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Reciprocating internal combustion engine driven alternating current generating sets —

Part 5: Generating sets

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

Partie 5: Groupes électrogènes

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 8528-5 was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*.

This second edition cancels and replaces the first edition (ISO 8528-5:1993), which has been technically revised.

ISO 8528 consists of the following parts, under the general title *Reciprocating internal combustion engine driven alternating current generating sets*:

— *Part 1: Application, ratings and performance*

— *Part 2: Engines*

— *Part 3: Alternating current generators for generating sets*

— *Part 4: Controlgear and switchgear*

— *Part 5: Generating sets*

— *Part 6: Test methods*

— *Part 7: Technical declarations for specification and design*

— *Part 8: Requirements and tests for low-power generating sets*

— *Part 9: Measurement and evaluation of mechanical vibrations*

— *Part 10: Measurement of airborne noise by the enveloping surface method*

— *Part 11*[1]*: Rotary uninterruptible power supply systems — Performance requirements and test methods*

— *Part 12: Emergency power supplies to safety services*

1) Part 11 will be published as ISO/IEC 88528-11.

Reciprocating internal combustion engine driven alternating current generating sets —

Part 5:
Generating sets

1 Scope

This part of ISO 8528 defines terms and specifies design and performance criteria arising out of the combination of a Reciprocating Internal Combustion (RIC) engine and an Alternating Current (a.c.) generator when operating as a unit.

It applies to a.c. generating sets driven by RIC engines for land and marine use, excluding generating sets used on aircraft or to propel land vehicles and locomotives.

For some specific applications (e.g. essential hospital supplies and high-rise buildings) supplementary requirements may be necessary. The provisions of this part of ISO 8528 should be regarded as a basis for establishing any supplementary requirements.

For generating sets driven by other reciprocating-type prime movers (e.g. steam engines), the provisions of this part of ISO 8528 should be used as a basis for establishing these requirements.

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.

ISO 3046-4, *Reciprocating internal combustion engines — Performance — Part 4: Speed governing*

ISO 3046-5, *Reciprocating internal combustion engines — Performance — Part 5: Torsional vibrations*

ISO 8528-1:2005, *Reciprocating internal combustion engine driven alternating current generating sets — Part 1: Application, ratings and performance*

ISO 8528-2:2005, *Reciprocating internal combustion engine driven alternating current generating sets — Part 2: Engines*

ISO 8528-3:2005, *Reciprocating internal combustion engine driven alternating current generating sets — Part 3: Alternating current generators for generating sets*

ISO 8528-12, *Reciprocating internal combustion engine driven alternating current generating sets — Part 12: Emergency power supplies to safety services*

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

3 Symbols, terms and definitions

For indications of technical data for electrical equipment, IEC uses the term “rated” and the subscript “N”. For indications of technical data for mechanical equipment, ISO uses the term “declared” and the subscript “r”. Therefore, in this part of ISO 8528, the term “rated” is applied only to electrical items. Otherwise, the term “declared” is used throughout.

An explanation of the symbols and abbreviations used in this International Standard are shown in Table 1.

