

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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



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CONTENTS

FOREWORD	5
1 Scope	7
2 Normative references	7
3 Terms and definitions	8
4 General	8
4.1 General rules	8
4.2 Rated conditions	9
4.2.1 Generators	9
4.2.2 Compensators	9
4.3 Rated voltage	9
4.4 Power factor	9
4.5 Rated speed	10
4.6 Ranges of voltage and frequency	10
4.7 Direction of rotation	11
4.8 Stator winding, output voltage	11
4.9 Winding insulation	11
4.9.1 Insulation systems, thermal class	11
4.9.2 Withstand voltage tests	11
4.10 Insulation against shaft current	12
4.11 Overspeed test	12
4.12 Critical speeds	12
4.13 <i>P-Q</i> capability diagram	12
4.14 Overcurrent requirements	14
4.14.1 General	14
4.14.2 Stator current	14
4.14.3 Rotor field current	14
4.15 Unbalanced currents and current harmonics capability	15
4.15.1 Negative sequence current	15
4.15.2 Current harmonics	15
4.16 Sudden short circuit	16
4.17 Synchronisation	16
4.18 Short circuit ratio (SCR)	17
4.19 Direct axis transient and subtransient reactances	17
4.20 Tolerances on short circuit ratio and direct axis transient and subtransient reactances	17
4.21 Mechanical conditions for rotors	17
4.21.1 Number of starts	17
4.21.2 Turning gear operation	18
4.22 Coolers	18
5 Air-cooled generators or compensators	18
5.1 General	18
5.2 Cooling system	18
5.3 Temperature of primary coolant	19
5.3.1 General	19
5.3.2 Temperature detectors	19
6 Hydrogen-cooled or liquid-cooled generators or compensators	19

6.1	General.....	19
6.2	Hydrogen pressure and purity in the casing	19
6.3	Machine housing and cover plates	20
6.4	Stator winding terminals.....	20
6.5	Temperature of primary coolants, temperatures and temperature rises	20
6.6	Temperature detectors.....	20
6.7	Auxiliary systems	21
7	Generators for combustion gas turbines or combined cycle applications	21
7.1	General.....	21
7.2	Service conditions.....	21
7.2.1	General	21
7.2.2	Primary coolant temperature.....	22
7.2.3	Number of starts.....	22
7.2.4	Application of load	22
7.3	Rated output	22
7.4	Capabilities	22
7.4.1	General	22
7.4.2	Base capability	22
7.4.3	Temperature rise and temperatures at base capability	24
7.4.4	Peak capability	24
7.5	Rating plate	25
7.6	Temperature tests.....	25
Annex A	(normative) Precautions to be taken when using hydrogen- cooled synchronous generators or compensators	26
A.1	General.....	26
A.2	Hydrogen purity	26
A.3	Normal operating conditions.....	26
A.4	Protective measures for sliprings and coupled exciters	26
A.5	Auxiliary equipment	27
A.5.1	General	27
A.5.2	Degassing tanks	27
A.5.3	Gas dryer	27
A.5.4	Instrumentation, control devices	27
A.5.5	Electrical connections	27
A.5.6	Containment of hydrogen.....	28
A.5.7	Accumulation of hydrogen-air mixture	29
A.5.8	Vent pipes	29
A.5.9	Adjacent area	29
A.6	Operation of the generator and its auxiliary equipment.....	29
A.6.1	Sources of ignition.....	29
A.6.2	Hydrogen-air mixture	29
A.6.3	Air or hydrogen displacement	29
A.6.4	Seal oil supply and hydrogen pressure	30
A.6.5	Gas tightness	30
A.6.6	Water system	31
A.7	Guidance for adequate ventilation.....	31
Bibliography	33
Figure 1	– Operation over ranges of voltage and frequency	10

Figure 2 – Typical P - Q capability diagram of a generator 13

Figure 3 – Typical generator capability curves 23

Figure A.1 – Example of a large hydrogen supply unit feeding one or more generators
(simplified diagram) 32

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ROTATING ELECTRICAL MACHINES –

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

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International Standard IEC 60034-3 has been prepared by IEC technical committee 2: Rotating machinery.

