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IEC 60034-22

Edition 2.0 2009-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Rotating electrical machines –
Part 22: AC generators for reciprocating internal combustion (RIC) engine driven generating sets

Machines électriques tournantes –
Partie 22: Génératrices à courant alternatif pour groupes électrogènes entraînés par un moteur à combustion interne

IEC 60034-22:2009

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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 60034-22 has been prepared by IEC technical committee 2: Rotating machinery.

This second edition cancels and replaces the first edition published in 1996 and constitutes a technical revision.

The technical changes with regard to the previous edition include:

– Clause 2: The standards which were not referenced in the text have been deleted.
– Clause 3: Technical and editorial changes to many of the definitions have been made.
– Clause 4: In the NOTE, the quantity T_L has been replaced by *TL.*
– Clause 7: Technical and editorial changes to many clauses have been made.
– Clause 9: Table 1 has been revised.
– Annex A: This annex has been revised.

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

FDIS	Report on voting
2/1568/FDIS	2/1573/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, under the general title, *Rotating electrical machines*, can be found on the IEC website.

NOTE A table of cross-references of all IEC TC 2 publications can be found in the IEC TC 2 dashboard 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 22: AC generators for reciprocating internal combustion (RIC) engine driven generating sets

1 Scope

This part of IEC 60034 establishes the principal characteristics of a.c. generators under the control of their voltage regulators when used for reciprocating internal combustion (RIC) engine driven generating set applications and supplements the requirements given in IEC 60034-1. It covers the use of such generators for land and marine use, but excludes generating sets used on aircraft or used to propel land vehicles and locomotives.

NOTE 1 For some specific applications (e.g. essential hospital supplies, high-rise buildings, etc.) supplementary requirements may be necessary. The provisions of this standard should be regarded as a basis for such requirements.

NOTE 2 Attention is drawn to the need to take note of additional regulations or requirements imposed by various regulatory bodies. Such regulations or requirements may form the subject of agreement between the customer and the manufacturer when conditions of use of the end product invoke such requirements.

NOTE 3 Examples of regulatory authorities:

– classification societies, for generating sets used on ships and offshore installations;
– government agencies;
– inspection agencies, local utilities, etc.

Annex A discusses the behaviour of generators covered by this standard when subjected to sudden load changes.

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 60034-1:2004, *Rotating electrical machines – Part 1: Rating and performance*

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

CISPR 11, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

NOTE 1 In this standard, suffix “N” is used for “rated” in accordance with IEC 60027-1 and IEC 60027-4 whereas in ISO 8528, suffix “r” is so used.

NOTE 2 Voltage terms relate to a generator running at constant (rated) speed under the control of the normal excitation and voltage control system.

3.1
rated output
$\boldsymbol{S_N}$
the product of the rated r.m.s. voltage, the rated r.m.s. current and a constant *m*, expressed in volt-amperes (VA) or its decimal multiples

where

m = 1 for single-phase;

$m = \sqrt{2}$ for two-phase;

$m = \sqrt{3}$ for three-phase

3.2
rated active power
$\boldsymbol{P_N}$
the product of the rated r.m.s. voltage, the in-phase component of the rated r.m.s. current and a constant *m*, expressed in watts (W) or its decimal multiples

where

m = 1 for single-phase;

$m = \sqrt{2}$ for two-phase;

$m = \sqrt{3}$ for three-phase

3.3
rated power factor
cos $\boldsymbol{\phi_N}$
the ratio of the rated active power to the rated output

$$\cos \phi_N = \frac{P_N}{S_N}$$

3.4
rated reactive power
$\boldsymbol{Q_N}$
the geometrical difference of the rated apparent power and the rated active power expressed in volt-amperes reactive (var) or its decimal multiples

$$Q_N = \sqrt{\left(S_N^2 - P_N^2\right)}$$

3.5
rated speed of rotation
$\boldsymbol{n_N}$
the speed of rotation necessary for voltage generation at rated frequency

NOTE 1 For a synchronous generator, the rated speed of rotation is given by:

$$n_N = \frac{f_N}{p}$$

where
p is the number of pole pairs;
f_N is the rated frequency (according to load requirements).

For an asynchronous generator the rated speed of rotation is given by:

$$n_N = \frac{f_N}{p}(1 - s_N)$$

where

p is the number of pole pairs;

f_N is the rated frequency (according to load requirements);

s_N is the rated slip.

NOTE 2 Since the slip of an asynchronous generator is always negative, the rated speed is above the synchronous speed.

3.6
rated slip
$\boldsymbol{s_N}$
the difference between the synchronous speed and the rated speed of the rotor divided by the synchronous speed, when the generating set is giving its rated active power

$$s_N = \frac{\frac{f_N}{p} - n_N}{\frac{f_N}{p}}$$

NOTE Rated slip s_N is only relevant to an asynchronous generator.

3.7
rated voltage
$\boldsymbol{U_N}$
the line-to-line voltage at the terminals of the generator at rated frequency

NOTE Rated voltage is the voltage assigned by the manufacturer for operating and performance characteristics.