Table 1 — Symbols, terms and definitions

Symbol	Term	Unit	Definition
f	Frequency	Hz	
$f_{d,max}$	Maximum transient frequency rise (overshoot frequency)	Hz	Maximum frequency which occurs on sudden change from a higher to a lower power. NOTE The symbol is different from that given in ISO 3046-4.
$f_{d,min}$	Maximum transient frequency drop (undershoot frequency)	Hz	Minimum frequency which occurs on sudden change from a lower to a higher power. NOTE The symbol is different from that given in ISO 3046-4.
f_{do} [a]	Operating frequency of overfrequency limiting device	Hz	The frequency at which, for a given setting frequency, the overfrequency limiting device starts to operate.
f_{ds}	Setting frequency of overfrequency limiting device	Hz	The frequency of the generating set, the exceeding of which activates the overfrequency limiting device. NOTE In practice, instead of the value for the setting frequency, the value for the permissible overfrequency is stated (also see Table 1 of ISO 8528-2).
f_i	No-load frequency	Hz	
$f_{i,r}$	Rated no-load frequency	Hz	
f_{max} [b]	Maximum permissible frequency	Hz	A frequency specified by the generating set manufacturer which lies a safe amount below the frequency limit (see Table 1 of ISO 8528-2)
f_r	Declared frequency (rated frequency)	Hz	
$f_{i,max}$	Maximum no-load frequency	Hz	
$f_{i,min}$	Minimum no-load frequency	Hz	
f_{arb}	Frequency at actual power	Hz	
$\overset{\wedge}{\underset{\vee}{f}}$	Width of frequency oscillation	Hz	
I_k	Sustained short-circuit current	A	
t	Time	s	
t_a	Total stopping time	s	Time interval from the stop command until the generating set has come to a complete stop and is given by: $t_a = t_i + t_c + t_d$

Table 1 (*continued*)

Symbol	Term	Unit	Definition
t_b	Load pick-up readiness time	s	Time interval from the start command until ready for supplying an agreed power, taking into account a given frequency and voltage tolerance and is given by: $t_b = t_p + t_g$
t_c	Off-load run-on time	s	Time interval from the removal of the load until generating set off signal is given to the generating set. Also known as the "cooling run-on time".
t_d	Run-down time	s	Time from the generating set off signal to when the generating set has come to a complete stop.
t_e	Load pick-up time	s	Time interval from start command until the agreed load is connected and is given by: $t_e = t_p + t_g + t_s$
$t_{f,de}$	Frequency recovery time after load decrease	s	The time interval between the departure from the steady-state frequency band after a sudden specified load decrease and the permanent re-entry of the frequency into the specified steady-state frequency tolerance band (see Figure 4).
$t_{f,in}$	Frequency recovery time after load increase	s	The time interval between the departure from the steady-state frequency band after a sudden specified load increase and the permanent re-entry of the frequency into the specified steady-state frequency tolerance band (see Figure 4).
t_g	Total run-up time	s	Time interval from the beginning of cranking until ready for supplying an agreed power, taking into account a given frequency and voltage tolerance.
t_h	Run-up time	s	Time interval from the beginning of cranking until the declared speed is reached for the first time.
t_i	On-load run-on time	s	Time interval from a stop command being given until the load is disconnected (automatic sets).
t_p	Start preparation time	s	Time interval from the start command until the beginning of cranking.
t_s	Load switching time	s	Time from readiness to take up an agreed load until this load is connected.
t_u	Interruption time	s	Time interval from the appearance of the criteria initiating a start until the agreed load is connected and is given by: $t_u = t_v + t_p + t_g + t_s$ $= t_v + t_e$ NOTE 1 This time shall be particularly taken into account for automatically started generating sets (see Clause 11). NOTE 2 Recovery time (ISO 8528-12) is a particular case of interruption time.

Table 1 (*continued*)

