

Electric traction — Rotating electrical machines for rail and road vehicles —

Part 1: Machines other than electronic convertor-fed alternating current motors

The European Standard EN 60349-1:2000, with the incorporation of amendment A1:2002, has the status of a British Standard

ICS 29.160.30; 29.280; 43.060.01

National foreword

This British Standard is the official English language version of EN 60349-1:2000, including Amendment A1:2002. It is identical with IEC 60349-1:1999, Edition 1.1:2002, which comprises Edition 1:1999 consolidated by the incorporation of amendment 1:2002. It supersedes BS 173-1:1992 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GEL/9, Railway electrotechnical applications, to Subcommittee GEL/9/2, Rolling stock, 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.

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Cross-references

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**Electric traction —
Rotating electrical machines for rail and road vehicles —
Part 1: Machines other than electronic convertor-fed
alternating current motors
(includes amendment A1:2002)
(IEC 60349-1:1999 + A1:2002)**

Traction électrique -
Machines électriques tournantes
des véhicules ferroviaires et routiers
Partie 1: Machines autres que les moteurs
à courant alternatif alimentés
par convertisseur électronique
(inclut l'amendement A1:2002)
(CEI 60349-1:1999 + A1:2002)

Elektrische Zugförderung -
Drehende elektrische Maschinen
für Bahn- und Straßenfahrzeuge
Teil 1: Elektrische Maschinen
ausgenommen umrichter gespeiste
Wechselstrommotoren
(enthält Änderung A1:2002)
(IEC 60349-1:1999 + A1:2002)

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

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

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Foreword

The text of document 9/529/FDIS, future edition 1 to IEC 60349-1, prepared by IEC TC 9, Electric railway equipment, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60349-1 on 2000-01-01.

The following dates were fixed:

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with the EN have to be withdrawn (dow) 2003-01-01

Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, annexes A, D and ZA are normative and annexes B, C and E are informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60349-1:1999 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 61287-1 NOTE: EN 50207 is related to this International Standard.

IEC 61373 NOTE: Harmonized as EN 61373:1999 (not modified).

Foreword to amendment A1

The text of document 9/683/FDIS, future amendment 1 to IEC 60349-1:1999, prepared by IEC TC 9, Electrical equipment and systems for railways, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as amendment A1 to EN 60349-1:2000 on 2002-10-01.

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Annexes designated "informative" are given for information only.

In this standard, annex C is informative.

Endorsement notice

The text of amendment 1:2002 to the International Standard IEC 60349-1:1999 was approved by CENELEC as an amendment to the European Standard without any modification.

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ELECTRIC TRACTION – ROTATING ELECTRICAL MACHINES FOR RAIL AND ROAD VEHICLES –

Part 1: Machines other than electronic convertor-fed alternating current motors

1 Scope and object

1.1 This part of IEC 60349 is applicable to rotating electrical machines, other than electronic convertor-fed alternating current motors, forming part of the equipment of electrically propelled rail and road vehicles. The vehicles may obtain power either from an external supply or from an internal source.

The object of this standard is to enable the performance of a machine to be confirmed by tests and to provide a basis for assessment of its suitability for a specified duty and for comparison with other machines.

NOTE 1 This standard also applies to machines installed on trailers hauled by electrically propelled vehicles.

NOTE 2 The basic requirements of this standard may be applied to rotating electrical machines for special purpose vehicles such as mine locomotives, but it does not cover flameproof or other special features that may be required.

NOTE 3 It is not intended that this standard should apply to machines on small road vehicles such as battery-fed delivery vehicles, works trucks, etc. Neither does it apply to minor machines such as windscreen wiper motors, etc. that may be used on all types of vehicles.

NOTE 4 Industrial type machines complying with the IEC 60034 series may be suitable for certain auxiliary applications.