This seventh edition cancels and replaces the sixth edition published in 2007. This edition constitutes a technical revision.

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

- a) title modified;
- b) scope extended to synchronous compensators;
- c) rotor overcurrent requirements added;
- d) impact of stator harmonics on rotor unbalanced load capability introduced;
- e) synchronisation requirements added;

- f) adjustments of temperatures or temperature rise revised for gas turbine applications;
- g) requirements for auxiliaries updated.

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

FDIS	Report on voting
2/1987/FDIS	2/1993/RVD

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

This document 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 document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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ROTATING ELECTRICAL MACHINES –

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

1 Scope

This part of IEC 60034 applies to large three-phase synchronous generators, having rated outputs of 10 MVA and above driven by steam turbines or combustion gas turbines. Also included are synchronous Mvar compensators of the same output range connected to a grid for the purpose of exchanging reactive power.

This document supplements basic requirements for rotating machines given in IEC 60034-1.

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

This document 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.

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.

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

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

2 Normative references

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

IEC 60034-1:2017, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-4-1, *Rotating electrical machines – Part 4-1: Methods for determining electrically excited synchronous machine quantities from tests*

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

IEC 60079 (all parts), *Explosive atmospheres*

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

3 Terms and definitions

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

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

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

3.1

grid

public electrical network or local (e.g. industrial) network, which is connected to the generator or compensator either directly or through a transformer

3.2

synchronous generator

large synchronous machine driven by steam or gas turbines which converts mechanical energy into electrical energy and supplies it to an electrical grid

Note 1 to entry: Generators can also provide reactive power to the grid. The driving unit itself or additional equipment is used to start up the generating unit.

3.3

synchronous compensator

large synchronous machine electrically coupled to the grid but not exchanging mechanical energy through the shaft during steady state operation

Note 1 to entry: Reactive power is supplied to the grid or imported to the compensator by means of adjusting the field current.

Note 2 to entry: The losses are covered by the grid. A compensator needs a start-up device, which accelerates the unit to operating speed or can be started asynchronously if design is appropriate.

Note 3 to entry: Synchronous compensators are commonly named synchronous condensers.

3.4

mechanical start

change in speed from zero or turning gear speed to rated speed

3.5

turning gear operation

rotation at low speed to avoid undesirable bending of turbine- and/or generator/compensator-rotors due to uneven circumferential temperature distribution

4 General

4.1 General rules

Turbine driven synchronous generators and synchronous compensators shall fulfil the basic requirements for rotating machines specified in IEC 60034-1 unless otherwise specified in this document.

Wherever there is reference to an agreement in this document, it shall be understood as an agreement between manufacturer and purchaser.

4.2 Rated conditions

4.2.1 Generators

The rated conditions of a generator are given by the rated values of:

- the apparent power;
- frequency;
- voltage;
- power factor;
- primary coolant temperature (40°C unless otherwise agreed upon);
- field current and field voltage (see also 4.2.2);

and where applicable:

- site altitude;
- hydrogen pressure with indication whether the figure is to be interpreted as absolute or gauge pressure;
- range of hydrogen purity, see IEC 60034-1.

4.2.2 Compensators

The rated conditions of a compensator are basically the same as those of a generator but with different definitions of apparent power and power factor.

- The rated apparent power consists mainly of the maximum continuous reactive output at rated voltage when the machine is overexcited, and of a small amount of active power delivered to the compensator. [IEC 60034-3:2020](https://standards.iteh.ai/catalog/standards/sist/d7cac87-03f1-4f50-9849-4756b3e9c95d/iec-60034-3-2020)
- The rated power factor is close to zero, reflecting mainly the maximum reactive power and the losses compensated by the grid. <https://standards.iteh.ai/catalog/standards/sist/d7cac87-03f1-4f50-9849-4756b3e9c95d/iec-60034-3-2020>

For compensators, the range of reactive power shall be agreed upon.

