

# Reciprocating internal combustion engine driven alternating current generating sets —

## Part 5: Specification for generating sets

UDC 621.313.12.025-843:001.4

# Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Machinery and Components Standards Policy Committee (MCE/-) to Technical Committee MCE/14, upon which the following bodies were represented:

- Association of Consulting Engineers
- British Railways Board
- Ministry of Defence
- Society of Motor Manufacturers and Traders Ltd.

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- Agricultural Engineers' Association
- Association of Manufacturers of Power Generating Systems and Association of British Generating Set Manufacturers
- British Industrial Truck Association
- Department of Transport
- Health and Safety Executive
- Marine Engine and Equipment Manufacturers' Association

This British Standard, having been prepared under the direction of the Machinery and Components Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 15 October 1993

© BSI 08-1999

The following BSI references relate to the work on this standard:  
Committee reference MCE/14  
Draft for comment 89/73538 DC

ISBN 0 580 22569 0

## Amendments issued since publication

| Amd. No. | Date | Comments |
|----------|------|----------|
|          |      |          |
|          |      |          |
|          |      |          |
|          |      |          |

# Contents

|                                                                                                                                                                                  | Page               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| Committees responsible                                                                                                                                                           | Inside front cover |
| National foreword                                                                                                                                                                | ii                 |
| 1 Scope                                                                                                                                                                          | 1                  |
| 2 Normative references                                                                                                                                                           | 1                  |
| 3 Symbols                                                                                                                                                                        | 1                  |
| 4 Other regulations and additional requirements                                                                                                                                  | 4                  |
| 5 Frequency characteristics                                                                                                                                                      | 4                  |
| 6 Overfrequency characteristics                                                                                                                                                  | 7                  |
| 7 Voltage characteristics                                                                                                                                                        | 7                  |
| 8 Sustained short circuit current                                                                                                                                                | 10                 |
| 9 Factors affecting generating set performance                                                                                                                                   | 10                 |
| 10 Cyclic irregularity                                                                                                                                                           | 11                 |
| 11 Starting characteristics                                                                                                                                                      | 11                 |
| 12 Stop time characteristics                                                                                                                                                     | 12                 |
| 13 Parallel operation                                                                                                                                                            | 13                 |
| 14 Rating plates                                                                                                                                                                 | 16                 |
| 15 Further factors influencing generating set performance                                                                                                                        | 16                 |
| 16 Operating limit values for performance classes                                                                                                                                | 19                 |
| Figure 1 — Frequency/power characteristic, range of frequency setting                                                                                                            | 22                 |
| Figure 2 — Frequency/power characteristic, deviation from the linear curve                                                                                                       | 23                 |
| Figure 3 — Steady-state frequency band                                                                                                                                           | 23                 |
| Figure 4 — Dynamic frequency behaviour                                                                                                                                           | 24                 |
| Figure 5 — Transient voltage characteristics without quadrature-current compensation voltage droop                                                                               | 24                 |
| Figure 6 — Guide values for maximum possible sudden power increases as a function of brake mean effective pressure, $p_{me}$ , at declared power (four stroke engines)           | 25                 |
| Figure 7 — Guide values for maximum possible sudden power increases as a function of brake mean effective pressure, $p_{me}$ , at declared power (two-stroke high-speed engines) | 25                 |
| Figure 8 — Starting characteristics                                                                                                                                              | 26                 |
| Figure 9 — Power sharing in parallel running                                                                                                                                     | 27                 |
| Figure 10 — Stopping characteristics                                                                                                                                             | 27                 |
| Figure 11 — Sinusoidal voltage modulation of an amplitude $a_{10}$ and a regular frequency of 10 Hz                                                                              | 28                 |
| Figure 12 — Curve $g_f = \frac{a_{10}}{a_f}$ giving equivalent perceptibility due to change in brightness                                                                        | 28                 |
| Figure 13 — Example of a rating plate for an RIC engine driven generating set                                                                                                    | 29                 |
| Table 1 — Examples of active power sharing                                                                                                                                       | 14                 |
| Table 2 — Examples of reactive power sharing                                                                                                                                     | 15                 |
| Table 3 — Operating limit values                                                                                                                                                 | 20                 |
| List of references                                                                                                                                                               | Inside back cover  |

# National foreword

This Part of BS 7698 has been prepared under the direction of the Machinery and Components Standards Policy Committee. It is identical with ISO 8528-5:1993 *Reciprocating internal combustion engine driven alternating current generating sets — Part 5: Generating sets*, published by the International Organization for Standardization (ISO).