1.2 Electrical inputs or outputs of machines covered by this standard may be as follows:

- a) direct current (including rectified polyphase alternating current);
- b) pulsating current (rectified single-phase alternating current);
- c) unidirectional chopper-controlled current;
- d) single-phase alternating current;
- e) polyphase alternating current (in general three-phase).

1.3 In this standard, the electrical machines concerned are classified as follows.

1.3.1 Traction motors

Motors for propelling rail or road vehicles.

1.3.2 Engine-driven main generators

Generators for supplying power to traction motors on the same vehicle or train.

1.3.3 Main motor-generator sets

Machines obtaining power from a line or battery, and supplying power to traction motors on the same vehicle or train.

1.3.4 Auxiliary motors

Motors for driving compressors, fans, auxiliary generators or other auxiliary machines.

1.3.5 Auxiliary generators

Generators for supplying power for auxiliary services such as air conditioning, heating, lighting, battery charging, etc.

1.3.6 Auxiliary motor-generator sets and auxiliary rotary convertors

Machines which obtain their power from the line or other source to provide an electrical supply for auxiliary services.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034-8, *Rotating electrical machines – Part 8: Terminal markings and direction of rotation of rotating machines*

IEC 60034-14:1996, *Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of the vibration*

IEC 60050(131), *International Electrotechnical Vocabulary (IEV) – Chapter 131: Electric and magnetic circuits*

IEC 60050(151), *International Electrotechnical Vocabulary (IEV) – Chapter 151: Electrical and magnetic devices*

IEC 60050(411), *International Electrotechnical Vocabulary (IEV) – Chapter 411: Rotating machinery*

IEC 60050(811), *International Electrotechnical Vocabulary (IEV) – Chapter 811: Electric traction*

IEC 60085, *Thermal evaluation and classification of electrical insulation*

IEC 60411-2, *Power convertors for electric traction – Part 2: Additional technical information*

IEC 60638, *Criteria for assessing and coding of the commutation of rotating electrical machines for traction*

IEC 60850, *Supply voltage of traction systems*

ISO/IEC Guide 2, *Standardization and related activities – General vocabulary*

3 Definitions

3.1 General

For the purpose of this part of IEC 60349, the following definitions apply; for the definitions of general terms used, reference should be made to IEC 60050(131), IEC 60050(151), IEC 60050(411) and IEC 60050(811).

3.2

rating of a machine

combination of simultaneous values of electrical and mechanical quantities, with their duration and sequence, assigned to a machine by the manufacturer

3.2.1

rated value

numerical value of any quantity included in a rating. For traction machines, certain special quantities are often included such as current ripple factor for a pulsating current motor, excitation condition for a variable field motor, etc.

3.2.2

continuous rating

electrical load the machine can withstand on the test bed for an unlimited period under the conditions specified in 8.1 without exceeding the limits of temperature rise given in table 2, all other appropriate requirements in this standard also being satisfied

continuous ratings of an engine-driven main generator

an engine-driven main generator normally has two continuous ratings which are defined below:

a) continuous rating "at lower voltage"

continuous rating determined by the temperature rise of the windings through which the load current flows (higher value of load current and lower voltage)

b) continuous rating "at higher voltage"

continuous rating determined by the temperature rise of the field windings (lower value of load current and higher voltage)

NOTE 1 These two continuous ratings correspond to points on the full power regulated characteristic as defined in 3.9.2 or on the inherent characteristic as defined in 3.9.3.

NOTE 2 Ratings similar to those specified above may, where appropriate, be applied to a main motor-generator set.

3.2.3

short-time (for example, 1 h) rating

electrical load that a machine can withstand on the test bed for the stated time without exceeding the limits of temperature rise given in table 2, the test being carried out as specified in 8.1 starting with the machine cold (see A.1), all other appropriate requirements in this standard also being satisfied

3.2.4**short-time overload rating**

electrical load that a machine can withstand on the test bed for the stated time without exceeding the limits of temperature rise given in table 3 (the test being started and carried out as specified in annex A)

NOTE Short-time overload ratings are of value in determining the suitability of machines for duties which involve relatively long periods of operation below the continuous rating followed by a period above it. These are most likely to occur in locomotive applications. They are not relevant to the repeated short-load cycles of rapid transit and similar duties and should not be specified for such applications.