Symbol	Term	Unit	Definition
$t_{U,de}$	Voltage recovery time after load decrease	s	Time interval from the point at which a load decrease is initiated until the point when the voltage returns to and remains within the specified steady-state voltage tolerance band (see Figure 5).
$t_{U,in}$	Voltage recovery time after load increase	s	Time interval from the point at which a load increase is initiated until the point when the voltage returns to and remains within the specified steady-state voltage tolerance band (see Figure 5).
t_v	Start delay time	s	Time interval from the appearance of the criteria initiating a start to the starting command (particularly for automatically started generating units). This time does not depend on the applied generating set. The exact value of this time is the responsibility of and is determined by the customer or, if required, by special requirements of legislative authorities. For example, this time is provided to avoid starting in case of a very short mains failure.
t_z	Cranking time	s	Time interval from the beginning of cranking until the firing speed of the engine is reached.
t_0	Pre-lubricating time	s	Time required for some engines to ensure that oil pressure is established before the beginning of cranking. This time is usually zero for small generating sets, which normally do not require pre-lubrication.
v_f	Rate of change of frequency setting		Rate of change of frequency setting under remote control expressed as a percentage of related range of frequency setting per second and is given by: $$v_f = \frac{(f_{i,max} - f_{i,min})/f_r}{t} \times 100$$
v_u	Rate of change of voltage setting		Rate of change of voltage setting under remote control expressed as a percentage of the related range of voltage setting per second and is given by: $$v_U = \frac{(U_{s,up} - U_{s,do})/U_r}{t} \times 100$$
$U_{s,do}$	Downward adjustable voltage	V	
$U_{s,up}$	Upward adjustable voltage	V	
U_r	Rated voltage	V	Line-to-line voltage at the terminals of the generator at rated frequency and at rated output. NOTE Rated voltage is the voltage assigned by the manufacturer for operating and performance characteristics.

Table 1 (*continued*)

Symbol	Term	Unit	Definition
U_{rec}	Recovery voltage	V	Maximum obtainable steady-state voltage for a specified load condition. NOTE Recovery voltage is normally expressed as a percentage of the rated voltage. It normally lies within the steady-state voltage tolerance band (ΔU). For loads in excess of the rated load, recovery voltage is limited by saturation and exciter/regulator field forcing capability (see Figure 5).
U_s	Set voltage	V	Line-to-line voltage for defined operation selected by adjustment.
$U_{st,max}$	Maximum steady-state voltage	V	Maximum voltage under steady-state conditions at rated frequency for all powers between no-load and rated output and at specified power factor, taking into account the influence of temperature rise.
$U_{st,min}$	Minimum steady-state voltage	V	Minimum voltage under steady-state conditions at rated frequency for all powers between no-load and rated output and at specified power factor, taking into account the influence of temperature rise.
U_0	No-load voltage	V	Line-to-line voltage at the terminals of the generator at rated frequency and no-load.
$U_{dyn,max}$	Maximum upward transient voltage on load decrease	V	Maximum voltage which occurs on a sudden change from a higher load to a lower load.
$U_{dyn,min}$	Minimum downward transient voltage on load increase	V	Minimum voltage which occurs on a sudden change from a lower load to a higher load.
$\hat{U}_{max,s}$	Maximum peak value of set voltage	V	
$\hat{U}_{min,s}$	Minimum peak value of set voltage	V	
$\hat{U}_{mean,s}$	Average value of the maximum and minimum peak value of set voltage	V	
$\hat{U}_{mod,s}$	Voltage modulation	%	Quasi-periodic voltage variation (peak-to-peak) 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 constant speed: $\hat{U}_{mod,s} = 2\frac{\hat{U}_{mod,s,max} - \hat{U}_{mod,s,min}}{\hat{U}_{mod,s,max} + \hat{U}_{mod,s,min}} \times 100$ NOTE 1 This is a cyclic or random disturbance which may be caused by regulators, cyclic irregularity or intermittent loads. NOTE 2 Flickering lights are a special case of voltage modulation (see Figures 11 and 12).
$\hat{U}_{mod,s,max}$	Maximum peak of voltage modulation	V	Quasi-periodic maximum voltage variation (peak-to-peak) about a steady-state voltage

Table 1 (*continued*)

