INTERNATIONAL STANDARD

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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

Reference number
ISO 8528-3:1993(E)

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.

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.

International Standard ISO 8528-3 was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*, Sub-Committee SC 2, *Performance and tests*.

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: Low-power general-purpose generating sets*

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

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— *Part 10: Measurement of airborne noise — Enveloping surface method*

— *Part 11: Security generating sets with uninterruptible power systems*

Parts 7, 8, 9 and 10 are in course of preparation. Part 11 is at an early stage of preparation and may be split into two parts.

Annex A forms an integral part of this part of ISO 8528.

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Reciprocating internal combustion engine driven alternating current generating sets —

Part 3:
Alternating current generators for generating sets

1 Scope

This part of ISO 8528 specifies the principal characteristics of alternating current (a.c.) generators under the control of their voltage regulators when used for generating set applications. It supplements the requirements of IEC 34-1.

NOTE 1 At present no International Standard is available for asynchronous generators. When such an International Standard is published, this part of ISO 8528 will be revised accordingly. See subclause 12.2.

This part of ISO 8528 applies to a.c. generators for a.c. generating sets driven by reciprocating internal combustion (RIC) engines for land and marine use, excluding generating sets used on aircraft or to propel land vehicles and locomotives.

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

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

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 8528. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 8528 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 8528-1:1993, *Reciprocating internal combustion engine driven alternating current generating sets — Part 1: Application, ratings and performance.*

IEC 34-1:1983, *Rotating electrical machines — Part 1: Rating and performance.*

CISPR 14:1985, *Limits and methods of measurement of radio interference characteristics of household electrical appliances, portable tools and similar electrical apparatus.*

CISPR 15:1985, *Limits and methods of measurement of radio interference characteristics of fluorescent lamps and luminaires.*

3 Symbols

NOTE 2 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.

U_s	Set voltage
$U_{st,max}$	Maximum steady-state voltage deviation
$U_{st,min}$	Minimum steady-state voltage deviation
U_r	Rated voltage
U_{rec}	Recovery voltage
$U_{s,do}$	Downward adjustable voltage
$U_{s,up}$	Upward adjustable voltage
U_0	No-load voltage
$U_{dyn,max}$	Maximum upward transient voltage on load decrease
$U_{dyn,min}$	Minimum downward transient voltage on load increase
ΔU	Steady-state voltage tolerance band
ΔU_s	Range of voltage setting
$\Delta U_{s,do}$	Downward range of voltage setting
$\Delta U_{s,up}$	Upward range of voltage setting
δU_{dyn}	Transient voltage deviation
δU_{dyn}^-	Transient voltage deviation on load increase
δU_{dyn}^+	Transient voltage deviation on load decrease
δU_s	Related range of voltage setting
$\delta U_{s,do}$	Related downward range of voltage setting
$\delta U_{s,up}$	Related upward range of voltage setting
δU_{st}	Steady-state voltage deviation
$\hat{U}_{mod,max}$	Maximum peak of voltage modulation
$\hat{U}_{mod,min}$	Minimum peak of voltage modulation
$\hat{U}_{mod}$	Voltage modulation
$\delta U_{2,0}$	Voltage unbalance
δ_{QCC}	Grade of quadrature-current compensation voltage droop
$s_{r,G}$	Rated slip of asynchronous generator
f_r	Rated frequency
p	Number of pole pairs
$n_{r,G}$	Rated speed of rotation of generator
S_r	Rated output (rated apparent power)
P_r	Rated active power
$\cos \varphi_r$	Rated power factor
Q_r	Rated reactive power
t_U	Voltage recovery time
$t_{U,in}$	Voltage recovery time after load increase
$t_{U,de}$	Voltage recovery time after load decrease
I_L	Real current drawn by the load
T_L	Relative thermal life expectancy factor

4 Other regulations and additional requirements

4.1 For a.c. generators for generating sets used on board ships and offshore installations which have to comply with rules of a classification society, the additional requirements of the classification society shall be observed. The classification society shall be stated by the customer prior to placing of the order.

For a.c. generators operating in non-classed equipment, such additional requirements are in each case subject to agreement between the manufacturer and customer.

4.2 If special requirements from regulations of any other authority (e.g. inspecting and/or legislative authorities) have to be met, the authority shall be stated by the customer prior to placing of the order.