3.8
no-load voltage
$\boldsymbol{U_0}$
the line-to-line voltage at the terminals of the generator at rated frequency and no-load

3.9
range of voltage setting
$\boldsymbol{\Delta U_s}$
the range of possible upward and downward adjustment of voltage at generator terminals (ΔU_{sup} and ΔU_{sdo} , where U_{sup} is the upper limit of voltage setting and U_{sdo} is the lower limit of voltage setting) at rated frequency, for all loads between no-load and rated output.

$$\Delta U_s = | \Delta U_{sup} | + | \Delta U_{sdo} |$$

The voltage setting range is expressed as a percentage of the rated voltage.

a) upward range, ΔU_{sup}

$$\Delta U_{sup} = \frac{U_{sup} - U_N}{U_N} \times 100 \ \%$$

b) downward range, ΔU_{sdo}

$$\Delta U_{sdo} = \frac{U_{sdo} - U_N}{U_N} \times 100 \ \%$$

3.10
steady-state voltage tolerance band
ΔU [1)]
the agreed voltage band about the steady-state voltage that the voltage may reach within a given voltage recovery time after a specified sudden increase or decrease of load

3.11
steady-state voltage regulation
ΔU_{st} [1)]
the change in steady-state voltage for all load changes between no-load and rated output, taking into account the influence of temperature but not considering the effect of quadrature current compensation voltage droop.

NOTE The initial set voltage is usually rated voltage, but may be anywhere within the range of voltage setting, ΔU_s. See 3.9.

The steady-state voltage regulation is expressed as a percentage of the rated voltage.

$$\Delta U_{st} = \frac{U_{st:max} - U_{st:min}}{U_N} \times 100\,\%$$

3.12
transient voltage regulation
δ_{dynU}
the maximum voltage change following a sudden change of load, expressed as a percentage of the rated voltage.

a) With load increase

maximum transient voltage drop δ^-_{dynU}

the voltage drop when the generator, initially at rated voltage, is switched onto a symmetrical load which absorbs a specified current at rated voltage at a given power factor or range of power factors.

$$\delta^-_{dynU} = \frac{U_{dyn:min} - U_N}{U_N} \times 100\,\%$$

b) With load decrease

maximum transient voltage rise δ^+_{dynU}

the voltage rise when a specified load at a given power factor is suddenly switched off.

$$\delta^+_{dynU} = \frac{U_{dyn:max} - U_N}{U_N} \times 100\ \%$$

3.13
voltage recovery time
t_{rec} [1)]
the time interval from the time at which a load change is initiated (t_0) until the time when the voltage returns to and remains within the specified steady-state voltage tolerance band ($t_{u,\,in}$)

$$t_{rec} = \left(t_{u,\,in}\right) - \left(t_0\right)$$

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1) For an explanation of these terms and examples of their use, see Annex A.

3.14
recovery voltage U_{rec} [2)]
the final steady-state voltage for a specified load condition

NOTE Recovery voltage is normally expressed as a percentage of the rated voltage. For loads in excess of rated, recovery voltage is limited by saturation and exciter-regulator field forcing capability.

3.15
voltage modulation
$\hat{U}_{mod}$
the quasi-periodic voltage variation (peak-to-valley) about a steady-state voltage having typical frequencies below the fundamental generation frequency expressed as a percentage of average peak voltage at rated frequency and uniform drive

$$\hat{U}_{mod} = 2 \times \frac{\hat{U}_{mod:max} - \hat{U}_{mod:min}}{\hat{U}_{mod:max} + \hat{U}_{mod:min}} \times 100\ \%$$

3.16
voltage unbalance
U_{ubal}
the rms value of the unbalanced phase voltages between consecutive phases in a three-phase system that may occur.

Voltage unbalance is expressed as a percentage of the mean voltage

$$\hat{U}_{ubal} = \frac{\hat{U}_{max} - \hat{U}_{mean}}{\hat{U}_{mean}} \times 100\ \%$$

3.17
voltage regulation characteristics
curves of terminal voltage as a function of load current at a given power factor under steady-state conditions at rated speed without any manual adjustment of the voltage regulation system

3.18
relative thermal life expectancy factor
TL
the relative thermal life expectancy related to the thermal life expectancy in case of duty type S1 with rated output (see Annex A of IEC 60034-1)

4 Rating

The generator rating class shall be specified in accordance with IEC 60034-1. In the case of generators for RIC engine driven generating sets, continuous ratings (duty type S1) or ratings with discrete constant loads (duty type S10) are applicable.

For the purpose of this standard, the maximum continuous rating based on duty type S1 is named the base continuous rating (BR).

Additionally, for duty type S10, there is a peak continuous rating (PR), where the permissible generator temperature rises are increased by a specific amount according to the thermal classification.

NOTE In the case of duty type S10, operation at the peak continuous rating (PR) thermally ages the generator insulation systems at an increased rate. Quantity *TL* for the relative thermal life expectancy of the insulation system is therefore an important integral part of the rating class (see 4.2.10 of IEC 60034-1).