NOTE During operation, the field current of a generator or compensator is adjusted depending on the demand of reactive power. Generator/compensator rated field current and field voltage are those values needed to operate the generator/compensator at rated conditions. Generator/compensator modelling studies can require base values for field current and field voltage other than rated.

4.3 Rated voltage

The rated voltage shall be agreed upon.

4.4 Power factor

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

It is recommended that the generator be capable of providing a power factor of 0,95 underexcited at rated active power output.

NOTE The lower the rated power factor the larger the generator will be.

The rated power factor should reflect the demand on reactive power overexcited at rated active power output including some margin.

The power factor of a synchronous compensator deviates from zero only by an amount, which depends on the losses compensated by the grid.

4.5 Rated speed

Synchronous generators or compensators are typically connected to a grid with a fundamental operating frequency of 50 Hz or 60 Hz.

The rated speed is:

$3\ 000/p$ min⁻¹ for 50 Hz generators or compensators;

$3\ 600/p$ min⁻¹ for 60 Hz generators or compensators;

where p is the number of pole pairs.

4.6 Ranges of voltage and frequency

Synchronous generators and compensators shall be capable of continuous rated output at the rated power factor over the ranges of $\pm 5\%$ in voltage and $\pm 2\%$ in frequency, as defined by the shaded area of Figure 1.

The temperature rise limits in Tables 8 and 9 of IEC 60034-1:2017, or the temperature limits in Table 13 of IEC 60034-1:2017 shall apply at the rated voltage and frequency.

Continuous operation at rated output at certain parts of the boundary of the shaded area may cause additional temperature rise of up to approximately 10 K.

Generators or compensators will also carry output at rated power factor within the ranges of $\pm 5\%$ in voltage and -5% to $+3\%$ in frequency, as defined by the outer boundary of Figure 1, but temperature rises will be further increased. Therefore, operation outside the shaded area should be limited in extent, duration and frequency of occurrence in order to minimize the reduction of lifetime due to thermal effects. The output should be reduced or other corrective measures taken as soon as practicable.

Potentially required operation outside the dashed borderline of Figure 1 shall be the subject of an agreement.

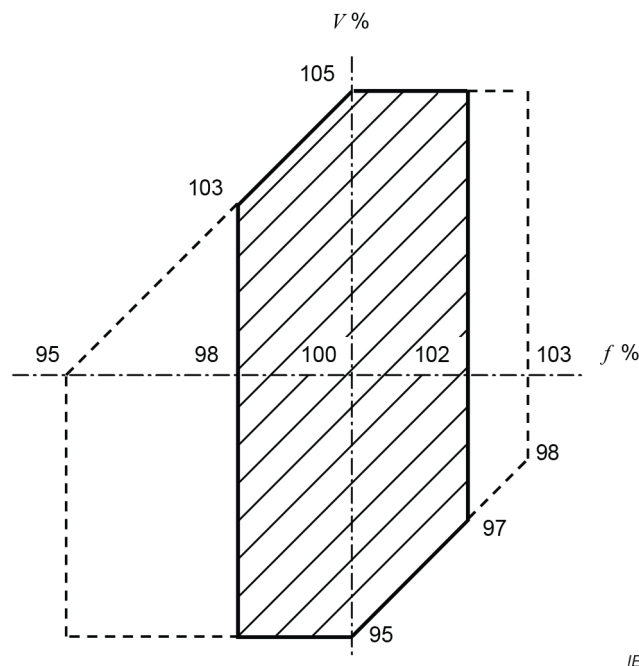


Figure 1 – Operation over ranges of voltage and frequency

NOTE Overvoltage together with low frequency, or low voltage with over-frequency, are considered to be unlikely operating conditions. The former condition most likely increases the temperature rise of the field winding. Figure 1 shows operation in these quadrants restricted to conditions that will cause the generator or compensator and its transformer to be over- or under-fluxed by approximately 5 %. Margins of excitation and of stability will be reduced under some of the operating conditions shown. With the operating frequency deviating from the rated frequency, effects outside the generator or compensator can become important and will be considered. For example: the turbine manufacturer will specify permissible ranges of frequency and corresponding operating periods. Also, a certain range of permissible operating voltages and frequencies can apply to auxiliary equipment.