Any further additional requirements shall be subject to agreement between the manufacturer and customer.

5 Rating

The generator rating class shall be specified in accordance with IEC 34-1. In the case of generators for RIC engine driven generating sets, continuous rating (duty type S1) or rating with discrete constant loads (duty type S10) shall be specified.

For the purposes of this part of ISO 8528, the maximum continuous rating based on duty type S1 is called the basic 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.

In the case of duty type S10, operation at the PR thermally ages the generator insulation systems at an increased rate. Factor T_L for the relative thermal life expectancy of the insulation system is therefore an important integral part of the rating class.

6 Limits of temperature and temperature rise

6.1 Basic continuous rating

The generator shall be capable of delivering its basic continuous rating (BR) over the whole range of operating conditions (e.g. minimum to maximum coolant temperatures) with total temperatures not exceeding 40 °C plus the temperature rises specified in IEC 34-1:1983, table I (see note 3).

6.2 Peak continuous rating

At the generator peak continuous rating (PR), the total temperatures may be increased by the following allowances (see notes 3 and 4):

Thermal classification	Rating < 5 MV·A	Rating ≥ 5 MV·A
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 the total temperature shall be reduced by 1 °C for each degree Celsius by which the ambient temperature is below 10 °C.

NOTES

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

4 When the generator operates at these higher temperatures, the generator insulation systems will age thermally from two to six times faster (depending on the temperature increase and specific insulation system) than at the generator BR temperature rise values; i.e. operating 1 h at PR temperature rise values is approximately equal to operating 2 h to 6 h at BR temperature rise values. The exact value for the factor T_L is to be given by the manufacturer and marked on the rating plate (see also clause 14).

7 Rated power and speed characteristics

Terms, symbols and definitions for rated power and speed are given in 7.1 to 7.5.

No.	Term	Symbol	Definition
7.1	Rated output (rated apparent power)	S_r	Apparent electric power at the terminals, expressed in volt-amperes (V·A), or its decimal multiples together with the power factor.
7.2	Rated active power	P_r	Rated apparent power multiplied by the rated power factor, expressed in watts (W), or its decimal multiples: $P_r = S_r \cos \varphi_r$
7.3	Rated power factor	$\cos \varphi_r$	Ratio of the rated active power to the rated apparent power: $\cos \varphi_r = \frac{P_r}{S_r}$
7.4	Rated reactive power	Q_r	Geometrical difference between the rated apparent power and the rated active power, expressed in vars (var), or its decimal multiples: $Q_r = \sqrt{S_r^2 - P_r^2}$

No.	Term	Symbol	Definition
7.5	Rated speed of rotation of generator	$n_{r,G}$	Speed of rotation necessary for voltage generation at the rated frequency.
7.5.1	Rated speed of rotation for synchronous generator		Speed given by the following formula: $$n_{r,G} = \frac{f_r}{p}$$
7.5.2	Rated speed of rotation for asynchronous generator		Speed given by the following formula: $$n_{r,G} = \frac{f_r}{p}(1 - s_{r,G})$$

8 Voltage characteristics

Terms, symbols and definitions for voltages are given in 8.1 to 8.12.

No.	Term	Symbol	Definition
8.1	Rated voltage	U_r	Line-to-line voltage at the terminals of the generator at the rated frequency and rated output. NOTE — Rated voltage is the voltage assigned by the manufacturer for operating and performance characteristics.
8.2	Set voltage	U_s	Line-to-line voltage for defined operation selected by adjustment.
8.3	No-load voltage	U_0	Line-to-line voltage at the terminals of the generator at rated frequency and no-load.
8.4	Range of voltage setting	ΔU_s	Range of maximum possible upward 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: $$\Delta U_s = \Delta U_{s,up} + \Delta U_{s,do}$$
	Related range of voltage setting	δU_s	Range of voltage setting expressed as a percentage of the rated voltage: $$\delta U_s = \frac{\Delta U_{s,up} + \Delta U_{s,do}}{U_r} \times 100$$
8.4.1	Downward range of voltage setting	$\Delta U_{s,do}$	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 within the agreed range of power factor: $$\Delta U_{s,do} = U_r - U_{s,do}$$
	Related downward range of voltage setting	$\delta U_{s,do}$	Downward range of voltage setting expressed as a percentage of the rated voltage: $$\delta U_{s,do} = \frac{U_r - U_{s,do}}{U_r} \times 100$$