3.2.5**intermittent duty rating**

electrical loads and conditions at which a machine may be operated on a duty cycle without the temperature rises at any point in the cycle exceeding the limits given in table 2

3.2.6**equivalent rating**

continuous rating with constant values of voltage, current and speed that, as far as temperature rise is concerned, is equivalent to a long series of the intermittent duty cycles which the machine has to withstand in service. This rating should be agreed between user and manufacturer

3.2.7**guaranteed rating**

rating guaranteed by the manufacturer

3.2.7.1**guaranteed rating of a traction motor**

the guaranteed rating is normally a continuous rating, but in special cases the manufacturer and user may agree that it is a short-time or intermittent rating

3.2.7.2**guaranteed ratings of an engine-driven main generator**

the guaranteed ratings are normally the two continuous ratings defined in 3.2.2, but in special cases, the manufacturer and user may agree that they are short-time or intermittent ratings

3.2.7.3**guaranteed ratings of a main motor-generator set**

the guaranteed ratings are normally the continuous rating, but in special cases, the manufacturer and user may agree that they are short-time or intermittent ratings

3.2.7.4**guaranteed rating of an auxiliary machine**

unless otherwise specified, the guaranteed rating is the continuous rating

3.3

rated voltage

specified value of the voltage at the terminals of the machine when operating at a rating. If unidirectional, the voltage is the arithmetic mean of the recurring waveform and if alternating it is the root mean square value of the fundamental frequency component of the recurring waveform

NOTE In the case of a machine with a protective resistor permanently in series, the resistor is considered as an integral part of the machine.

3.3.1

rated voltage of a motor fed directly or indirectly from a contact system (including motors of motor-generator sets)

highest value of voltage (excluding transients) which can appear at the motor terminals when it is drawing its rated current with the contact system at its nominal voltage as defined in annex D

In some cases, it may be necessary to assign ratings at other than the above voltage in order to fully define the performance of a machine, an example being a motor-generator set giving constant power output over a range of input voltages

If, in the case of an indirectly fed motor, the regulation characteristic of the transformer or other device is not specified, the rated voltage is taken as 90 % of the open-circuit value

3.3.2 rated voltage of a motor fed from a generator or battery located on the vehicle

3.3.2.1

traction motors

rated voltage corresponding to the maximum voltage of the source when supplying the motor at its rated current

3.3.2.2

auxiliary motors

rated voltage corresponding to the nominal voltage of the auxiliary supply (see note to 3.3.4)

3.3.3

rated voltages of a main generator

two rated voltages corresponding to the two continuous ratings defined in 3.2.2

3.3.4

rated voltage of an auxiliary generator (including generators of auxiliary motor-generator sets or rotary converters)

voltage corresponding to the nominal voltage of the auxiliary supply

NOTE The nominal voltage of the auxiliary supply should normally be agreed between the manufacturer and the user, taking into account factors (such as standardization with other vehicles), which may influence the choice.

3.4

rated speed of a machine

speed at a guaranteed rating of the machine

3.4.1

rated speed of an engine-driven main or auxiliary generator

speed of the generator corresponding to the rated speed of the engine

3.4.2

rated speed of an axle-driven generator

speed agreed between the manufacturer and the user

3.5 maximum (or minimum) voltage

3.5.1

maximum (or minimum) voltage of a machine

highest (or lowest) voltage which the machine will be called upon to withstand in service, transient voltages being excluded. Also excluded is any reduction in the minimum voltage by control means during starting or acceleration

Unless otherwise agreed the maximum voltage of an auxiliary machine connected in series with other machines without mechanical coupling is taken as 1,2 times the highest voltage of the supply to the machines divided by the number in series

