

# Rotating electrical machines —

## Part 1: Rating and performance

The European Standard EN 60034-1:1998, with the incorporation of amendments A1:1998, A2:1999 and A11:2002, has the status of a British Standard

ICS 29.160.01

# National foreword

This British Standard is the English language version of EN 60034-1:1998, including amendments A1:1998, A2:1999 and A11:2002. It was derived by CENELEC from IEC 60034-1:1996, including amendments 1:1997 and 2:1999. It supersedes BS EN 60034-1:1995 which is withdrawn.

The CENELEC common modifications have been implemented at the appropriate places in the text. The start and finish of each common modification is indicated in the text by tags **[C]** **[C]**.

The start and finish of text introduced or altered by amendment is indicated in the text by tags **[A<sub>1</sub>]** **[A<sub>1</sub>]**. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 2 is indicated by **[A<sub>2</sub>]** **[A<sub>2</sub>]**. Amendments to CENELEC text, in this case Annex ZA, introduced by CENELEC amendment A2 are also indicated by **[A<sub>2</sub>]** **[A<sub>2</sub>]**.

NOTE Amendment A1:1998 to EN 60034-1:1998 was incorporated into BS EN 60034-1:1998.

The UK participation in its preparation was entrusted to Technical Committee PEL/2, Rotating electrical machinery, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

From 1 January 1997, all IEC publications have the number 60000 added to the old number. For instance, IEC 27-1 has been renumbered as IEC 60027-1. For a period of time during the change over from one numbering system to the other, publications may contain identifiers from both systems.

## Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

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

(includes amendments A1:1998, A2:1999 and A11:2002)  
(IEC 60034-1:1996 + A1:1997 + A2:1999, modified)

Machines électriques tournantes —  
Partie 1: Caractéristiques assignées et  
caractéristiques de fonctionnement  
(inclut les amendements A1:1998, A2:1999  
et A11:2002)  
(CEI 60034-1:1996 + A1:1997 + A2:1999,  
modifiée)

Drehende elektrische Maschinen —  
Teil 1: Bemessung und Betriebsverhalten  
(enthält Änderungen A1:1998, A2:1999 und  
A11:2002)  
(IEC 60034-1:1996 + A1:1997 + A2:1999,  
modifiziert)

This European Standard was approved by CENELEC on 1998-04-01; amendment A1 was approved by CENELEC on 1998-04-01; amendment A2 was approved by CENELEC on 1999-08-01; amendment A11 was approved by CENELEC on 2002-07-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

## CENELEC

European Committee for Electrotechnical Standardization  
Comité Européen de Normalisation Electrotechnique  
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B-1050 Brussels

## Foreword

The text of the International Standard IEC 60034-1:1996, prepared by IEC TC 2, Rotating machinery, together with common modifications prepared by the Technical Committee CENELEC TC 2, Rotating machinery, was submitted to the formal vote and was approved by CENELEC as EN 60034-1 on 1998-04-01.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1999-04-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 2000-04-01

Annexes designated “normative” are part of the body of the standard.

Annexes designated “informative” are given for information only.

In this standard, Annex ZA is normative and Annex A and Annex B are informative. Annex ZA has been added by CENELEC.

## Foreword to amendment A1

The text of document 2/956/FDIS, future amendment 2 to IEC 60034-1:1994, prepared by IEC TC 2, Rotating machinery, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as amendment A2 to EN 60034-1:1995. The text of the new International Standard IEC 60034-1:1996, with common modifications prepared by the Technical Committee CENELEC TC 2, Rotating machinery, was approved by CENELEC as EN 60034-1:1998.

As the text of amendment 2 to IEC 60034-1:1994 is also that of amendment 1 to IEC 60034-1:1996, the Technical Board of CENELEC has approved this text as amendment A1 to EN 60034-1:1998 on 1998-04-01.

The following dates were fixed:

- latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1999-04-01
- latest date by which the national standards conflicting with the amendment have to be withdrawn (dow) 2000-04-01

Annexes designated “normative” are part of the body of the standard.

In this standard, Annex ZA is normative.

Annex ZA has been added by CENELEC.

## Foreword to amendment A2

The texts of documents 2/1031/FDIS, 2/1055/FDIS and 2/1056/FDIS, future amendment 2 to IEC 60034-1, prepared by IEC TC 2, Rotating machinery, were submitted to the IEC-CENELEC parallel vote and were approved by CENELEC as amendment A2 to EN 60034-1:1998 on 1999-08-01.