Symbol	Term	Unit	Definition
$\hat{U}_{\text{mod,s,min}}$	Minimum peak of voltage modulation	V	Quasi-periodic minimum voltage variation (peak-to-peak) about a steady-state voltage
$\hat{\check{U}}$	Width of voltage oscillation	V	
Δf_{neg}	Downward frequency deviation from linear curve	Hz	
Δf_{pos}	Upward frequency deviation from linear curve	Hz	
Δf	Steady-state frequency tolerance band		The agreed frequency band about the steady-state frequency which the frequency reaches within a given governing period after increase or decrease of the load.
Δf_{c}	Maximum frequency deviation from a linear curve	Hz	The larger value of Δf_{neg} and Δf_{pos} that occur between no load and rated load (see Figure 2)
Δf_{s}	Range of frequency setting	Hz	The range between the highest and lowest adjustable no-load frequencies (see Figure 1) as given by: $\Delta f_{\text{s}} = f_{\text{i,max}} - f_{\text{i,min}}$
$\Delta f_{\text{s,do}}$	Downward range of frequency setting	Hz	Range between the declared no-load frequency and the lowest adjustable no-load frequency (see Figure 1) as given by: $\Delta f_{\text{s,do}} = f_{\text{i,r}} - f_{\text{i,min}}$
$\Delta f_{\text{s,up}}$	Upward range of frequency setting	Hz	Range between the highest adjustable no-load frequency and the declared no-load frequency (see Figure 1) as given by: $\Delta f_{\text{s,up}} = f_{\text{i,max}} - f_{\text{i,r}}$
ΔU	Steady-state voltage tolerance band	V	Agreed voltage band about the steady-state voltage that the voltage reaches within a given regulating period after a specified sudden increase or decrease of load. Unless otherwise stated it is given by: $\Delta U = 2\delta U_{\text{st}} \times \frac{U_r}{100}$
ΔU_{s}	Range of voltage setting	V	Range of maximum possible upward and downward adjustments of voltage at the generator terminals at rated frequency, for all loads between no-load and rated output and within the agreed range of power factor as given by: $\Delta U_{\text{s}} = \Delta U_{\text{s,up}} + \Delta U_{\text{s,do}}$
$\Delta U_{\text{s,do}}$	Downward range of voltage setting	V	Range between the rated voltage and downward adjustment of voltage at the generator terminals at rated frequency, for all loads between no-load and rated output and within the agreed range of power factor as given by: $\Delta U_{\text{s,do}} = U_{\text{r}} - U_{\text{s,do}}$

Table 1 (*continued*)

Symbol	Term	Unit	Definition
$\Delta U_{s,up}$	Upward range of voltage setting	V	Range between the rated voltage and upward adjustment of voltage at the generator terminals at rated frequency, for all loads between no-load and rated output and within the agreed range of power factor as given by: $\Delta U_{s,up} = U_{s,up} - U_r$
$\Delta \delta f_{st}$	Frequency/power characteristic deviation	%	Maximum deviation from a linear frequency/power characteristic curve in the power range between no-load and declared power, expressed as a percentage of rated frequency (see Figure 2) as given by: $\Delta \delta f_{st} = \frac{\Delta f_c}{f_r} \times 100$
	Frequency/power characteristic curve		Curve of steady-state frequencies in the power range between no-load and declared power, plotted against active power of generating set (see Figure 2).
α_U	Related steady-state voltage tolerance band	%	The tolerance band expressed as a percentage of the rated voltage as given by: $\alpha_U = \frac{\Delta U}{U_r} \times 100$
α_f	Related frequency tolerance band	%	This tolerance band usually is expressed as a percentage of the rated frequency as given by: $\alpha_f = \frac{\Delta f}{f_r} \times 100$
β_f	Steady-state frequency band	%	Envelope width oscillation $\overset{\wedge}{\underset{\vee}{f}}$ of generating set frequency at constant power around a mean value, expressed as a percentage of rated frequency as given by: $\beta_f = \frac{\overset{\wedge}{\underset{\vee}{f}}}{f_r} \times 100$ NOTE 1 The maximum value of β_f occurring in the range between 20 % power and declared power shall be stated. NOTE 2 For powers below 20 %, the steady-state frequency band may show higher values (see Figure 3), but should allow synchronization.