3.5.2

maximum and minimum voltage of a machine supplied directly or indirectly from a contact system

voltages normally corresponding to the highest and lowest voltages of the traction system (see annex D), account being taken of the regulation of any transformer or control equipment interposed between the line and the machine

3.6

maximum current

maximum value of current shown on the characteristic curve supplied by the manufacturer

3.7 maximum working speed

3.7.1

maximum working speed of a traction motor

highest rotational speed assigned to the traction motor by the manufacturer

NOTE When the characteristics of the vehicle for which the motor is intended are specified, this speed should be not less than that corresponding to the maximum service speed of the vehicle, assuming fully worn metal wheels or the minimum rolling diameter of rubber types.

3.7.2

maximum working speed of an engine-driven main or auxiliary generator

generator speed corresponding to the maximum governed speed of the engine for the particular application

NOTE This will normally be the maximum governed speed on "no-load". Transient speed variations during load changes should be disregarded.

3.7.3

maximum working speed of a generator with a rotational speed proportional to the speed of the vehicle

highest rotational speed assigned to the generator by the manufacturer. See note in 3.7.1

3.7.4

maximum working speed of a main or auxiliary motor-generator set, an auxiliary convertor or an auxiliary motor

highest rotational speed assigned to the machine by the manufacturer

NOTE For specific applications account should be taken, when assigning this maximum speed, of the most unfavourable conditions of voltage, excitation, frequency, loading, etc., that can occur in service.

3.8 output and input power of electrical machines and heat engines

3.8.1

output power of a motor

mechanical output power available at the motor shaft, expressed in kilowatts (kW)

3.8.2

maximum service output power of a heat engine

maximum output power assigned to a heat engine for a particular application

3.8.3

available input power to a main generator

input power converted to electricity to supply the traction motors and other loads, such as train heating, connected to it. It is used to derive the ratings and characteristics of the generator

The maximum available input power to a main generator is the maximum service output power of the heat engine, less the power it provides to drive, either directly or indirectly, the engine cooling equipment and vehicle auxiliaries, assuming these are operating at their minimum input power for the given condition

NOTE The available input power is not necessarily absorbed by the main generator over its whole working current range.

3.9 main generator characteristics

3.9.1

regulated characteristic

characteristic obtained if the power demand of a main generator is regulated to absorb the available input power, the product of current and voltage remaining substantially constant between the limits of regulation

3.9.2

full power regulated characteristic

regulated characteristic corresponding to the maximum available input power

3.9.3

inherent characteristic

characteristic of a generator designed to operate without load regulating equipment to match its power demand to the available engine output power

3.10

effective field ratio of a series motor

ratio of the actual field ampere-turns to the maximum obtainable at the same armature current

NOTE 1 A series motor is said to be

- in full field when the field current is equal to the armature current;
- in maximum field when the effective field ratio is the maximum used in service;
- in weak field when the effective field ratio is below the maximum;
- in minimum field when the effective field ratio is the minimum used in service.

NOTE 2 For motors without permanent shunts across the field windings, full field and maximum field are the same.

3.11**effective resistance of a series motor**

resistance value which, when multiplied by the load current, gives the total resistive voltage drop in the machine windings, i.e. it takes account of any shunt across the field windings

3.12**ripple factor**

ripple factor of a continuous pulsating current is defined as:

$$\frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} \times 100$$

expressed as a percentage in which $I_{\max}$ and $I_{\min}$ are respectively the maximum and the minimum values of the current waveform

NOTE This is in accordance with IEC 60411-2.

3.13**pulsating frequency**

frequency of the fundamental alternating component of a pulsating current or voltage

3.14**pulse control**

control of the power supply to a machine by varying the starting and terminating points of repeated pulses of voltage or current. Pulse control devices include, but are not limited to, choppers, inverters and electronically controlled rectifiers

4 Environmental conditions

Unless otherwise specified by the user, the following environmental conditions are assumed:

a) Altitude

Height above sea level not exceeding 1 200 m.

b) Temperature

Temperature in the shade not exceeding 40 °C.