No.	Term	Symbol	Definition
8.4.2	Upward range of voltage setting	$\Delta U_{s,up}$	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 within the agreed range of power factor: $$\Delta U_{s,up} = U_{s,up} - U_r$$
	Related upward range of voltage setting	$\delta U_{s,up}$	Upward range of voltage setting, expressed as a percentage of the rated voltage: $$\delta U_{s,up} = \frac{U_{s,up} - U_r}{U_r} \times 100$$
8.5	Steady-state voltage deviation[1)]	δU_{st}	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 droop. NOTE — The initial set voltage is usually the rated voltage, but may be anywhere within the range specified in accordance with 8.4. The steady-state voltage deviation is expressed as a percentage of the rated voltage: $$\delta U_{st} = \pm \frac{U_{st,max} - U_{st,min}}{2U_r} \times 100$$
8.6	Transient voltage deviation, on load increase (−) and on load decrease (+), respectively[1)]	δU_{dyn}^{-}	Transient voltage deviation on load increase is the voltage drop when the generator, driven at rated speed and at rated voltage under normal excitation control, is switched onto rated load, expressed as a percentage of rated voltage: $$\delta U_{dyn}^{-} = \frac{U_{dyn,min} - U_r}{U_r} \times 100$$
		δU_{dyn}^{+}	Transient voltage deviation on load decrease is the voltage rise when the generator, driven at rated speed and at rated voltage under normal excitation control, has a sudden rejection of rated load, expressed as a percentage of rated voltage: $$\delta U_{dyn}^{+} = \frac{U_{dyn,max} - U_r}{U_r} \times 100$$ If the load change differs from the above-defined values, then the specified values and the associated power factors shall be stated.
8.7	Recovery voltage	U_{rec}	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 A.1).
8.8	Steady-state voltage tolerance band	ΔU	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: $$\Delta U = 2\delta U_{st} \times \frac{U_r}{100}$$

No.	Term	Symbol	Definition
8.9	Voltage recovery time	t_U $t_{U,\text{in}}$ 2) $t_{U,\text{de}}$ 2)	Time interval from the point at which a load change is initiated (t_1) until the point when the voltage returns to and remains within the specified steady-state voltage tolerance band (t_2) (see figures A.1 to A.3): $t_U = t_2 - t_1$ This time interval applies to constant speed and depends on the power factor. If the load change differs from the rated apparent power, the value of the power change and the power factor shall be stated.
8.10	Voltage modulation	$\hat{U}_{\text{mod}}$	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: $\hat{U}_{\text{mod}} = 2 \dfrac{\hat{U}_{\text{mod,max}} - \hat{U}_{\text{mod,min}}}{\hat{U}_{\text{mod,max}} + \hat{U}_{\text{mod,min}}} \times 100$
8.11	Voltage unbalance	$\delta U_{2,0}$	Ratio of the negative sequence or the zero sequence voltage components to the positive sequence voltage component at no-load. Voltage unbalance is expressed as a percentage of the rated voltage.
8.12	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 regulating system.

1) Further details are given in annex A.

2) See also ISO 8528-5:1993, figure 5.

9 Parallel operation

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 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 lagging $U_{(Q=S_r)}$ expressed as a percentage of rated voltage U_r:

$$\delta_{QCC} = \frac{U_0 - U_{(Q=S_r)}}{U_r} \times 100$$

The value of δ_{QCC} should be < 8 %. Higher values have to be considered in the case of excessive system voltage variations.

NOTES

5 Unity power factor loads produce virtually no droop.

6 Identical a.c. generators with identical excitation systems may operate in parallel without required voltage droop when their field windings are connected by equalizer links. Adequate reactive load sharing is achieved in the case of correct active load sharing and approximately the same load characteristics.

7 When generating sets are operating in parallel with star points directly connected together circulating currents may occur, particularly third-harmonic currents.

10 Special load conditions

In the case of more severe conditions than the standard conditions given in IEC 34-1, see 10.1 to 10.3 for assistance in specifying special load conditions.

10.1 Unbalanced load current

The requirements of IEC 34-1:1983, clause 22 shall apply, except that generators with ratings up to 1 000 kV·A, 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.

10.2 Sustained short-circuit current

Under short-circuit conditions on the generator, it is normally 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.

