IEC 60034-3

Edition 6.0 2007-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Rotating electrical machines –
Part 3: Specific requirements for synchronous generators driven by steam turbines or combustion gas turbines

Machines électriques tournantes –
Partie 3: Règles spécifiques pour les alternateurs synchrones entraînés par turbines à vapeur ou par turbines à gaz à combustion

IEC 60034-3:2007

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX U

ICS 29.160

ISBN 2-8318-9371-2

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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International Standard IEC 60034-3 has been prepared by IEC Technical Committee 2: Rotating machinery.

This sixth edition cancels and replaces the fifth edition published in 2005. This edition constitutes a technical revision. The significant technical changes with respect to the previous edition are as follows:

- the contents is now restricted to synchronous generators driven by steam turbines or combustion gas turbines, but covers as well cylindrical rotor and salient-pole generators;
- synchronous motors have been taken out of the scope of part 3.

The text of this standard is based on the following documents:

FDIS	Report on voting
2/1461/FDIS	2/1474/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

ROTATING ELECTRICAL MACHINES –

Part 3: Specific requirements for synchronous generators driven by steam turbines or combustion gas turbines

1 Scope

This part of IEC 60034 applies to three-phase synchronous generators, having rated outputs of 10 MVA and above driven by steam turbines or combustion gas turbines. It supplements the basic requirements for rotating machines given in IEC 60034-1.

Common requirements are prescribed together with specific requirements for air, for hydrogen or for liquid cooled synchronous generators.

This part of IEC 60034 also gives the precautions to be taken when using hydrogen cooled generators including:

– rotating exciters driven by synchronous generators;
– auxiliary equipment needed for operating the generators;
– parts of the building where hydrogen might accumulate.

NOTE 1 These requirements also apply to a synchronous generator driven by both a steam turbine and a combustion gas turbine as part of a single shaft combined cycle unit.

NOTE 2 These requirements do not apply to synchronous generators driven by water (hydraulic) turbine or wind turbine.

NOTE 3 The precautions to be taken when using hydrogen are valid for all cases where hydrogen is used as a coolant.

2 Normative references

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

IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-4, *Rotating electrical machines – Part 4: Methods for determining synchronous machine quantities from tests*

IEC 60045-1, *Steam turbines – Part 1: Specifications*

IEC 60079 (all parts), *Electrical apparatus for explosive gas atmospheres*

3 Terms and definitions

For the purposes of this document, the terms and definitions in IEC 60034-1 together with the following additions apply.

3.1
mechanical start
change in speed from zero or turning gear speed to rated speed

3.2
turning gear operation
rotation at low speed to maintain thermal equilibrium of the turbine and/or rotor

4 General

4.1 General rules

Turbine driven synchronous generators shall be in accordance with the basic requirements for rotating machines specified in IEC 60034-1 unless otherwise specified in this standard. Wherever in this standard there is reference to an agreement, it shall be understood that this is an agreement between the manufacturer and the purchaser.

4.2 Rated conditions

The rated conditions are given by the rated values of

– the apparent power;
– frequency;
– voltage;
– power factor;
– primary coolant temperature (40°C unless otherwise agreed upon);

and where applicable,

– site altitude;
– hydrogen pressure;
– range of hydrogen purity, see IEC 60034-1.

4.3 Rated voltage

The rated voltage shall be fixed by agreement.

4.4 Power factor

The power factor shall be agreed upon between the purchaser and manufacturer. Standardised rated power factors at the generator terminals are 0,8, 0,85 and 0,9 overexcited.

NOTE 1 Other values may be agreed upon, the lower the power factor the larger will be the generator.

NOTE 2 It is recommended that the generator should be capable of providing 0,95 underexcited power factor at rated MW.

4.5 Rated speed

The rated speed shall be

$3\,000/p$ min^{-1} for 50 Hz generators;

$3\,600/p$ min^{-1} for 60 Hz generators;

where p is the number of pole pairs.

4.6 Ranges of voltage and frequency

Generators shall be capable of continuous rated output at the rated power factor over the ranges of ±5 % in voltage and ±2 % in frequency, as defined by the shaded area of Figure 1.