Whenever the machines are intended to operate where one or both of these limits will be exceeded, special requirements may be agreed between user and manufacturer.

The manufacturer shall be informed by the user of any particularly arduous conditions such as dust, humidity, temperature, snow, dynamic effects, etc. under which the machines are intended to work.

5 Characteristics**5.1 General**

Machine specifications shall, as a general rule, include characteristic curves in accordance with the following subclauses. These curves, defined as the "specified characteristics", shall be plotted up to the designed operating limits of each variable.

When the first few machines of a type have been tested, "declared characteristics" shall be produced from the results in accordance with 8.2.

Unless otherwise agreed, the declared characteristics of machines electromagnetically identical with any previously manufactured for the same user or application shall be those of the existing machines, in which case compliance with the characteristics shall be demonstrated by routine tests only.

5.2 Reference temperature

All characteristics, irrespective of the class of insulation used on the machine to which they apply, shall be drawn for a winding reference temperature of 150 °C which shall be stated on the characteristics.

5.3 Efficiency characteristics

Efficiency characteristics shall take account of losses in external resistances normally included in either the main or excitation circuits. Any power used in providing separate excitation shall be included in the losses unless otherwise accounted for (e.g. as an auxiliary load), in which case the omission shall be stated.

5.4 Commutator type traction motor characteristics

The characteristic curves shall normally show motor speed, torque and efficiency as a function of current. Alternatively the curves may show vehicle speed and tractive effort at the rail as a function of current, in which case the gear ratio, wheel diameter and transmission losses shall be stated. If conventional values are used for the latter, they shall be in accordance with figure B.10.

Curves shall be drawn for each excitation condition employed on the application except that where continuously variable field control is employed, only the maximum and minimum curves need be drawn. The effective machine resistance for each effective field ratio shall be stated.

The characteristic curves of traction motors supplied directly or indirectly from a contact system, or from a battery located on the vehicle, shall be drawn at the rated voltage, except when the circuit includes equipment (such as a transformer or inductor) which introduces a current-dependent voltage drop at the motor terminals. For these exceptions, the curves shall be drawn for a motor voltage corresponding to the nominal supply voltage and a motor voltage current curve shall be included in the characteristics. If this information is not available, the curves may be drawn for the rated voltage.

The characteristic curves of traction motors used on thermo-electric vehicles shall normally be drawn for a voltage corresponding to the lower voltage of the generator at its continuous rating, but they may, by agreement, be drawn for other voltages.

The characteristic curves of a.c. commutator motors shall be plotted for the rated frequency and shall show the power factor as a function of current.

In the case of motors used for rheostatic or regenerative braking, the characteristics shall show the performance in this mode. Unless otherwise agreed, regenerative braking characteristics shall be drawn for a motor voltage corresponding to 1,1 times the nominal system voltage.

The declared braking characteristics may be derived either by calculation from the results of motoring tests or directly from tests in the braking mode.

5.5 Main generator characteristics

The characteristic curves shall show voltage as a function of load current. In the case of an a.c. generator intended to operate with a rectifier, the characteristics shall also show the output of the rectifier. A brushless alternator and its exciter shall be regarded as a single machine.

Characteristic curves shall be drawn corresponding to the generator input power available for traction at maximum and minimum engine speeds, and if the engine has a number of predetermined intermediate speed notches, additional curves shall be drawn for a sufficient number of these speeds to adequately show the performance of the generator.

Each curve shall be identified with its excitation condition, input power, generator speed and, if applicable, notch number. In addition, the efficiency on the full power characteristic shall be shown for at least two continuous ratings.

NOTE See 5.3 concerning the inclusion of excitation power in the losses when determining the efficiency.

Similar characteristics shall be drawn for the generators of main motor-generator sets, due account being taken of the characteristics of the driving motor and regulating equipment.