BS 7698 consists of the following Parts, which are identical with the corresponding Parts of ISO 8528:

- *Part 1: Specification for application, ratings and performance*;
- *Part 2: Specification for engines*;
- *Part 3: Specification for alternating current generators for generating sets*;
- *Part 4: Specification for controlgear and switchgear*;
- *Part 5: Specification for generating sets*;
- *Part 6: Test methods*;
- *Part 7: Technical declarations for specification and design*<sup>1)</sup>.

Further Parts of ISO 8528 are in preparation. It is envisaged that when these Parts of ISO 8528 are published they will be implemented as dual-numbered Parts of BS 7698.

### Cross-references

| International Standard | Corresponding British Standard                                                                         |
|------------------------|--------------------------------------------------------------------------------------------------------|
|                        | BS 5514 <i>Reciprocating internal combustion engines: performance</i>                                  |
| ISO 3046-4:1978        | Part 4:1979 <i>Speed governing</i><br>(Identical)                                                      |
| ISO 3046-5:1978        | Part 5:1979 <i>Torsional vibrations</i><br>(Identical)                                                 |
|                        | BS 7698 <i>Reciprocating internal combustion engine driven alternating current generating sets</i>     |
| ISO 8528-1:1993        | Part 1:1993 <i>Specification for application, ratings and performance</i><br>(Identical)               |
| ISO 8528-2:1993        | Part 2:1993 <i>Specification for engines</i><br>(Identical)                                            |
| ISO 8528-3:1993        | Part 3:1993 <i>Specification for alternating current generators for generating sets</i><br>(Identical) |

The Technical Committee has reviewed the provisions of IEC 34-1:1983 to which normative reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

**Compliance with a British Standard does not of itself confer immunity from legal obligations.**

### Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 30, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

<sup>1)</sup> In preparation.

## 1 Scope

This part of ISO 8528 defines terms and specifies design 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 (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 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 3046-4:1978, *Reciprocating internal combustion engines — Performance — Part 4: Speed governing*.

ISO 3046-5:1978, *Reciprocating internal combustion engines — Performance — Part 5: Torsional vibrations*.

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

ISO 8528-2:1993, *Reciprocating internal combustion engine driven alternating current generating sets — Part 2: Engines*.

ISO 8528-3:1993, *Reciprocating internal combustion engine driven alternating current generating sets — Part 3: Alternating current generators for generating sets*.

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

## 3 Symbols

NOTE 1 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 through-out.

|             |                                                      |
|-------------|------------------------------------------------------|
| $f_d$       | Dynamic frequency (frequency deviation)              |
| $f_{d,max}$ | Maximum transient frequency rise                     |
| $f_{d,min}$ | Maximum transient frequency drop                     |
| $f_{do}$    | Operating frequency of overfrequency limiting device |
| $f_{ds}$    | Setting frequency of overfrequency limiting device   |
| $f_l$       | No-load frequency                                    |
| $f_{l,r}$   | Rated no-load frequency                              |
| $f_{max}$   | Maximum permissible frequency                        |
| $f_r$       | Declared frequency (rated frequency)                 |
| $f_{l,max}$ | Maximum no-load frequency                            |
| $f_{l,min}$ | Minimum no-load frequency                            |
| $f_{arb}$   | Frequency at actual power                            |
| $f_{ov}$    | Overload frequency                                   |

