exclusivement sur convertisseur la plupart du temps conçues à la demande selon les besoins, la pratique, dans le cas où une IVIC est attribuée n’est pas de définir un niveau d’IVIC par défaut (voir l’IEC TS 60034-25). Si la topologie du convertisseur de fréquence et le système sont connus, l’IEC TS 61800-8 peut être utilisée pour donner une indication de la tension de crête aux bornes de la machine et, de ce fait, l’IVIC nécessaire du moteur.

Dans le cas où une IVIC est attribuée, le niveau d’IVIC doit être indiqué dans la documentation et de préférence sur la plaque signalétique (voir l’Article 10).

NOTE Pour plus d’informations sur les considérations particulières pour les machines alimentées par convertisseur, voir l’IEC TS 60034-25.

Tout transfert par bus ou réenclenchement rapide d’une machine à courant alternatif, tel qu’il peut s’en produire, par exemple, en raison des exigences d’alimentation continue sous tension des codes de réseau, peut conduire à des courants de crête très élevés mettant en danger la tête de l’enroulement statorique et à un couple de crête très élevé pouvant atteindre 20 fois le couple assigné mettant en danger la structure mécanique comportant le couplage et le matériel moteur ou entraîné, si le réenclenchement est effectué sans synchronisation. Un transfert par bus ou un réenclenchement rapide n’est donc admis que s’il est spécifié et accepté par le constructeur de la machine électrique et du matériel entraîné.

Pour les machines à induction de caractéristiques assignées ≤ 10 MW ou MVA, un réenclenchement lent dépassant 1,5 fois la constante de temps en circuit ouvert est admis s’il est spécifié et accepté par le constructeur de la machine électrique et du matériel entraîné. Pour les caractéristiques assignées > 10 MW ou MVA, il convient de déterminer le temps minimal admis pour le réenclenchement lent par analyse transitoire du système au complet par l’intégrateur de système et il est admis s’il est accepté par le constructeur de la machine électrique et du matériel entraîné.