The temperature rise limits in Tables 7 and 8, or the temperature limits in Table 12 of IEC 60034-1 shall apply at the rated voltage and frequency only.

NOTE 1 As the operating point moves away from the rated values of voltage and frequency, the temperature rise or total temperatures may progressively increase. Continuous operation at rated output at certain parts of the boundary of the shaded area causes temperature rises to increase by up to 10 K approximately. Generators will also carry output at rated power factor within the ranges of ±5 % in voltage and $^{+3}_{-5}$ % in frequency, as defined by the outer boundary of Figure 1, but temperature rises will be further increased. Therefore, to minimize the reduction of the generator's lifetime due to the effects of temperature or temperature differences, operation outside the shaded area should be limited in extent, duration and frequency of occurrence. The output should be reduced or other corrective measures taken as soon as practicable.

If an operation over a still wider range of voltage or frequency or deviations from rated frequency and voltage are required, this should be the subject of an agreement.

NOTE 2 It is considered that overvoltage together with low frequency, or low voltage with over-frequency, are unlikely operating conditions. The former is the condition most likely to increase the temperature rise of the field winding. Figure 1 shows operation in these quadrants restricted to conditions that will cause the generator and its transformer to be over- or under-fluxed by no more than 5 %. Margins of excitation and of stability will be reduced under some of the operating conditions shown. As the operating frequency moves away from the rated frequency, effects outside the generator may become important and need to be considered. As examples: the turbine manufacturer will specify ranges of frequency and corresponding periods during which the turbine can operate; and the ability of auxiliary equipment to operate over a range of voltage and frequency should be considered.

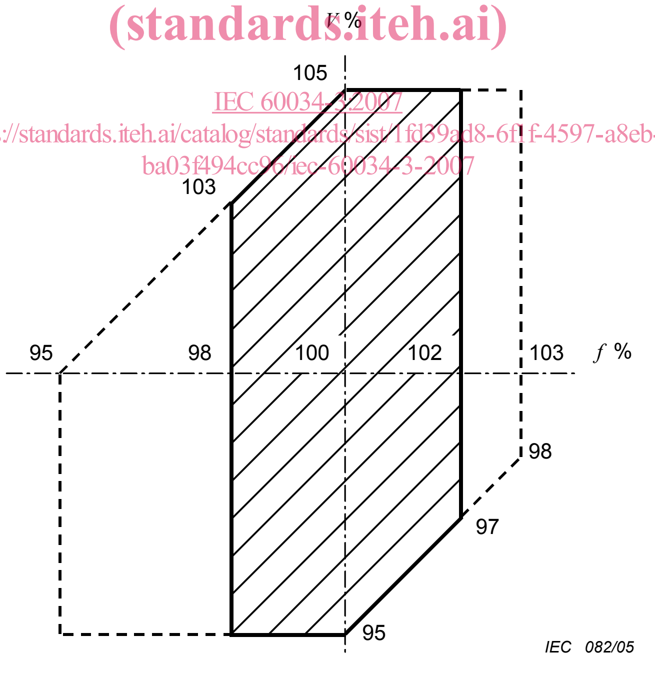


Figure 1 – Operation over ranges of voltage and frequency

4.7 Direction of rotation

The direction of rotation shall be shown on the generator or on its rating plate, and the time-phase sequence of the stator voltage shall then be indicated by marking the terminals in the sequence in which their voltages reach maximum, for example, U_1, V_1, W_1.

NOTE Terminal markings may not be consistent with IEC 60034-8.

For generators having one driving end, this shall be the reference end for the direction of rotation.

For generators having two drive ends, the more powerful drive end shall be the reference end. If not applicable, the end opposite to the excitation leads shall be the reference end for the direction of rotation.

The sense of rotation (clockwise or counter-clockwise) shall be defined when facing the generator rotor coupling from the reference side.

4.8 Stator winding

Unless otherwise agreed upon, rated generator voltage corresponds to star connection. All winding ends shall be brought out and arranged in an agreed arrangement of the external connections to the generator.