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- latest date by which the national standards conflicting with the amendment have to be withdrawn (dow) 2002-08-01

Annexes designated “normative” are part of the body of the standard.

In this standard, Annex ZA is normative.

Annex ZA has been added by CENELEC.

## Foreword to amendment A11

This amendment was prepared by the Technical Committee CENELEC TC 2, Rotating machinery. The text of the draft was submitted to the Unique Acceptance Procedure and was approved by CENELEC as amendment A11 to EN 60034-1:1998 on 2002-07-01.

The following dates were fixed:

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- latest date by which the national standards conflicting with the amendment have to be withdrawn (dow) 2005-07-01

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# Section 1. General

## 1.1 Scope

This standard is applicable to all rotating electrical machines except those covered by other IEC standards — for example, IEC 349.

Machines within the scope of this standard may also be subject to superseding, modifying or additional requirements in other publications — for example, IEC 79, and IEC 92.

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

## 1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 34. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 27-1:1992, *Letter symbols to be used in electrical technology — Part 1: General*.

IEC 27-4:1985, *Letter symbols to be used in electrical technology — Part 4: Symbols for quantities to be used for rotating electrical machines*.

IEC 34-2:1972, *Rotating electrical machines — Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)*.

IEC 34-3:1988, *Rotating electrical machines — Part 3: Specific requirements for turbine-type synchronous machines*.

IEC 34-5:1991, *Rotating electrical machines — Part 5: Classification of degrees of protection provided by enclosures of rotating electrical machines (IP code)*.

IEC 34-6:1991, *Rotating electrical machines — Part 6: Methods of cooling (IC code)*.

IEC 34-12:1980, *Rotating electrical machines — Part 12: Starting performance of single-speed three-phase cage induction motors for voltages up to and including 660 V*.

IEC 34-15:1995, *Rotating electrical machines — Part 15: Impulse voltage withstand levels of rotating a.c. machines with form-wound stator coils*.

IEC 34-17:1992, *Rotating electrical machines — Part 17: Guide for the application of cage induction motors when fed from converters*.

IEC 38:1983, *IEC standard voltages*.

IEC 50(411):1996, *International Electrotechnical Vocabulary (IEV) — Chapter 411: Rotating machines*.

IEC 72, *Dimensions and output series for rotating electrical machines*.

IEC 85:1984, *Thermal evaluation and classification of electrical insulation*.

IEC 279:1969, *Measurement of the winding resistance of an a.c. machine during operation at alternating voltage*.

IEC 364-4-41:1992, *Electrical installations of buildings — Part 4: Protection for safety — Chapter 41: Protection against electric shock*.

IEC 445:1988, *Identification of equipment terminals and of terminations of certain designated conductors, including general rules for an alphanumeric system*.

IEC 449:1973, *Voltage bands for electrical installations of buildings*.

IEC 971:1989, *Semiconductor convertors — Identification code for convertor connections*.

IEC 60060, *High-voltage test techniques*.

IEC 60060-1:1989, *High-voltage test techniques — Part 1: General definitions and test requirements*. 

Ⓐ IEC 60204-1:1992, *Electrical equipment of industrial machines — Part 1: General requirements*. Ⓐ

Ⓐ IEC 61293:1994, *Marking of electrical equipment with ratings related to electrical supply — Safety requirements*. Ⓐ

Ⓐ CISPR 11:1990, *Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific and medical (ISM) radio-frequency equipment*.

CISPR 14:1993, *Limits and methods of measurement of radio disturbance characteristics of electrical motor-operated and thermal appliances for household and similar purposes, electric tools and electric apparatus*.

CISPR 16, *Specification for radio disturbance and immunity measuring apparatus and methods*. Ⓐ

ISO 497:1973, *Guide to the choice of series of preferred numbers and series containing more rounded values of preferred numbers*.

## Section 2. Definitions

For the purpose of this International Standard, the definitions in IEC 50(411) and the following definitions apply.

For definitions, other than those in **2.17** to **2.22**, concerning cooling and coolants, reference should be made to IEC 34-6.

For the purpose of this standard, the term “agreement” means “agreement between the manufacturer and purchaser”.