4.7 Direction of rotation

The direction of rotation shall be shown on the machine 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 driven end, this shall be the reference end for the direction of rotation.

For generators driven on both ends, the end of the more powerful drive shall be the reference end. In case of comparable drive power on either end, the end opposite to the excitation terminals shall be the reference end for the direction of rotation.

The reference end of synchronous compensators shall be the end opposite to the excitation terminals.

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

The phase sequence of the generator or compensator shall coincide with the phase sequence of the grid to which the generator or compensator is to be connected.

4.8 Stator winding, output voltage

Unless otherwise agreed upon, the stator winding shall be arranged in star configuration. All phase ends shall be accessible from outside of the casing. The arrangement of the electrical terminals shall be agreed upon.

Output voltage is defined as the line to line voltage of the stator winding.

4.9 Winding insulation

4.9.1 Insulation systems, thermal class

The stator winding as well as the field winding shall be insulated with appropriate insulating systems. An insulation system includes the necessary combinations of insulating materials around the electrical conductors.

Insulation systems used for the windings of a generator or compensator shall be classified according to IEC 60085. Thermal class 130 (B) or higher shall be applied.

NOTE The term “winding” includes the coils and all electrical connections between coils and terminals.

4.9.2 Withstand voltage tests

Withstand voltage tests shall be in accordance with IEC 60034-1:2017, 9.2.

4.10 Insulation against shaft current

Suitable precautions shall be taken to prevent harmful flow of shaft current and to earth the rotor shaft adequately. A turbine-generator shaft shall be earthed at a shaft position close to the reference end of the generator. Shaft voltage spikes caused by static excitation with controlled rectifiers shall be kept down by suitable means to non-critical values. These spikes can cause damage, for example to the bearing Babbitt, by breaking through the bearing oil film.

Requirements for bearing insulation resistance to be measured during operation of the generator or compensator shall be agreed upon at the time of purchase.

4.11 Overspeed test

Rotors, i.e. main shaft and if applicable slip ring shaft or exciter shaft, shall each be tested completely assembled at 1,2 times rated speed for 2 min.

If rotor fan blades are not assembled to avoid larger windage loss at overspeed test, this can be acceptable when the mechanical strength is assured by traceability of the material which would be proven by mill test report and non-destructive test report for design requirements.

The purpose of the rotor over-speed test is verifying the mechanical integrity of the rotor. This test is not intended to indicate the in-service operating capability of the machine. The in-service over-speed withstand capability of the generator/compensator and the frequency with which such an over-speed may be applied depends upon the design of the generator or compensator. It is necessary to consider carefully any in-service over-speed conditions which could result from sudden disconnection of full load for example. Any particular requirements shall be agreed upon.

4.12 Critical speeds

IEC 60034-3:2020

Critical speeds shall not cause unsatisfactory operation of the combined generator-/turbine-shaft train within the speed-/frequency-range corresponding to IEC 60045-1 or agreed upon otherwise. This also applies to compensator rotors.

If generator and turbine are purchased from different manufacturers, there shall be an agreement on which party is responsible for achieving the desired performance of the combined turbine/generator shaft line including exchange of turbine and generator shaft data.