4.9 Generator rated field current and voltage

The generator rated field current and voltage are those values needed for the generator to operate at rated conditions.

4.10 Winding insulation

4.10.1 Thermal class

Insulation systems used for the windings shall be of thermal class 130 or higher.

4.10.2 Withstand voltage tests

Withstand voltage tests shall be in accordance with IEC 60034-1, Table 16.

4.11 Insulation against shaft current

Suitable precautions shall be taken to prevent harmful flow of shaft current and to earth the rotor shaft adequately. Any insulation needed shall preferably be arranged so that it can be measured while the generator is operating. Shaft voltage spikes caused by static excitation with controlled rectifiers shall be kept down by suitable means to non-critical values. These spikes could cause damage, for example the bearing Babbitt by breaking through the bearing oil film.

4.12 Over-speed test

Rotors shall be tested at 1,2 times rated speed for 2 min.

4.13 Critical speeds

Critical speeds of the combined shaft train shall not cause unsatisfactory operation within the speed range corresponding to the frequency range agreed upon in accordance with 4.6 (see also IEC 60045-1).

4.14 P-Q capability diagram

The manufacturer shall supply a P-Q capability diagram indicating the limits of operation. The P-Q diagram shall be drawn for operation at rated conditions. A typical P-Q diagram is shown in Figure 2, its boundaries are set by the following limitations:

– curve A represents operation with constant rated field current and therefore with approximately constant temperature rise of the field winding;

– curve B represents constant rated stator current and consequently approximately constant temperature rise of the stator winding;

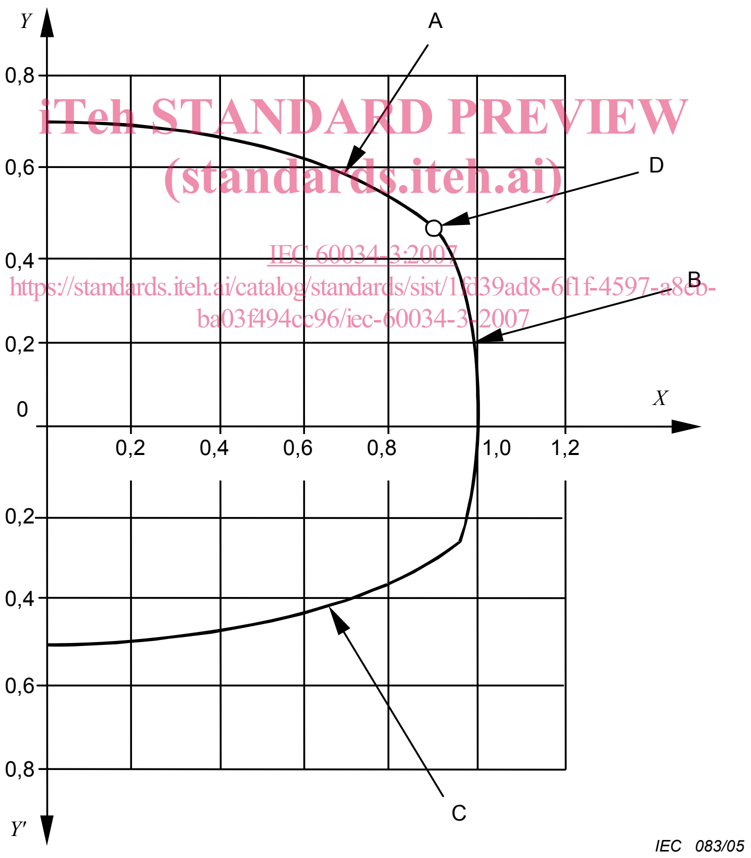
– curve C indicates the limit set by localized end region heating, or by steady-state stability, or by a combination of both effects.

NOTE 1 Figure 2 may contain other operational limits such as maximum turbine limits and minimum excitation limits.

By agreement between the manufacturer and the purchaser, other diagrams may be provided for operation at agreed upon conditions within the voltage and frequency ranges agreed upon in accordance with 4.6, and for cooling and temperature conditions and where applicable hydrogen pressures other than rated.