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

10.3 Occasional excess current capability

See IEC 34-1:1983, 18.1.

10.4 Telephone harmonic factor (THF)

Limiting values of the telephone harmonic factor of the line-to-line terminal voltages shall be in accordance with IEC 34-1:1983, clause 28. A 5 % THF shall also apply to generators from 62,5 kV·A to 300 kV·A, and a THF of 8 % shall apply for generators below 62,5 kV·A.

10.5 Radio interference suppression (F)

Limiting values of radio interference of continuous and clicking disturbances shall be in accordance with CISPR 14 and CISPR 15.

The grade of radio interference suppression involves the interference voltage, power and field strength. This shall be decided by agreement between the customer and manufacturer.

11 Effect of electromechanical frequency of vibrations when sets operate in parallel

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

If there is an engine torque irregularity at a frequency close to the electrical natural frequency, resonance will occur. The electrical natural frequency usually lies in the range of 1 Hz to 3 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 an investigation.

12 Asynchronous generators with excitation equipment

12.1 General

Asynchronous generators need reactive power for voltage generation.

When running in single operation, special excitation equipment is necessary to provide the excitation for asynchronous generators; this equipment shall also supply the reactive power demand of the connected load.

All the terms defined in 12.2 to 12.5 are valid for asynchronous generators which are not connected to the power grid for supplying the required reactive power but are provided with specially incorporated excitation equipment.

12.2 Rated speed and rated slip (see also 7.5.2)

Rated speed is the speed of rotation required for generating voltage of rated frequency, taking into account the value of the rated slip:

$$n_{r,G} = \frac{f_r}{p}(1 - s_{r,G})$$

The rated slip of an asynchronous generator is the difference between the synchronous speed and the rated speed of the rotor referred to the synchronous speed, where the generating set is giving its rated active power:

$$s_{r,G} = \frac{(f_r/p) - n_{r,G}}{f_r/p}$$

12.3 Sustained short-circuit current (see also 10.2)

Asynchronous generators deliver a sustained short-circuit current only with a specially equipped excitation source.

12.4 Range of voltage setting (see also 8.4)

Controllable special excitation equipment is required for reaching the range of voltage adjustment for asynchronous generators.

12.5 Parallel operation (see also clause 9)

Asynchronous generators with special excitation equipment running in parallel share the reactive power demand of the connected load according to their excitation output capability.

Asynchronous generators share the active power demand of the connected load according to the speed of the RIC engine.

13 Operating limit values

Four performance classes are defined to describe the generator characteristics (see ISO 8528-1). The operating limit values are given in table 1.

The values given in table 1 apply only to the generator, exciter and regulator operating at constant (rated) speed and starting from ambient temperature. The effect of the prime mover speed regulation may cause these values to differ from the values given in table 1.

14 Rating plate

The generator rating plate shall be in accordance with IEC 34-1 and, in addition, the rated output and class of rating shall be combined as follows:

a) where a continuous rating based on duty type S1 is stated, the rated output shall be followed by the marking "BR" (basic continuous rating), e.g. $S_r = 22$ kV·A BR;

b) where a rating with discrete constant loads based on duty type S10 is stated, the basic continuous rating based on duty S1 shall be marked as in a). In addition the peak rated output shall be shown followed by the marking "PR" (peak continuous rating), the maximum running time of 500 h per year (see ISO 8528-1:1993, 13.3.3) and the factor T_L, e.g. $S_r = 24$ kV·A PR 500 h per year, $T_L = 0{,}9$.

Upon request, the generator manufacturer shall provide the set manufacturer with a capability graph or set of values showing the permissible output of the generator set over the range of coolant temperature involved.

Table 1 — Operating limit values

No.	Term	Symbol	Unit	Reference clause No.	Operating limit values			
					Performance class			
					G1	G2	G3	G4
13.1	Related range of voltage setting	δU_s	%	8.4	⩾ ± 5 1)			AMC2)
13.2	Steady-state voltage deviation	δU_{st}	%	8.5	± 5	± 2,5	± 1	AMC
13.3	Transient voltage3) 4) 5) deviation on load increase	δU_{dyn}^{-}	%	8.6	− 30	− 24	− 18	AMC
13.4	Transient voltage3) 4) 5) deviation on load decrease	δU_{dyn}^{+}	%	8.6	35	25	20	AMC
13.5	Voltage recovery time3) 4)	t_U	s	8.9	< 2,5	< 1,5	< 1,5	AMC
13.6	Voltage unbalance	$\delta U_{2,0}$	%	8.11	1 6)	1 6)	1 6)	1 6)

1) Not necessary if no parallel operation or fixed voltage setting is required.