Table 1 (*continued*)

Symbol	Term	Unit	Definition
δf_d^-	Transient frequency deviation (from initial frequency) on load increase (-) related to initial frequency	%	Temporary frequency deviation between undershoot frequency and initial frequency during the governing process following a sudden load increase, related to initial frequency, expressed as a percentage as given by: $$\delta f_d^- = \frac{f_{d,min} - f_{arb}}{f_{arb}} \times 100$$ NOTE 1 (A minus sign relates to an undershoot after a load increase, and a plus sign to an overshoot after a load decrease.) NOTE 2 Transient frequency deviation shall therefore be in the allowable consumer frequency tolerance and shall be particularly stated.
δf_d^+	Transient frequency deviation (from initial frequency) on load decrease (+) related to initial frequency	%	Temporary frequency deviation between overshoot frequency and initial frequency during the governing process following a sudden load decrease, related to initial frequency, expressed as a percentage as given by: $$\delta f_d^+ = \frac{f_{d,max} - f_{arb}}{f_{arb}} \times 100$$ NOTE 1 (A minus sign relates to an undershoot after a load increase, and a plus sign to an overshoot after a load decrease.) NOTE 2 Transient frequency deviation shall therefore be in the allowable consumer frequency tolerance and shall be particularly stated.
δf_{dyn}^-	Transient frequency deviation (from initial frequency) on load increase (-) related to rated frequency	%	Temporary frequency deviation between undershoot (or overshoot) frequency and initial frequency during the governing process following a sudden load change, related to rated frequency, expressed as a percentage as given by: $$\delta f_{dyn}^- = \frac{f_{d,min} - f_{arb}}{f_r} \times 100$$ NOTE 1 Transient frequency deviation shall therefore be in the allowable consumer frequency tolerance and shall be particularly stated. NOTE 2 (A minus sign relates to an undershoot after a load increase, and a plus sign to an overshoot after a load decrease.)

Table 1 (*continued*)

Symbol	Term	Unit	Definition
δf^{+}_{dyn}	Transient frequency deviation (from initial frequency) on load decrease (+) related to rated frequency	%	Temporary frequency deviation between overshoot frequency and initial frequency during the governing process following a sudden load change, related to rated frequency, expressed as a percentage as given by: $$\delta f^{+}_{dyn} = \frac{f_{d,max} - f_{arb}}{f_r} \times 100$$ NOTE 1 Transient frequency deviation shall therefore be in the allowable consumer frequency tolerance and shall be particularly stated. NOTE 2 (A minus sign relates to an undershoot after a load increase, and a plus sign to an overshoot after a load decrease.)
δU^{-}_{dyn}	Transient voltage deviation on load increase	%	Transient voltage deviation on load increase is the voltage drop when the generator, driven at rated frequency and at rated voltage under normal excitation control, is switched onto rated load, expressed as a percentage of rated voltage as given by: $$\delta U^{-}_{dyn} = \frac{U_{dyn,min} - U_r}{U_r} \times 100$$ NOTE 1 Transient voltage deviation shall therefore be in the allowable consumer voltage tolerance and shall be particularly stated. NOTE 2 (A minus sign relates to an undershoot after a load increase, and a plus sign to an overshoot after a load decrease.)
δU^{+}_{dyn}	Transient voltage deviation on load decrease	%	Transient voltage deviation on load decrease is the voltage rise when the generator, driven at rated frequency and at rated voltage under normal excitation control, has a sudden rejection of rated load, expressed as a percentage of rated voltage as given by: $$\delta U^{+}_{dyn} = \frac{U_{dyn,max} - U_r}{U_r} \times 100$$ NOTE 1 Transient voltage deviation shall therefore be in the allowable consumer voltage tolerance and shall be particularly stated. NOTE 2 (A minus sign relates to an undershoot after a load increase, and a plus sign to an overshoot after a load decrease.)
δf_s	Related range of frequency setting	%	Range of frequency setting, expressed as a percentage of rated frequency as given by: $$\delta f_s = \frac{f_{i,max} - f_{i,min}}{f_r} \times 100$$