5.6 Auxiliary motor characteristics

Characteristic curves of speed, torque (or output power), efficiency and, in the case of a.c. machines, power factor shall be plotted as a function of motor current at the rated voltage and frequency.

Alternatively, and through agreement between the manufacturer and user, the characteristics may be plotted as a function of speed or output power.

Curves shall be drawn for each excitation condition employed in the application.

5.7 Auxiliary generator characteristics

The characteristic curves of output voltage, power and efficiency shall be plotted as a function of output current at the rated speed and, for variable speed machines, at the minimum and maximum speeds for the application. The frequency of a.c. outputs shall be stated.

In the case of generators operating with a voltage regulator the characteristics shall be plotted at the nominal voltage and the range of excitation current stated.

A brushless alternator and its exciter shall be regarded as a single machine.

5.8 Auxiliary motor-generator set and rotary convertor characteristics

The characteristic curves of output voltage, output power, machine speed, and input current shall be plotted as a function of output current with the machine supplied at minimum, rated and maximum voltage. The overall efficiency at the continuous rating shall be stated. The characteristics of a.c. machines shall show the power factor.

In the case of machines operating with a voltage or frequency regulator, the characteristics shall be drawn with the voltage or frequency at its nominal value. The range of excitation current shall be stated.

If the machine drives an external load, such as a blower, the power absorbed by this external load shall be shown or stated and the statement of overall efficiency shall be replaced by one of the total input power to the machine at the continuous rating.

6 Marking

6.1 Nameplate

All the machines covered by this standard shall carry a nameplate visible when the machine is on the workshop floor. It shall include at least the following information:

- a) manufacturer's name;
- b) machine type designation;
- c) machine serial number;
- d) year of manufacture.

The machine serial number and, if applicable, rotation arrow, shall also be easily read when the machine is installed in the vehicle.

A serial number, or unique identification number, shall be punched on both the rotor and the stator of each machine.

6.2 Terminal and lead markings

Terminal and lead markings shall be in accordance with IEC 60034-8, unless otherwise agreed.

7 Test categories and summary of tests

7.1 Test categories

7.1.1 General

There are three categories of tests:

- type tests;
- routine tests;
- investigation tests.

7.1.2 Type tests

Type tests are intended to establish the ratings, characteristics and performance of new types of machine. Where there is a change in place and/or method of manufacture, the user and manufacturer shall agree upon type tests to be repeated. In addition, tests to establish the declared characteristics shall be carried out on further machines in accordance with 8.2.

Unless otherwise agreed, the fully tested machine shall be one of the first ten manufactured.

A machine may be exempted from type tests if the manufacturer produces a record, acceptable to the user, of type tests already carried out on a machine of the same electromagnetic design for the same environmental conditions and at the same ratings.

Before testing commences the manufacturer shall provide the user with a test specification outlining the tests to be undertaken to demonstrate compliance with this standard. Following completion of the type tests the manufacturer shall supply the user with a full type test report as defined in ISO/IEC Guide 2.

By agreement between manufacturer and user, more machines may be fully or partially type tested at intervals.

Type tested machines shall also be routine tested.

7.1.3 Routine tests

Routine tests are intended to demonstrate that each machine is sound both electrically and mechanically, and that it is essentially identical with the machine which has been type tested.

Routine tests as specified in clause 9 shall normally be carried out on all machines but alternative tests may be agreed between user and manufacturer. It may also be agreed that only a proportion of machines chosen at random from those built on the order shall be fully routine tested, subject to overspeed and dielectric tests in accordance with 9.4 and 9.5 being carried out on all machines.

7.1.4 Investigation tests

Investigation tests are optional special tests performed to obtain additional information. They shall be carried out only if agreement between user and manufacturer has been reached before placing the order. The results of these tests shall not influence the acceptance of a machine unless agreement to the contrary has been similarly reached.

7.2 Summary of tests

Table 1 lists the tests required for compliance with this standard.