2) AMC = by agreement between manufacturer and customer.

3) Rated apparent power at rated voltage and rated frequency with constant impedance load. Other power factors and limit values may be by agreement between manufacturer and customer.

4) It should be appreciated that the choice of a grade of transient voltage deviation and/or recovery time lower than is actually necessary can result in a much larger generator. Since there is a fairly consistent relationship between transient voltage performance and transient reactances, the system fault level will also be increased.

5) Higher values may be applied to generators with rated outputs higher than 5 MV·A and speed of or below 600 min^{-1}.

6) In the case of parallel operation, these values are reduced to 0,5.

Annex A
(normative)

Transient voltage characteristic of an a.c. generator following a sudden change in load

A.1 General

A.1.1 When a generator is subjected to a sudden load change there will be a resultant time-varying change in terminal voltage. One function of the exciter-regulator system is to detect this change in terminal voltage, and to vary the field excitation as required to restore the terminal voltage. The maximum transient deviation in terminal voltage that occurs is a function of:

a) the magnitude, power factor and rate of change of the applied load;

b) the magnitude, power factor and current versus the voltage characteristic of any initial load;

c) the response time and voltage forcing capability of the exciter-regulator system; and

d) the RIC engine speed versus time following the sudden load change.

Transient voltage performance is therefore a system performance characteristic involving the generator, exciter, regulator and RIC engine, and cannot be established from the generator data alone.

This annex covers only the generator and exciter-regulator system.

A.1.2 In selecting or applying generators, the maximum transient voltage deviation from rated voltage (voltage dip) following a sudden increase in load is often specified or requested. When requested by the customer, the generator manufacturer shall furnish the expected transient voltage deviation in either of the two following cases:

a) generator, exciter and regulator are supplied as a whole package by the a.c. generator manufacturer; or

b) complete data defining the transient performance of the regulator (and exciter, if applicable) are made available to the generator manufacturer.

A.1.3 When furnishing the expected transient voltage deviation, the following conditions shall be assumed unless otherwise specified:

a) constant speed (rated);

b) generator, exciter and regulator operate initially at no-load, rated voltage, starting from ambient temperature;

c) application of a constant load of linear impedance as specified.

NOTE 8 The expected transient voltage deviation from rated voltage refers to the average voltage change of all phases at the generator terminals; i.e. it takes no account of asymmetry which is influenced by factors beyond the control of the generator manufacturer.

A.2 Examples

Strip charts of the output voltage as a function of time demonstrate the transient performance of the generator, exciter and regulator system to sudden changes in load. The entire voltage envelope should be recorded to determine the performance characteristics.

Strip charts representing two types of voltage recorder are illustrated in figures A.1, A.2 and A.3. The labelled charts and sample calculations should be used as a guide to determine the generator-exciter-regulator performance when subjected to a sudden load change.

A.3 Motor starting loads

The following test conditions are recommended for demonstrating the motor starting performance of a synchronous generator, exciter and regulator system.

A.3.1 Load simulation

Test conditions for load simulation are as follows:

a) constant impedance (non-saturable reactive load);

b) power factor $\leqslant$ 0,4 lagging.

NOTE 9 The current drawn by the simulated motor starting load should be corrected by the ratio

U_r/U_{rec}

whenever the generator terminal voltage fails to return to rated voltage. This corrected value of current and rated terminal voltage should be used to determine the actual kV·A load applied.

A.3.2 Temperature

The test should be conducted with the generator and excitation system initially at ambient temperature.