4.13 *P-Q* capability diagram

For generators, 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:

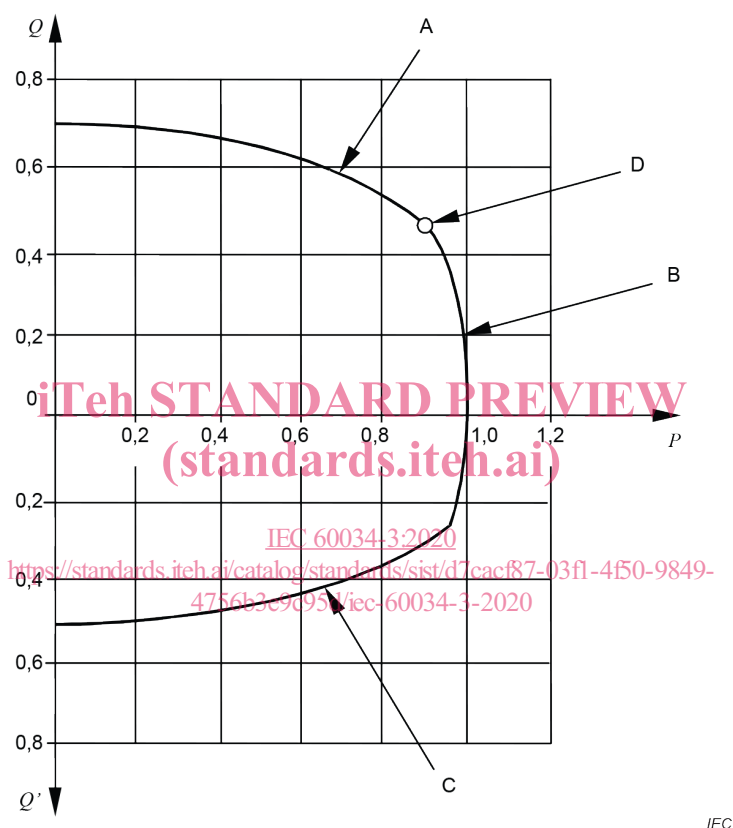
- curve A represents operation with constant rated field current and therefore with approximately constant temperature rise of the field winding;
- curve B represents constant rated stator current and consequently approximately constant temperature rise of the stator winding;
- curve C represents limits due to the temperatures of the core end parts. In many cases this line is also shown as constrained by stability considerations, determination of which requires knowledge of the power system to which the machine will be connected. Such power system data is frequently unavailable or insufficient when a "synchronous machine only *P-Q* diagram" is created. Hence, it is common for line C on the *P-Q* diagram, for a machine alone, to be drawn showing any absolute limits required to protect core end parts and showing further stability factor constraints for illustration purposes only.

Additional diagrams may be provided for operation at agreed conditions, for instance at reduced cooling or, where applicable, at hydrogen pressures other than rated.

For synchronous compensators no P - Q capability applies.

If a particular generator or motor with existing P - Q capability is used as a synchronous compensator, the available output range of reactive power can be understood as the line between the intersection of the Q -axis and curve A and the intersection of the Q -axis and curve C of the P - Q diagram. The losses compensated by the grid would cause a slight shift of the operating point towards negative values on the P -axis.

The generator should be operated within the boundaries of the diagram at the applicable cooling conditions. Operation outside these boundaries will shorten the life of the generator.



Key

- | | | | |
|---|--|------|----------------------------|
| A | limited by field winding temperature | P | per unit kW |
| B | limited by stator winding temperature | Q | per unit kvar overexcited |
| C | limited by the temperatures of the core-end parts or by steady state stability, including margin to theoretical limits | Q' | per unit kvar underexcited |
| D | rated output | | per unit kVA |

Figure 2 – Typical P - Q capability diagram of a generator

NOTE 1 Figure 2 can contain other operational limits such as maximum turbine limits or minimum excitation limits.

NOTE 2 Figure 2 can be supplemented with isolines of constant efficiency.

NOTE 3 It is understood that Figure 2 gives the permissible load points with all limiters of the automated voltage regulator (AVR) engaged.

NOTE 4 Increases in renewable energy generation and the consequent frequent changes of load points of synchronous machines can impact the lifetime of the machine.