Table 1 – Summary of tests

Class of machine (subclause 1.3)	Test	Temperature rise		Soundness		Characteristics		Commutation		Transient		Starting		Noise	Overspeed		Dielectric	Vibration		Commutator run-out
		Type	Routine	Type	Routine	Type	Routine	Type	Routine	Type	Routine	Type	Routine		Internally generated characteristic	Imbalance				
																		Type	Routine	
Test category (subclause 5.1)		Clause or subclause																		
Traction motors (subclause 1.3.1)	Commutator	8.1	9.1	8.2.2	9.2.2	8.3.2	9.3.2	8.4.2*	8.6.2*	Annex C	NA	9.4.2	9.5	8.8	9.6	9.7				
	Wound rotor	8.1	9.1	8.2.3	9.2.3	NA	NA	NA	NA		9.4.2	9.5	8.8	9.6	9.7					
	Cage rotor	8.1	NA	8.2.3	9.2.3	NA	NA	NA	8.7		NA	9.5	8.8	9.6	9.7					
	DC	8.1	9.1	8.2.3	9.2.3	8.3.3	9.3.3	NA	NA	Annex C	NA	9.4.3	9.5	8.8	9.6	9.7				
Main Generators (subclause 1.3.2)	AC	8.1	9.1	8.2.3	9.2.3/4	NA	NA	8.5	NA		NA	9.4.3	9.5	8.8	9.6	NA				
	Motor Generator	8.1	9.1	8.2.2	9.2.2	8.3.2*	9.3.2*	8.4.2*	8.6.3	Annex C	NA	9.4.5	9.5	8.8	9.6	9.7*				
Main motor-generator sets (subclause 1.3.3)	Motor Generator	8.1	9.1	8.2.3	9.2.3	8.3.3*	9.3.3*	8.5	NA		NA	9.4.5	9.5	8.8	9.6	9.7*				
Auxiliary motors (subclause 1.3.4)	Commutator	8.1	9.1	8.2.4	9.2.5	8.3.4	9.3.4	8.4.3/4*	8.6.4	Annex C	NA	9.4.5	9.5	8.8	9.6	9.7				
	Wound rotor	8.1	9.1	8.2.4	9.2.5	NA	NA	NA	8.6.4		NA	9.4.5	9.5	8.8	9.6	NA				
	Cage rotor	8.1	9.1	8.2.4	9.2.5	NA	NA	NA	8.6.4		8.7	NA	9.5	8.8	9.6	NA				
Auxiliary generators (subclause 1.3.5)	DC	8.1	9.1	8.2.5	9.2.6	8.3.4	9.3.4	NA	NA	Annex C	NA	9.4.5	9.5	8.8	9.6	9.7				
	AC	8.1	9.1	8.2.5	9.2.6	NA	NA	8.5	NA		NA	9.4.5	9.5	8.8	9.6	NA				
Auxiliary motor-generator sets, rotary converters (subclause 1.3.6)	Motor	8.1	9.1	8.2.6	9.2.7	8.3.4*	9.3.4*	8.4.3/4	8.6.4	Annex C	NA	9.4.5	9.5	8.8	9.6	9.7*				
	Generator	8.1	9.1	8.2.6	9.2.7	8.3.4*	9.3.4*	8.5	NA		NA	9.4.5	9.5	8.8	9.6	9.7*				
NA = Not applicable.																				
* Not applicable to all machines in the class; refer to relevant clause.																				
All machines, including those type tested, are to be routine tested.																				

8 Type tests

8.1 Temperature-rise tests

8.1.1 General

The tests shall be carried out at the guaranteed ratings except that the user and manufacturer may agree that main alternators be tested as follows:

- a) a test at the rated frequency with the terminals short-circuited and the excitation adjusted to give an output current deemed to produce practically the same stator winding temperature rise as would a load test at the continuous rating at lower voltage;
- b) a test at the rated frequency on open circuit with the excitation adjusted to the value specified for the continuous rating at higher voltage.