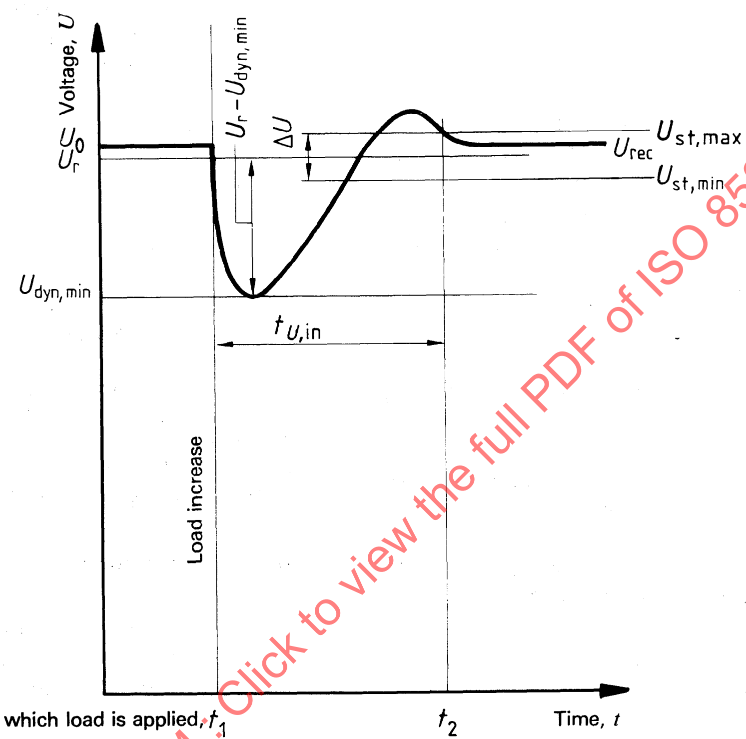


Figure A.1 — Transient voltage characteristic (load increase)

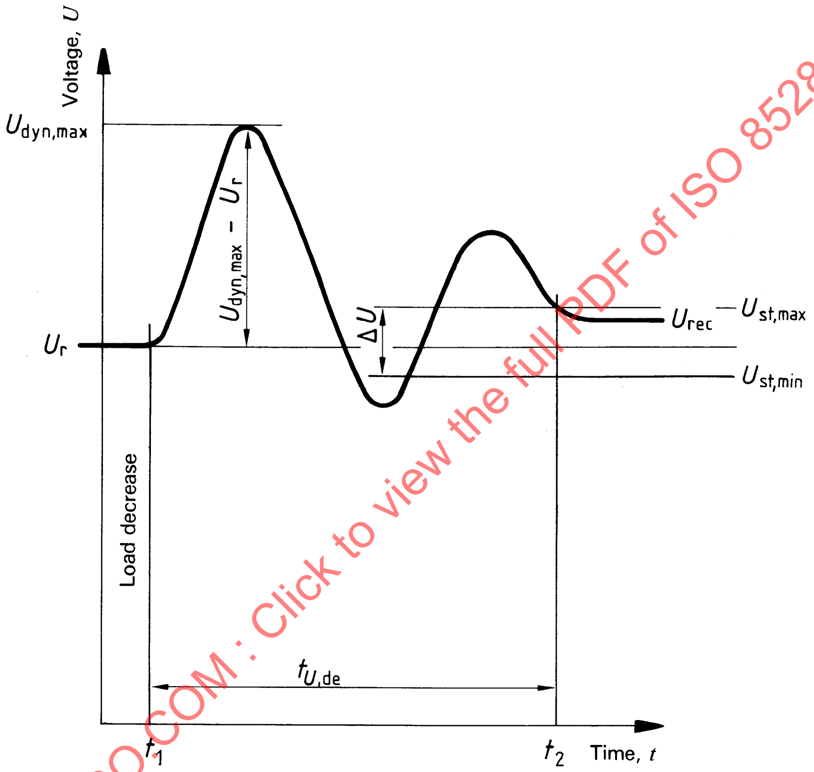
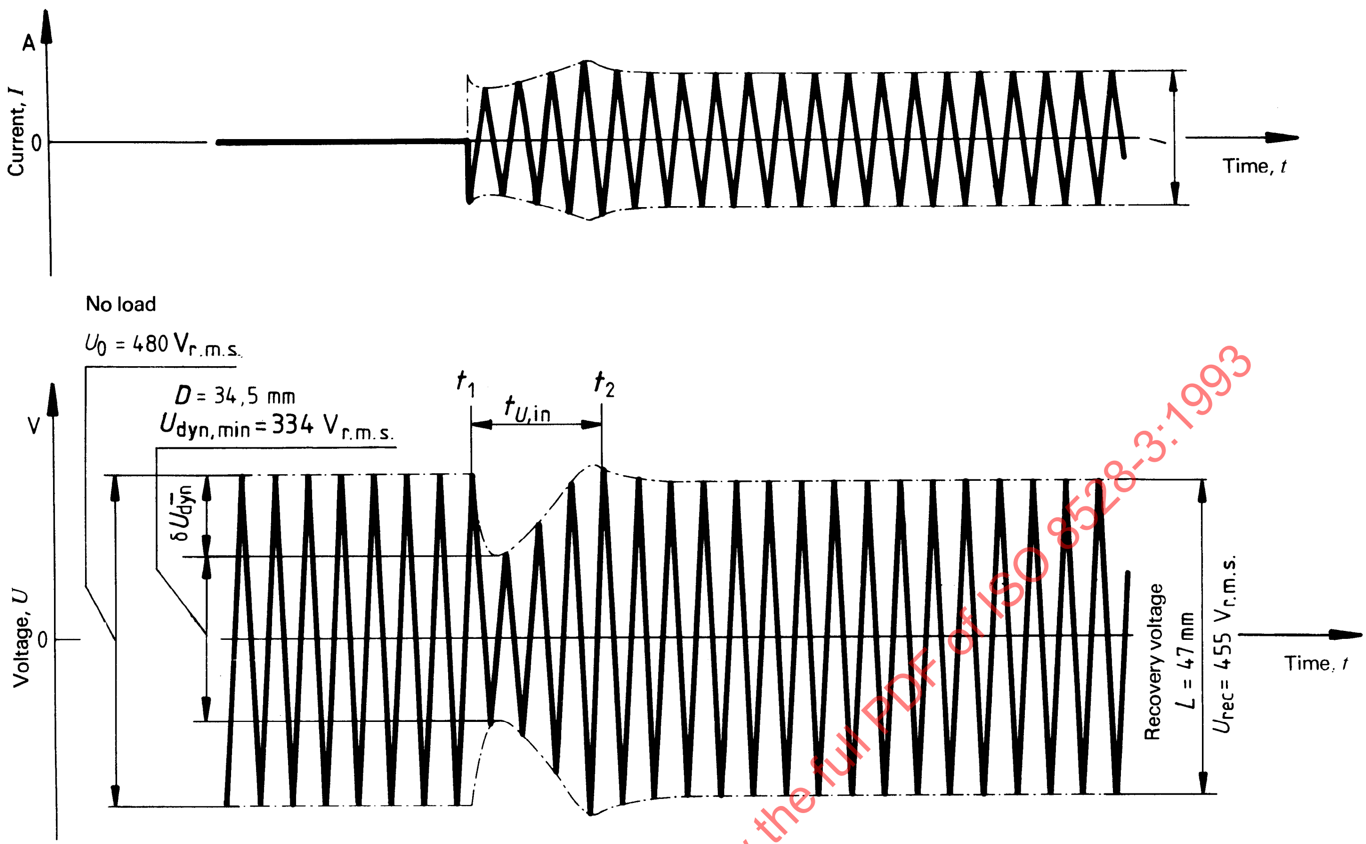