|                   |                                                     |
|-------------------|-----------------------------------------------------|
| $\hat{f}$         | Width of frequency oscillation                      |
| $I_k$             | Sustained short-circuit current                     |
| $t$               | Time                                                |
| $t_a$             | Total stopping time                                 |
| $t_b$             | Load pick-up readiness time                         |
| $t_c$             | Off-load run-on time                                |
| $t_d$             | Run-down time                                       |
| $t_e$             | Load pick-up time                                   |
| $t_{f,de}$        | Frequency recovery time after load decrease         |
| $t_{f,in}$        | Frequency recovery time after load increase         |
| $t_g$             | Total run-up time                                   |
| $t_h$             | Run-up time                                         |
| $t_i$             | On-load run-on time                                 |
| $t_p$             | Start preparation time                              |
| $t_s$             | Load switching time                                 |
| $t_u$             | Interruption time                                   |
| $t_U$             | Voltage recovery time                               |
| $t_{U,de}$        | Voltage recovery time after load decrease           |
| $t_{U,in}$        | Voltage recovery time after load increase           |
| $t_v$             | Start delay time                                    |
| $t_z$             | Cranking time                                       |
| $t_0$             | Pre-lubricating time                                |
| $v_f$             | Rate of change of frequency setting                 |
| $v_U$             | Rate of change of voltage setting                   |
| $U_{s,do}$        | Downward adjustable voltage                         |
| $U_{s,up}$        | Upward adjustable voltage                           |
| $U_r$             | Rated voltage                                       |
| $U_{rec}$         | Recovery voltage                                    |
| $U_s$             | Set voltage                                         |
| $U_{st,max}$      | Maximum steady-state voltage deviation              |
| $U_{st,min}$      | Minimum steady-state voltage deviation              |
| $U_o$             | No-load voltage                                     |
| $U_{dyn,max}$     | Maximum upward transient voltage on load decrease   |
| $U_{dyn,min}$     | Minimum downward transient voltage on load increase |
| $\hat{U}_{max,s}$ | Maximum peak value of set voltage                   |
| $\hat{U}_{min,s}$ | Minimum peak value of set voltage                   |

|                               |                                                                     |
|-------------------------------|---------------------------------------------------------------------|
| $\hat{U}_{\text{mean,s}}$     | Average value of the maximum and minimum peak value of set voltage  |
| $\hat{U}_{\text{mod,s}}$      | Voltage modulation                                                  |
| $\hat{U}_{\text{mod,s,max}}$  | Maximum peak of voltage modulation                                  |
| $\hat{U}_{\text{mod,s,min}}$  | Minimum peak of voltage modulation                                  |
| $\hat{U}$                     | Width of voltage oscillation                                        |
| $\Delta f_{\text{neg}}$       | Downward frequency deviation from linear curve                      |
| $\Delta f_{\text{pos}}$       | Upward frequency deviation from linear curve                        |
| $\Delta f$                    | Steady-state frequency tolerance band                               |
| $\Delta f_{\text{c}}$         | Frequency deviation from a linear curve                             |
| $\Delta f_{\text{s}}$         | Range of frequency setting                                          |
| $\Delta f_{\text{s,do}}$      | Downward range of frequency setting                                 |
| $\Delta f_{\text{s,up}}$      | Upward range of frequency setting                                   |
| $\Delta U$                    | Steady-state voltage tolerance band                                 |
| $\Delta U_{\text{s}}$         | Range of voltage setting                                            |
| $\Delta U_{\text{s,do}}$      | Downward range of voltage setting                                   |
| $\Delta U_{\text{s,up}}$      | Upward range of voltage setting                                     |
| $\Delta \delta f_{\text{st}}$ | Frequency/power characteristic deviation                            |
| $\alpha_U$                    | Related steady-state voltage tolerance band                         |
| $\alpha_f$                    | Related frequency tolerance band                                    |
| $\beta_f$                     | Steady-state frequency band                                         |
| $\delta f_{\text{d}}$         | Transient frequency difference (from initial frequency) [see 5.3.3] |
| $\delta U_{\text{dyn}}$       | Transient voltage deviation                                         |
| $\delta f_{\text{dyn}}$       | Transient frequency deviation (from rated frequency) [see 5.3.4]    |
| $\delta f_{\text{s}}$         | Related range of frequency setting                                  |
| $\delta f_{\text{s,do}}$      | Related downward range of frequency setting                         |
| $\delta f_{\text{s,up}}$      | Related upward range of frequency setting                           |
| $\delta f_{\text{st}}$        | Frequency droop                                                     |
| $\delta_{\text{QCC}}$         | Grade of quadrature-current compensation droop                      |
| $\delta_{\text{s}}$           | Cyclic irregularity                                                 |
| $\delta f_{\text{lim}}$       | Overfrequency setting ratio                                         |
| $\delta U_{\text{st}}$        | Steady-state voltage deviation                                      |
| $\delta U_{\text{s}}$         | Related range of voltage setting                                    |
| $\delta U_{\text{s,do}}$      | Related downward range of voltage setting                           |
| $\delta U_{\text{s,up}}$      | Related upward range of voltage setting                             |
| $\delta U_{2,0}$              | Voltage unbalance                                                   |