When the output of an alternator is rectified, it shall be type tested with its rectifier or with one having similar characteristics.

If one or more of the following conditions apply, the tests shall be carried out with voltage and current waveforms closely resembling those in service:

- 1) if the ripple factor of the load current in service exceeds 10 % of the guaranteed rating;
- 2) if the excitation is pulse controlled.

If it is not practicable to meet this requirement, a method taking into account the effect of the difference between the test and service supplies shall be agreed between user and manufacturer.

NOTE 1 In the case of machines operating on rectified single-phase alternating current at power frequency (50 Hz or 60 Hz) the tests may be carried out using the supply frequency of the place of manufacture whether or not this differs from that of the place of use, provided that the current ripple factor is not less than that in service. The error in the results will be negligible and correction will not be necessary.

NOTE 2 In the case of continuous rating tests, the time to attain steady temperatures may be shortened by commencing the tests at an increased load or reduced ventilation provided that the rated conditions are subsequently maintained for at least 2 h or until it is demonstrated by appropriate means that steady temperatures have been reached.

NOTE 3 Steady temperature is defined as a change in temperature rise of less than 2 K during the final hour of test.

NOTE 4 If the declared excitation current differs from the specified value, the tests have to be carried out with the declared value.

8.1.2 Ventilation during temperature-rise tests

Machines shall be tested with the ventilation arranged as in service with all those parts in place which would affect its temperature rise, including any ducting and filters regarded as part of the vehicle or with an arrangement giving equivalent conditions.

Where cooling is by forced ventilation, the static pressure and the air flow shall be measured at the air inlet of the machine so that a table giving the relationship between these two quantities may be drawn up.

In general, no cooling corresponding to that produced by the motion of the vehicle shall be provided, but in special cases, such as totally enclosed traction motors where this cooling is particularly important, it may be employed if agreed between manufacturer and user.

8.1.3 Judgement of results

The temperature rises of the windings, commutators or slip rings at the "commencement of cooling" shall not exceed the values given in table 2.

8.1.4 Limits of temperature rise

The different classes of insulating materials are defined in IEC 60085.

Table 2 gives the permissible limits of temperature rise, measured on the test-bed above the temperature of the cooling air, for windings and other parts insulated with materials of the classes at present used in the construction of machines to which this standard applies.

If different parts of the same machine have different classes of insulation, the temperature-rise limit of each part shall be that of its individual class.

Table 2 – Limits of temperature rise for continuous or other ratings

Part of machine	Method of measurement	Insulation class			
		B	F	H	200
Stationary winding or rotating field windings of alternators or synchronous motors	Resistance	130 K	155 K	180 K	200 K
All other rotating windings	Resistance	120 K	140 K	160 K	180 K
Commutators or slip rings (see note)	Electrical thermometer	120 K	120 K	120 K	120 K
Cage rotors Damping windings	Electrical thermometer	The temperature rise shall not be sufficient to endanger any windings or other parts			

For totally enclosed machines, limits of table 2 are increased by 10 K.

Where the machines are directly or indirectly exposed to the heat from an engine or from any other source, the adoption of temperature rises lower than those specified in table 2 may be agreed between user and manufacturer.

NOTE Commutator temperature is only one of many factors affecting commutation and, whilst in general commutation improves with reduction in temperature, this is not invariably the case.

8.1.5 Short-time overload temperature-rise test

If short-time overload ratings are specified, they shall be verified by one or more tests carried out as follows.

At the conclusion of a previous rating test, the starting temperature rise given in table 3 may be obtained by continuing to plot the cooling curve for the critical winding (see note 1), until the time at which its temperature rise will reach the "start" value given in table 3 (see note 4) can be predicted by extrapolating the curve for a period not exceeding 5 min ahead of the last reading (see notes 2 and 3). The specified overload shall be applied at this predicted time with normal ventilation conditions and shall be maintained for the specified duration, at which point the test shall be concluded and the temperature rise determined by resistance measurement in accordance with A.5.