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Reciprocating internal combustion engine driven alternating current generating sets —

Part 3: Alternating current generators for generating sets

Groupes électrogènes à courant alternatif entraînés par moteurs alternatifs à combustion interne —

Partie 3: Alternateurs pour groupes électrogènes

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*, together with IEC/TC 2, *Rotating electrical machines*, by merging this document with IEC 60034-22:2009.

This third edition cancels and replaces the second edition (ISO 8528-3:2005), which has been technically revised.

The main changes compared to the previous edition are as follows:

— Clause 7 (ISO 8528-3:2005, Clause 9) has been updated with requirements for isochronous operation and grid parallel operation;

— requirements for asynchronous generators have been integrated in Clause 8 (ISO 8528-3:2005, Clause 10);

— new power rating “GPO” has been introduced for grid parallel operation;

— operating limits have been revised;

— new clauses have been added for specifying “bearings” and “maintenance”;

— identification markings BR and PR have been eliminated.

A list of all parts in the ISO 8528 series can be found on the ISO website.

Any feedback or questions on this document shall be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Reciprocating internal combustion engine driven alternating current generating sets —

Part 3: Alternating current generators for generating sets

1 Scope

This document specifies the principal characteristics of alternating current (a.c.) generators under the control of their excitation control system 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 a.c. generators for land and marine applications, excluding generating sets used on aircraft or to propel land vehicles and locomotives.

NOTE For some specific applications (e.g. essential hospital supplies, high-rise buildings, operation parallel with the grid), supplementary requirements can be necessary. The provisions of this document can be regarded as the basis for establishing any supplementary requirements.

For a.c. generating sets driven by other reciprocating-type prime movers (e.g. steam engines) the provisions of this document can be used as basis for establishing these requirements.

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.

ISO 281, *Rolling bearings — Dynamic load ratings and rating life*

ISO 8528-1:2018, *Reciprocating internal combustion engine driven alternating current generating sets — Part 1: Application, ratings and performance*

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

IEC 60034-5, *Rotating electrical machines — Part 5: Degrees of protection provided by the integral design of rotating machines (IP code) — Classification*

IEC 60034-6, *Rotating electrical machines — Part 6: Methods of cooling (IC code)*

IEC 60034-7, *Rotating electrical machines — Part 7: Classification of types of construction, mounting arrangements and terminal box position (IM code)*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

NOTE 1 This document uses suffix “r” for “rated” whereas in IEC standards the suffix “N” is used.

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

3.1
rated output
S_r
product of the rated rms voltage, the rated rms current and a constant *m*

Note 1 to entry: Where

— $m = 1$ for single-phase;

— $m=\sqrt{2}$ for two-phase;

— $m=\sqrt{3}$ for three-phase.

Note 2 to entry: $\sqrt{2}$ is applicable only when the a.c. generator is specifically designed in two-phase, an angle of 90° electrical between the two poles.

Note 3 to entry: S_r is expressed in volt-amperes (VA) or its multiples.

3.2
rated active power
P_r
product of the rated rms voltage, the in-phase component of the rated rms current and a constant *m*

Note 1 to entry: Where

— $m = 1$ for single-phase;

— $m=\sqrt{2}$ for two-phase;

— $m=\sqrt{3}$ for three-phase.

Note 2 to entry: $\sqrt{2}$ is applicable only when the a.c. generator is specifically designed in two-phase, an angle of 90° electrical between the two poles.

Note 3 to entry: P_r is expressed in watts (W) or its decimal multiples.

3.3
rated power factor
$\cos \varphi_r$
ratio of the *rated active power* (3.2) to the *rated output* (3.1)

Note 1 to entry: $\cos\varphi_r = \frac{P_r}{S_r}$.

3.4
rated speed
n_r
speed of rotation necessary for voltage generation at rated frequency

Note 1 to entry: n_r is expressed in revolution per minute (min^{-1}).

3.5
rated voltage
U_r
line-to-line voltage at the terminals of the a.c. generator at rated frequency and at *rated output* (3.1)

Note 1 to entry: Rated voltage is the voltage assigned by the a.c. generator manufacturer for operating and performance characteristics.

Note 2 to entry: U_r is expressed in volts (V) or its decimal multiples.

3.6
no-load voltage
U_0
line-to-line voltage at the terminals of the a.c. generator at rated frequency and no-load

Note 1 to entry: U_0 is expressed in volts (V) or its decimal multiples.

3.7
operating voltage
U_c
value of the voltage under normal conditions at a given instant and given point of the system

Note 1 to entry: U_c is expressed in volts (V) or its decimal multiples.

Note 2 to entry: This value can be expected, estimated or measured.

[SOURCE: IEC 60050-601:1985, 601-01-22, modified — The symbol and Note 1 to entry have been added.]

3.8
voltage recovery
U_{rec}
restoration of voltage to a value near to its previous value after a reduction of the voltage or a loss of voltage

Note 1 to entry: U_{rec} is expressed in volts (V) or its decimal multiples. Recovery voltage is normally expressed as a percentage of the *rated voltage* (3.5). For loads more than rated, recovery voltage is limited by saturation and exciter-regulator field forcing capability.