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2) For an explanation of these terms and examples of their use, see Annex A.

5 Limits of temperature and temperature rise

5.1 Base continuous rating

The generator shall be capable of delivering its base continuous rating (BR) over the whole range of operating conditions (e.g. minimum to maximum coolant temperatures) with total temperatures not exceeding the sum of 40 °C and the temperature rises specified in Table 6 of IEC 60034-1. See Note 1 below.

5.2 Peak continuous rating

At the generator peak continuous rating (PR), the total temperatures may be increased by the following allowances (see Notes 1 and 2).

Thermal classification in accordance with IEC 60085	Rating <5 MVA	Rating ≥5 MVA
A or E	15 °C	10 °C
B or F	20 °C	15 °C
H	25 °C	20 °C

For ambient temperatures below 10 °C, the limit of total temperature shall be reduced by 1 °C for each °C by which the ambient temperature is below 10 °C.

NOTE 1 The RIC engine output may vary with changes of ambient air temperature. In operation, the generator total temperature will depend upon its primary coolant temperature which is not necessarily related to the RIC engine inlet air temperature.

NOTE 2 When the generator operates at these higher temperatures, the generator insulation system will age thermally at between 2 to 6 times the rate which occurs at the generator base continuous rating temperature rise values (depending on the temperature increase and specific insulation system). For example, the thermal ageing relevant to operation for 1 h at peak continuous rating is approximately equal to that obtained with operation for 2 h to 6 h at base continuous rating. It is essential that the value of *TL* be determined by the manufacturer and marked on the rating plate in accordance with item b) of Clause 10.

6 Parallel operation

6.1 General

When running in parallel with other generator sets or with another source of supply, means shall be provided to ensure stable operation and correct sharing of reactive power.

This is most often effected by influencing the automatic voltage regulator by a sensing circuit with an additional reactive current component. This causes a voltage droop characteristic for reactive loads.

The grade of quadrature current compensation (QCC) voltage droop δ_{qcc} is the difference between the no-load voltage U_0 and the voltage at the rated current at the power factor zero (overexcited) U_Q when running isolated, expressed as a percentage of rated voltage U_N.

$$\delta_{qcc} = \frac{U_0 - U_Q}{U_N} \times 100 \ \%$$

NOTE 1 Unity power factor loads produce virtually no droop.

NOTE 2 Identical a.c. generators with identical excitation systems may operate in parallel without requiring voltage droop when their field windings are connected by equalizer links. Adequate reactive load sharing is achieved when there is correct active load sharing.

NOTE 3 When generating sets are operating in parallel with star points directly connected together, circulating currents may occur, particularly third harmonic currents. Circulating currents can increase the r.m.s. current which may reduce the thermal life expectancy of the insulation system.

6.2 Effect of electromechanical vibration and its frequency

It is the responsibility of the generating set manufacturer to ensure that the set shall operate stably in parallel with others, and the generator manufacturer shall collaborate as necessary to achieve this.

If there is a RIC engine torque irregularity at a frequency close to the electromechanical natural frequency, resonance will occur. The electrical natural frequency usually lies in the range of 1 Hz to 5 Hz, and hence resonance is most likely to arise with low speed (100 min^{-1} to 180 min^{-1}) RIC engine generator sets.

In such cases, the generating set manufacturer shall be prepared to give advice to the customer, assisted by a system analysis if necessary, and it is expected that the generator manufacturer will assist in such investigation.

7 Special load conditions

7.1 General

In addition to the conditions given in IEC 60034-1, the requirements given in 7.2 to 7.6 shall apply.

NOTE Consideration of the variation of these requirements from IEC 60034-1 will assist in the specification of special load conditions.

7.2 Unbalanced load current

Limiting values shall be in accordance with 7.2.3 of IEC 60034-1, except that generators with ratings up to 1 000 kVA, which are intended to be loaded between line and neutral, shall be capable of operating continuously with a negative phase sequence current up to and including 10 % of the rated current.

7.3 Sustained short-circuit current (see also 8.3)

Sustained short-circuit current is attained by an excitation system of a synchronous generator designed to provide a specified value of short-circuit current for a specified period of time. The value of sustained short-circuit current shall be decided by agreement between purchaser and manufacturer.

NOTE 1 Under short-circuit conditions on a synchronous generator, it may be necessary to sustain a minimum value of current (after the transient disturbance has ceased) for a sufficient time to ensure operation of the system's protective devices.

NOTE 2 Sustained short-circuit current is not necessary in cases where special relaying or other designs or means are employed to otherwise achieve selective protection, or where no selective protection is required.

7.4 Occasional excess current capability

Short-term excess current capability shall be in accordance with 9.3.2 of IEC 60034-1.

7.5 Total harmonic distortion (THD)

Limiting values of the total harmonic distortion of the line-to-line terminal voltages shall be in accordance with 9.11 of IEC 60034-1. When tested on open-circuit and at rated speed and voltage, the total harmonic distortion of the line-to-line terminal voltage shall not exceed 5 %.