### 2.1

#### **rated value**

a quantity value assigned, generally by a manufacturer, for a specified operating condition of a machine [IEV 411-51-23]

**A<sub>2</sub>** NOTE The rated voltage or voltage range is the rated voltage or voltage range between lines at the terminals. **A<sub>2</sub>**

### 2.2

#### **rating**

the set of rated values and operating conditions [IEV 411-51-24]

### 2.3

#### **rated output**

the value of the output included in the rating

### 2.4

#### **load**

all the values of the electrical and mechanical quantities that signify the demand made on a rotating machine by an electrical circuit or a mechanism at a given instant [IEV 411-51-01]

### 2.5

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

the state of a machine rotating with zero output power (but under otherwise normal operating conditions) [IEV 411-51-02, modified]

### 2.6

#### **full load**

the load which causes a machine to operate at its rating [IEV 411-51-10]

### 2.7

#### **full load value**

a quantity value for a machine operating at full load [IEV 411-51-11]

NOTE This concept applies to power, torque, current, speed, etc.

### 2.8

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

the complete absence of all movement and of all electrical supply or mechanical drive [IEV 411-51-03]

### 2.9

#### **duty**

the 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 [IEV 411-51-06]

### 2.10

#### **duty type**

a 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 [IEV 411-51-13]

## 2.11

### **cyclic duration factor**

the ratio between the period of loading, including starting and electric braking, and the duration of the duty cycle, expressed as a percentage [IEV 411-51-09]

## 2.12

### **locked-rotor torque**

the smallest measured torque the motor develops at its shaft and with the rotor locked, over all its angular positions at rated voltage and frequency [IEV 411-48-06]

## 2.13

### **locked rotor current**

the greatest steady-state r.m.s. current taken from the line with the motor held at rest, over all angular positions of its rotor, at rated voltage and frequency [IEV 411-48-16]

## 2.14

### **pull-up torque (of an a.c. motor)**

the smallest value of the 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

this definition does not apply to those asynchronous motors of which the torque continually decreases with increase in speed

NOTE 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.

## 2.15

### **breakdown torque (of an a.c. motor)**

the maximum value of the 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

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

## 2.16

### **pull-out torque (of a synchronous motor)**

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

## 2.17

### **cooling**

a 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 [IEV 411-44-01]

## 2.18

### **coolant**

a medium, liquid or gas, by means of which heat is transferred [IEV 411-44-02]

## 2.19

### **primary coolant**

a 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 [IEV 411-44-03]

## 2.20

### **secondary coolant**

a 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 [IEV 411-44-03]

**2.21****direct cooled (inner cooled) winding<sup>1)</sup>**

a 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 [IEV 411-44-08]

**2.22****indirect cooled winding<sup>1)</sup>**

any winding other than a direct cooled winding [IEV 411-44-09]

**2.23****supplementary insulation**

an 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

**2.24****moment of inertia**

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

**2.25****thermal equilibrium**

the state reached when the temperature rises of the several parts of the machine do not vary by more than a gradient of 2 K per hour [IEV 411-51-08]

<sup>[A2]</sup> NOTE 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 reasonable intervals each have a gradient of less than 2 K per hour. <sup>[A2]</sup>

**2.26****thermal equivalent time constant**

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

**2.27****encapsulated winding**

a winding which is completely enclosed or sealed by moulded insulation [IEV 411-39-06]

**2.28****rated form factor of direct current supplied to a d.c. motor armature from a static power converter**

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

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

**2.29****current ripple factor**

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

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

NOTE For small values of current ripple the ripple factor may be approximated by the following expression:

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

the above expression may be used as an approximation if the resulting calculated value of  $q_{\text{i}}$  is equal to or less than 0,4

<sup>1)</sup> In all cases when “indirect” or “direct” is not stated, an indirect cooled winding is implied.



## Section 3. Duty

### 3.1 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 3.2, 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 motor ( $J_M$ ) 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.

### 3.2 Duty types



#### 3.2.1 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.

#### 3.2.2 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

#### 3.2.3 Duty type S3 — Intermittent periodic duty<sup>2)</sup>

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 %

#### 3.2.4 Duty type S4 — Intermittent periodic duty with starting<sup>2)</sup>

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 %  $J_M = 0,15 \text{ kg} \times \text{m}^2$   $J_{ext} = 0,7 \text{ kg} \times \text{m}^2$

<sup>2)</sup> Periodic duty implies that thermal equilibrium is not reached during the time on load.