## 4 Other regulations and additional requirements

**4.1** For a.c. 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. generating sets 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 Frequency characteristics

The steady-state frequency characteristics depend mainly on the performance of the engine speed governor.

The dynamic frequency characteristics, i.e. the response to load changes, depend on the combined behaviour of all the system components (for example on the engine torque characteristics, including type of turbocharging system, the characteristics of the load, the inertias, the damping, etc.; see **5.3**) and thus on the individual design of all the relevant components. The dynamic frequency behaviour of the generating set may be related directly to the generator speed.

Terms, symbols and definitions for frequency characteristics are given in **5.1** to **5.3**.

### 5.1 Steady-state frequency behaviour

| No.   | Term                                     | Symbol                 | Definition                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------|------------------------------------------|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 5.1.1 | Frequency droop                          | $\delta f_{st}$        | Frequency difference between rated no-load frequency and the rated frequency $f_r$ at declared power expressed as a percentage of rated frequency at fixed frequency setting (see Figure 1):<br>$\delta f_{st} = \frac{f_{i,r} - f_r}{f_r} \times 100$                                                                                                                                                                                                 |
| 5.1.2 | Frequency/power characteristic curve     | —                      | Curve of steady-state frequencies in the power range between no-load and declared power, plotted against active power of the generating set (see Figure 2).                                                                                                                                                                                                                                                                                            |
| 5.1.3 | Frequency/power characteristic deviation | $\Delta \delta f_{st}$ | 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):<br>$\Delta \delta f_{st} = \frac{\Delta f}{f_r} \times 100$                                                                                                                                                                                                   |
| 5.1.4 | Steady-state frequency band              | $\beta_f$              | Envelope width oscillation $\hat{f}$ of generating set frequency at constant power around a mean value, expressed as a percentage of rated frequency:<br>$\beta_f = \frac{\hat{f}}{f_r} \times 100$<br>The maximum value of $\beta_f$ occurring in the range between 20 % power and declared power shall be stated.<br>For powers below 20 %, the steady-state frequency band may show higher values (see Figure 3), but should allow synchronization. |