[SOURCE: IEC 60050-614:2016, 614-01-27, modified — The symbol and Note 1 to entry have been added.]

3.9
range of voltage setting
ΔU_s
range of possible upward and downward adjustment of voltage at a.c. generator terminals at rated frequency, for all loads between no-load and *rated output* (3.1)

Note 1 to entry: $\Delta U_s = |\Delta U_{s,up}| + |\Delta U_{s,do}|$

$$\Delta U_{s,up} = \frac{U_{s,up} - U_r}{U_r} \cdot 100\%$$

$$\Delta U_{s,do} = \frac{U_{s,do} - U_r}{U_r} \cdot 100\%$$

where

$\Delta U_{s,up}$ is the upward range of voltage setting;

$\Delta U_{s,do}$ is the downward range of voltage setting;

$U_{s,up}$ is the upward adjustable limit for voltage settings, expressed in volts (V) or its decimal multiples;

$U_{s,do}$ is the downward adjustable limit for voltage settings, expressed in volts (V) or its decimal multiples.

Note 2 to entry: ΔU_s is expressed as a percentage of the *rated voltage* (3.5).

Note 3 to entry: Special controllable excitation equipment can provide a range of voltage adjustment for asynchronous generators.

3.10
steady-state voltage tolerance band
ΔU
agreed voltage band about the steady-state voltage that the voltage can reach within a given *voltage recovery time after load decrease* (3.15) or *voltage recovery time after load increase* (3.16)

Note 1 to entry: $\Delta U = 2 \cdot \Delta U_{st} \cdot \frac{U_r}{100}$.

Note 2 to entry: ΔU is expressed in volts (V) or its decimal multiples.

3.11
steady-state voltage deviation
ΔU_{st}
change in steady-state voltage for all load changes between no-load and *rated output* (3.1), considering the influence of temperature but ignoring the effect of quadrature current compensation voltage droop

Note 1 to entry: $\Delta U_{st} = \pm \frac{U_{st,max} - U_{st,min}}{2 \cdot U_r} \cdot 100\,\%$

where

$U_{st,max}$ is the maximum steady-state voltage deviation, expressed in volts (V) or its decimal multiples;

$U_{st,min}$ is the minimum steady-state voltage deviation, expressed in volts (V) or its decimal multiples.

Note 2 to entry: The initial set voltage is usually the *rated voltage* (3.5) but can be anywhere within the range of voltage setting.

Note 3 to entry: ΔU_{st} is expressed as a percentage of the rated voltage.

3.12
transient voltage drop
ΔU_{dyn}^{-}
maximum voltage drop, when the a.c. generator, driven at the *rated speed* (3.4) and at the *rated voltage* (3.5) under normal excitation control, is switched onto a symmetrical load which absorbs a specified current at the *rated voltage* (3.5) at a given power factor or range of power factors

Note 1 to entry: $\Delta U_{dyn}^{-} = \frac{U_{dyn,min} - U_r}{U_r} \cdot 100\,\%$

where $U_{dyn,min}$ is the minimum downward transient voltage on load increase, expressed in volts (V) or its decimal multiples.

Note 2 to entry: ΔU_{dyn}^{-} is expressed as a percentage of the rated voltage.

Note 3 to entry: see Figure A.2.

3.13
transient voltage rise
ΔU_{dyn}^{+}
maximum voltage rise, when the a.c. generator, driven at the *rated speed* (3.4) and at the *rated voltage* (3.5) under normal excitation control, has a sudden rejection of the *rated output* (3.1)

Note 1 to entry: $\Delta U_{dyn}^{+} = \frac{U_{dyn,max} - U_r}{U_r} \cdot 100\,\%$

where $U_{dyn,max}$ is the maximum upward transient voltage on load decrease, expressed in volts (V) or its decimal multiples.

Note 2 to entry: ΔU_{dyn}^{+} is expressed as a percentage of the rated voltage.

Note 3 to entry: see Figure A.3.

3.14
voltage unbalance factor
$\Delta U_{2,0}$
degree of voltage unbalance in a three-phase system

Note 1 to entry: $\Delta U_{2,0}$ is expressed as a percentage by the ratio of the rms values of the negative sequence component (or the zero-sequence component) to the positive sequence component of the fundamental component of voltage.

3.15
voltage recovery time after load decrease
$t_{u,de}$
time interval from the time at which a load decrease is initiated until the time when the voltage returns to and remains within specified *steady-state voltage tolerance band* (3.10)

Note 1 to entry: $t_{u,de}$ is expressed in seconds (s) or its decimal multiples.

Note 2 to entry: see Figure A.3.

3.16
voltage recovery time after load increase
$t_{u,in}$
time interval from the time at which a load increase is initiated until the time when the voltage returns to and remains within specified *steady-state voltage tolerance band* (3.10)

Note 1 to entry: $t_{u,in}$ is expressed in seconds (s) or its decimal multiples.

Note 2 to entry: see Figure A.2.