### 3.2.5 Duty type S5 — Intermittent periodic duty with electric braking<sup>3)</sup>

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

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

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

### 3.2.6 Duty type S6 — Continuous-operation periodic duty<sup>3)</sup>

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:  $S6\ 40\ \%$

### 3.2.7 Duty type S7 — Continuous-operation periodic duty with electric braking<sup>3)</sup>

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

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

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

### 3.2.8 Duty type S8 — Continuous-operation periodic duty with related load/speed changes<sup>3)</sup>

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

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

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

### 3.2.9 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.

### 3.2.10 Duty type S10 — Duty with discrete constant loads

A duty consisting of not more than four discrete values of load (or equivalent loading), each value 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 rest and de-energized).

<sup>3)</sup> Periodic duty implies that thermal equilibrium is not reached during the time on load.

The appropriate abbreviation is S10, followed by the p.u. quantities  $p/\Delta t$  for the respective load and its duration and the p.u. 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 = 0,6

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 (" $P_{\text{ref}}$ " in Figure 10) for the discrete loads.

NOTE 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.



## Section 4. Rating

### 4.1 Assignment of rating

The rating, as defined in 2.2, shall be assigned by the manufacturer. In assigning the rating the manufacturer shall select one of the classes of rating defined in 4.2.1 to 4.2.6. 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 34-17 gives guidance for the case of cage induction motors covered in IEC 34-12.

### 4.2 Classes of rating

#### 4.2.1 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 standard.

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

#### 4.2.2 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 standard.

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

#### 4.2.3 Rating for periodic duty

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

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 %. 

#### 4.2.4 Rating for non-periodic duty

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

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

#### 4.2.5 Rating for duty with discrete constant loads

A rating at which the machine may be operated with the associated loads of duty type S10 for an unlimited period of time while complying with the requirements of this standard. The maximum permissible load within one cycle shall take into consideration all parts of the machine, e.g. 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 1,2 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.

#### 4.2.6 Rating for equivalent loading

**A2** 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 at the end of the test on the specified duty type.

NOTE 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”. **A2**

#### 4.3 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 **3.2.2**.

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 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 **3.2.3** to **3.2.8**.

When a machine is intended non-periodically to supply variable loads at variable speeds, including overloads, the rating shall be a rating for non-periodic duty based on duty type S9, see **3.2.9**.

When a machine is intended to supply discrete constant loads including times of overload or times of no-load (or rest and de-energized) the rating shall be a rating with discrete constant loads based on duty type S10, see **3.2.10**.

#### 4.4 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 **3.2.1** to **3.2.8**.

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 **3.2.9** and **3.2.10**.

#### 4.5 Rated output

##### 4.5.1 DC generators

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

##### 4.5.2 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.

**A2** The rated power factor for synchronous generators shall be 0,8 lagging (over-excited), unless otherwise specified by the purchaser. **A2**

##### 4.5.3 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).

##### 4.5.4 Synchronous condensers

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

## 4.6 Rated voltage

**A2**

**A2**

**A2**

### 4.6.1 **A2** DC generators

For d.c. 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 **6.3**.

**A2**

### 4.6.2 **A2** AC generators

For a.c. 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 **6.3**).

## 4.7 Coordination of voltages and outputs

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

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

## 4.8 Machines with more than one rating

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

For multi-speed motors, 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 **6.3** or to star-delta connections intended for starting.



## Section 5. Site operating conditions

### 5.1 General

Unless otherwise specified machines shall be suitable for the following site operation conditions. For site operating conditions deviating from those values corrections are given in **Section 7**.

### 5.2 Altitude

The altitude shall not exceed 1 000 m above sea-level.

### 5.3 Maximum ambient air temperature

The ambient air temperature shall not exceed 40 °C.

### 5.4 Minimum ambient air temperature

The ambient air temperature shall not be less than –15 °C for any machine.

For a machine with any of the following:

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

the ambient air temperature shall not be less than 0 °C.

### 5.5 Water coolant temperature

The water coolant temperature at the inlet to a machine or heat exchanger shall not exceed +25 °C nor be less than +5 °C.

### 5.6 Storage and transport

When temperatures lower than specified in **5.4** are expected during transportation, storage, or after installation, the purchaser shall inform the manufacturer and specify the expected minimum temperature.

### 5.7 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 34-2, 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.



## Section 6. Electrical operating conditions

### 6.1 Electrical supply

**A<sub>2</sub>**

**A<sub>2</sub>**

**A<sub>2</sub>** For three-phase a.c. machines, 50 Hz or 60 Hz, intended to be directly connected to distribution or utilization systems, the rated voltages shall be derived from the nominal voltages given in IEC 60038.