NOTE 2 The generator should be operated within the boundaries of the diagram appropriate to the chosen conditions of voltage, frequency and cooling, and hydrogen pressure if applicable. Operation outside these boundaries will shorten the life of the generator.

NOTE 3 For a generator with a water cooled stator winding at reduced hydrogen pressure, the maximum water pressure within the winding can become higher than the hydrogen pressure. Hence, in the case of a leak, water can move from the water circuit towards the hydrogen environment within the casing. This could cause failure.



Key

A limited by field winding temperature

B limited by armature winding temperature

C limited by the temperatures of the core end parts or by steady state stability

D rated output

X per unit kW

Y per unit kvar overexcited

Y′ per unit kvar underexcited

Figure 2 – Typical P-Q capability diagram

4.15 Overcurrent requirements

Generators with rated outputs up to 1 200 MVA shall be capable of carrying, without damage, a stator current of 1,5 per unit (p.u.) for 30 s.

For ratings greater than 1 200 MVA, agreement should be reached on a time duration less than 30 s, decreasing as the rating increases, to a minimum of 15 s, the current remaining at 1,5 per unit for all ratings.

The generator shall be capable of other combinations of overcurrent and time that give the same degree of additional heat above that caused by 1 p.u. current.

Thus, for generators up to 1 200 MVA,

$$(I^2 - 1)t = 37,5 \text{ s}$$

where

I is the stator current per unit (p.u.);

t is its duration in seconds.

This relationship shall apply for values of t between 10 s and 60 s.

NOTE It is recognized that stator temperatures will exceed rated load values under these conditions, and therefore the generator construction is based upon the assumption that the number of operations to the limit conditions specified will not exceed two per year.

4.16 Sudden short circuit

The generator shall be designed to withstand without failure a short circuit of any kind at its terminals, while operating at rated load and 1,05 p.u. rated voltage, provided the maximum phase current is limited by external means to a value which does not exceed the maximum phase current obtained from a three-phase short circuit. 'Without failure' means that the generator shall not suffer damage that causes it to trip out of service, though some deformation of the stator winding might occur.

If it is agreed upon between purchaser and manufacturer that a sudden short-circuit test shall be made on a new generator, it shall be done after the full voltage dielectric acceptance test as described below.

A generator that is to be connected directly to the system shall have a 3-phase short circuit applied at its terminals when excited to rated voltage on no-load. For a generator that will be connected to the system through its own transformer or reactor, usually by an isolated phase bus, the test at the terminals shall be carried out at reduced voltage, agreed upon between the purchaser and the manufacturer, in order to produce the same stator current as would result in service from a three-phase short circuit applied at the high voltage terminals of the transformer.

This test shall be considered satisfactory if the generator is subsequently judged to be fit for service without repairs or with only minor repairs to its stator windings, and if it withstands a high-voltage test of 80 % of the value specified in IEC 60034-1 for a new generator. The term “minor repairs” implies some attention to end-winding bracing and to applied insulation, but not replacement of coils.

NOTE Abnormal high currents and torques can occur as a result of a short circuit close to the generator in service, or of clearance and re-closure of a more distant fault, or of faulty synchronizing. If such conditions do actually impose severe overcurrents, it would be prudent to examine the generator thoroughly, with particular attention to the stator windings. Any loosening of supports or packings should be made good before returning the generator to service, to avoid the possibility of consequential damage being caused by vibration. It may also be desirable to check for possible shaft balance changes and deformation of the coupling bolts and couplings.

4.17 Short-circuit ratio

For generators of all sizes and types of cooling covered by this standard, the value of the short-circuit ratio shall be not less than 0,35. Higher minimum values may be specified and agreed upon (for example by a grid demand), but, for a given cooling system, these usually require an increase in generator size and higher losses.

4.18 Direct axis transient and subtransient reactances for generators

When the direct axis transient or subtransient reactances are specified having regard to the operating conditions, the following values should be agreed upon:

- a minimum value of the direct axis subtransient reactance at the saturation level of rated voltage;
- a maximum value of the direct axis transient reactance at the unsaturated conditions of rated current.