3.17
relative thermal life expectancy factor
T_L
relative thermal life expectancy related to the thermal life expectancy in case of duty factor S1 with *rated output* (3.1)

Note 1 to entry: See IEC 60034-1:2017, Annex A.

3.18
grade of quadrature-current compensation voltage droop
δ_{QCC}
difference between the *no-load voltage* (3.6) and the voltage at the rated current at the power factor zero overexcited $U_{(Q=S_r)}$ when running isolated

Note 1 to entry: $\delta_{QCC} = \frac{U_0 - U_{(Q=S_r)}}{U_r} \cdot 100\,\%$

Note 2 to entry: δ_{QCC} is expressed as a percentage of the *rated voltage* (3.5).

4 Abbreviated terms

An explanation of abbreviated terms used in this document is shown in Table 1.

Table 1 — Abbreviated terms

Abbreviated term	Explanation
AMC	agreement between a.c. generator manufacturer and generating set manufacturer (customer)
a.c.	alternating current
EMF	electromagnetic field
GPO	grid parallel operation
HCF	harmonic current factor
IC	international cooling
IM	international mounting
IP	international protection
RIC	reciprocating internal combustion
rms	root mean square
THD	total harmonic distortion

5 Other requirements and additional regulations

The degree of protection provided by the enclosure of the a.c. generator (IP-code) shall be specified in accordance with IEC 60034-5 and agreed between the a.c. generator manufacturer and the generating set manufacturer. The a.c. generator manufacturer shall assure, i.e. by verification or graphical analysis, that the intended degree of protection will be provided under all normal conditions of use.

The method of cooling (IC-code) shall be specified in accordance with IEC 60034-6 and agreed between the a.c. generator manufacturer and the generating set manufacturer.

The type of a.c. generator construction, mounting arrangement and terminal box position (IM-code) shall be specified in accordance with IEC 60034-7 and agreed between the a.c. generator manufacturer and the generating set manufacturer.

For a.c. generators used on board ships and offshore installations which are subject to the rules of a classification society, it is presupposed that the additional requirements of the classification society are observed. The classification society name shall be stated by the generating set manufacturer prior to placing the order.

For a.c. generators operating in non-classed equipment, such additional requirements are subject to agreement between the a.c. generator manufacturer and the generating set manufacturer.

If special requirements from any other authority (e.g. inspecting and/or legislative authorities) apply, the authority name shall be stated by the generating set manufacturer prior to placing the order.

NOTE 1 Attention is drawn to the need to take note of additional regulations or requirements imposed by various regulatory bodies. Such regulations or requirements can form the subject of agreement between the a.c. generator manufacturer and the generating set manufacturer when conditions of use of the product invoke such requirements.

NOTE 2 Examples of regulatory authorities include:

— classification societies, for generating sets used on ships and offshore installations;

— government agencies;

— inspection agencies, local utilities, etc.

6 Rating

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

7 Operation of a.c. generators

7.1 Isochronous (stand-alone) operation

Isochronous operation, i.e. stand-alone operation, refers to the a.c. generator of a generating set, irrespective of its configuration or modes of start-up and control, operating as the sole source of electrical power and without the support of other sources of electrical supply.

For a.c. generators intended to operate over a relatively small range of voltage, the rated output and rated power factor shall apply at any voltage within the range, as specified in IEC 60034-1:2017, 7.3.

In accordance with IEC 60034-1:2017, 7.2.2, three-phase a.c. generators shall be suitable for supplying circuits which, when supplied by a system of balanced and sinusoidal voltages:

a) result in currents not exceeding a harmonic current factor (f_{HCF}) of 0,05, and

b) result in a system of currents where neither the negative-sequence component nor the zero-sequence component exceeds 5 percent of the positive-sequence component.

The harmonic current factor shall be computed by using Formula (1):

$$f_{HCF} = \sqrt{\sum_{n=2}^{13} i_n^2} \quad (1)$$

where

i_n is the ratio of the harmonic current (I_n) to the rated current (I_r);

n is the order of harmonic.

If the limits of deformations and imbalance occur simultaneously during operation at the rated load, this shall not lead to any harmful temperature in the a.c. generator. It is recommended that the resulting excess temperature rise related to the limits of temperature rise as specified in IEC 60034-1 does not exceed 10 K.

7.2 Parallel operation without grid

When an a.c. generator is running in parallel with other generating sets or with another source of electrical supply, i.e. island mode or marine applications, controlling means shall be provided to ensure stable operation and correct sharing of reactive power.

Stable operation is most often affected by influencing the a.c. generator excitation control system through sensing circuit with an additional reactive current component. This causes a voltage droop characteristic to be present for reactive loads.

The grade of quadrature-current compensation voltage droop δ_{QCC} is expected to be less than 8 %. Higher values shall be considered in the case of excessive system voltage variations.

NOTE 1 Identical a.c. generators with identical excitation systems are expected to operate in parallel without requiring droop compensation when their field windings are connected by equalizer links, i.e. cross-current compensation or reactive load sharing lines. Adequate reactive load sharing is achieved when there is correct active load sharing.