Figure A.2 — Transient voltage characteristic (load decrease)



δU_{dyn}^- = Voltage dip, in volts

U_r = Rated terminal voltage, in volts

U_0 = No-load voltage (r.m.s. of voltmeter reading), in volts

L = Measured peak-to-peak amplitude of recovery voltage, in millimetres

$I'_L = I_L \dfrac{U_r}{U_{rec}}$ = Current drawn by the load corrected to rated voltage, in amperes

I_L = Real current drawn by the load, in amperes

U_{rec} = Steady-state voltmeter reading (r.m.s. of recovery voltage), in volts

D = Measured peak-to-peak amplitude of minimum transient voltage, in millimetres

$U_{dyn,min}$ = Calculated minimum transient voltage, in volts

t_1 = Point at which load is applied

t_2 = Point of recovery to specified band

$t_{U,in}$ = Time of recovery to specified band, in seconds

EXAMPLE

U_r = 480 V; U_0 = 480 V

$$U_{dyn,min} = \frac{D}{L} U_{rec} = \frac{34,5}{47} \times 455 = 334 \text{ V}$$

$$\delta U_{dyn}^- = \frac{U_{dyn,min} - U_r}{U_r} \times 100 = \frac{(334 - 480)}{480} \times 100 = 30,4 \text{ \%}$$

Figure A.3 — Generator transient voltage versus time for sudden load increase