Since the two reactances depend to a great extent on common fluxes, care should be taken to ensure that the values specified and agreed upon are compatible, that is, that the upper limit of the subtransient reactance is not set too close to the lower limit of the transient reactance.

When the value of the direct axis subtransient reactance is not specified, it shall be not less than 0,1 p.u. at the saturation level corresponding to rated voltage.

The value of each of these reactances may be specified and agreed upon at another saturation level in accordance with IEC 60034-4. If it is agreed that values are to be determined by test, the test shall be in accordance with IEC 60034-4.

4.19 Tolerances on short-circuit ratio and direct axis transient and subtransient reactances

Where the limit values of this standard, or other limits, have been specified or agreed upon, there shall be no tolerance in the significant direction, that is, no negative tolerance on minimum values and no positive tolerance on maximum values. In the other direction, a tolerance of 30 % shall apply.

If values are specified but not declared to be limits, they shall be regarded as rated values, and shall be subject to a tolerance of ±15 %.

Where no values have been specified by the purchaser, the manufacturer shall give values, subject to a tolerance of ±15 %.

4.20 Mechanical conditions for rotors

4.20.1 Number of starts

Unless otherwise agreed upon, the rotor shall have a mechanical design capable of withstanding during its lifetime:

- normally not less than 3 000 starts;
- for those designed for regular start-stop duties such as daily service not less than 10 000 starts.

4.20.2 Turning gear operation

Before start-up and after shut-down, turning gear operation of the turbine generator set may be unavoidable primarily due to prime mover needs. However, prolonged turning gear operation may make the generator rotor susceptible to damage and should be limited. Susceptibility to turning gear operation damages can be influenced by the design. If a longer turning gear operation is considered additional design efforts for minimizing the harmful effects should be the subject of an agreement.

4.21 Coolers

Unless otherwise agreed upon, coolers shall be suitable for cold water intake temperatures up to 32 °C and a working pressure of not less than:

– 2,7 bar absolute (270 kPa) for air cooled generators;

– 4,5 bar absolute (450 kPa) for hydrogen and liquid cooled generators;

The test pressure shall be 1,5 times the maximum working pressure, and shall be applied for 15 min.

If the water pressure in the cooler is controlled by a valve or pressure-reducing device connected to a water supply where the pressure is higher than the working pressure of the cooler, the cooler shall be designed for the higher pressure, and tested at 1,5 times the higher pressure value, unless otherwise agreed upon. This pressure shall be specified by the purchaser.

Coolers shall be designed so that, if one section is intended to be taken out of service for cleaning, the unit can carry at least two-thirds (or, by agreement, another fraction) of rated load continuously, without the permissible temperatures of the active parts of the generator being exceeded. Under these conditions, the primary coolant temperature may be higher than the design value. For hydrogen and liquid cooled generators, attention should be paid to the fact that under some conditions of operation, for example during maintenance or while purging the casing of gas, a cooler might be subjected to gas pressure without water pressure. It shall therefore be designed for a differential pressure of 8 bar (800 kPa) on the gas side.

NOTE Increasing concentrations of chemicals in the water, for example salts or glycol can affect the cooling performance.

5 Air-cooled generators

5.1 General

This clause applies to generators, the active parts of which are cooled by air, either directly or indirectly or by a combination of the two methods.

5.2 Generator cooling

The system of ventilation should preferably be a closed air circuit system. If an open air system is specified or agreed upon, care shall be taken to avoid contaminating the ventilation passages with dirt, to avoid overheating and pollution of insulated surfaces.

When slip rings for excitation are provided, they should be ventilated separately to avoid contaminating the generator and exciter with carbon dust.

5.3 Temperature of primary coolant

Generators other than those driven by gas turbines shall be in accordance with IEC 60034-1.

If the maximum temperature of the ambient air, or of the primary cooling air where an air-to-water cooler is used, is other than 40 °C, the relevant clauses of IEC 60034-1 apply.

Particular requirements for generators driven by gas turbines are given in 7.2 and 7.3.