NOTE For large high-voltage a.c. machines, the voltages may be selected for optimum performance. **A<sub>2</sub>**

For a.c. motors supplied from static converters these restrictions on voltage, frequency and waveform do not apply. In this case the rated voltages shall be selected by agreement.

### 6.2 Form and symmetry of voltages and currents

#### 6.2.1 AC motors

**6.2.1.1** AC motors rated for use on a power supply of fixed frequency, supplied from an a.c. 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 34-12), unless the manufacturer declares otherwise;

0,03 for design N motors.

The HVF shall be computed by using the following formula:

$$\text{HVF} = \sqrt{\sum \frac{u_n^2}{n}}$$

where

$u_n$  is the per unit value of the harmonic voltage (referred to rated voltage  $U_N$ );

$n$  is the order of harmonic (not divisible by three in the case of three-phase a.c. motors).

Usually it is sufficient to consider harmonic orders  $n \leq 13$ .

Three-phase a.c. 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.

**C** NOTE Motors shall be able to operate with a negative sequence component of voltage of 2 %; but this may involve very severe conditions which could affect the life of motors. **C**

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 deleterious temperature in the motor and it is recommended that the excess resulting temperature rise or temperature related to the limits specified in this standard 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.

**6.2.1.2** AC motors supplied from static converters have to tolerate higher harmonic contents of the supply voltage, see IEC 34-17 for the case of cage motors within the scope of IEC 34-12.

NOTE When the supply voltage is significantly non-sinusoidal e.g. 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 a.c. machine.

#### 6.2.2 AC generators

AC generators shall be suitable for supplying circuits which are virtually non-deforming and virtually balanced, that is to say, when supplied by a sinusoidal voltage, none of the instantaneous values of the current differ from the corresponding instantaneous value of the fundamental by more than 5 % of the amplitude of the latter, and when supplied by a balanced system of voltages, neither the negative-sequence component nor the zero-sequence component of the system of currents exceeds 5 % of the positive-sequence component.

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

### 6.2.3 Synchronous machines

Unless otherwise specified, three-phase synchronous machines shall be capable of operating continuously on an unbalanced system such 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 1 and under fault conditions shall be capable of operation with the product of  $(I_2/I_N)^2$  and time ( $t$ ) not exceeding the values in Table 1.

**Table 1 — 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 |
|-----------------------------------------------|-----------------------------------------------------------|--------------------------------------------------|--------------------------------------------------------------------------------|
| <b>Salient pole machines</b>                  |                                                           |                                                  |                                                                                |
| 1                                             | Indirect cooled windings                                  |                                                  |                                                                                |
|                                               | motors                                                    | 0,1                                              | 20                                                                             |
|                                               | generators                                                | 0,08                                             | 20                                                                             |
|                                               | synchronous condensers                                    | 0,1                                              | 20                                                                             |
| 2                                             | Direct cooled (inner cooled) stator and/or field windings |                                                  |                                                                                |
|                                               | motors                                                    | 0,08                                             | 15                                                                             |
|                                               | generators                                                | 0,05                                             | 15                                                                             |
|                                               | synchronous condensers                                    | 0,08                                             | 15                                                                             |
| <b>Cylindrical rotor synchronous machines</b> |                                                           |                                                  |                                                                                |
| 3                                             | Indirect cooled rotor windings                            |                                                  |                                                                                |
|                                               | air-cooled                                                | 0,1                                              | 15                                                                             |
|                                               | hydrogen-cooled                                           | 0,1                                              | 10                                                                             |
| 4                                             | Direct cooled (inner cooled) rotor windings               |                                                  |                                                                                |
|                                               | $\leq 350$ MVA                                            | 0,08                                             | 8                                                                              |
|                                               | $> 350 \leq 900$ MVA                                      | See note 1                                       | See note 2                                                                     |
|                                               | $> 900 \leq 1\,250$ MVA                                   | See note 1                                       | 5                                                                              |
|                                               | $> 1\,250 \leq 1\,600$ MVA                                | 0,05                                             | 5                                                                              |

NOTE 1 For these machines, the value of  $I_2/I_N$  is calculated as follows:

$$\frac{I_2}{I_N} = 0,08 - \frac{S_N - 350}{3 \times 10^4}$$

NOTE 2 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 notes,  $S_N$  is the rated apparent power in megavoltamperes.

### 6.2.4 DC motors supplied from static power converters

In the case of a d.c. 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 d.c. motor supplied from a pure d.c. 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.