## 5.2 Frequency-setting parameters

| No.     | Term                                        | Symbol                   | Definition                                                                                                                                                                                         |
|---------|---------------------------------------------|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 5.2.1   | Range of frequency setting                  | $\Delta f_s$             | The range between the highest and lowest adjustable no-load frequencies (see Figure 1):<br>$\Delta f_s = f_{i,\max} - f_{i,\min}$                                                                  |
|         | Related range of frequency setting          | $\delta f_s$             | Range of frequency setting, expressed as a percentage of rated frequency:<br>$\delta f_s = \frac{f_{i,\max} - f_{i,\min}}{f_r} \times 100$                                                         |
| 5.2.1.1 | Downward range of frequency setting         | $\Delta f_{s,\text{do}}$ | Range between the declared no-load frequency and the lowest adjustable no-load frequency (see Figure 1):<br>$\Delta f_{s,\text{do}} = f_{i,r} - f_{i,\min}$                                        |
|         | Related downward range of frequency setting | $\delta f_{s,\text{do}}$ | Range of downward frequency setting expressed as a percentage of the rated frequency:<br>$\delta f_{s,\text{do}} = \frac{f_{i,r} - f_{i,\min}}{f_r} \times 100$                                    |
| 5.2.1.2 | Upward range of frequency setting           | $\Delta f_{s,\text{up}}$ | Range between the highest adjustable no-load frequency and the declared no-load frequency (see Figure 1):<br>$\Delta f_{s,\text{up}} = f_{i,\max} - f_{i,r}$                                       |
|         | Related upward range of frequency setting   | $\delta f_{s,\text{up}}$ | Range of upward frequency setting expressed as a percentage of the rated frequency:<br>$\delta f_{s,\text{up}} = \frac{f_{i,\max} - f_{i,r}}{f_r} \times 100$                                      |
| 5.2.2   | Rate of change of frequency setting         | $v_f$                    | Rate of change of frequency setting under remote control expressed as a percentage of related range of frequency setting per second:<br>$v_f = \frac{(f_{i,\max} - f_{i,\min})/f_r}{t} \times 100$ |

## 5.3 Dynamic frequency behaviour (see Figure 4)

| No.   | Term                                                    | Symbol       | Definition                                                                                                                                     |
|-------|---------------------------------------------------------|--------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| 5.3.1 | Maximum transient frequency rise (over-shoot frequency) | $f_{d,\max}$ | Maximum frequency which occurs on sudden change from a higher to a lower power.<br>NOTE The symbol is different from that given in ISO 3046-4. |
| 5.3.2 | Maximum transient frequency drop (undershoot frequency) | $f_{d,\min}$ | Minimum frequency which occurs on sudden change from a lower to a higher power.<br>NOTE The symbol is different from that given in ISO 3046-4. |

| No.   | Term                                                                                                                | Symbol                     | Definition                                                                                                                                                                                                                                                                                                                                                                         |
|-------|---------------------------------------------------------------------------------------------------------------------|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 5.3.3 | Transient frequency difference (from initial frequency) on load increase (–) and on load decrease (+), respectively | $\delta f_d$               | Temporary frequency difference 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:                                                                                                                                                               |
|       |                                                                                                                     | $\delta f_d^-$             | $\delta f_d^- = \frac{f_{d,\min} - f_{arb}}{f_r} \times 100$                                                                                                                                                                                                                                                                                                                       |
|       |                                                                                                                     | $\delta f_d^+$             | $\delta f_d^+ = \frac{f_{d,\max} - f_{arb}}{f_r} \times 100$<br><br>(A minus sign relates to an undershoot after a load increase, and a plus sign to an overshoot after a load decrease.)<br><br>NOTE The operating limit values given in 16.6 and 16.7 are valid only for $f_{arb} = f_i$ in the case of increasing load, and for $f_{arb} = f_r$ in the case of decreasing load. |
| 5.3.4 | Transient frequency deviation (from rated frequency) on load increase (–) and on load decrease (+), respectively    | $\delta f_{dyn}$           | Temporary frequency difference between undershoot (or overshoot) frequency and rated frequency during the governing process following a sudden load change, relative to rated frequency, expressed as a percentage:                                                                                                                                                                |
|       |                                                                                                                     | $\delta f_{dyn}^-$         | $\delta f_{dyn}^- = \frac{f_{d,\min} - f_r}{f_r} \times 100$                                                                                                                                                                                                                                                                                                                       |
|       |                                                                                                                     | $\delta f_{dyn}^+$         | $\delta f_{dyn}^+ = \frac{f_{d,\max} - f_r}{f_r} \times 100$<br><br>Transient frequency deviation shall therefore be in the allowable consumer frequency tolerance and shall be particularly stated.<br><br>(A minus sign relates to an undershoot after a load increase, and a plus sign to an overshoot after a load decrease.)                                                  |
| 5.3.5 | Frequency recovery time                                                                                             | $t_{f, in}$<br>$t_{f, de}$ | The time interval between the departure from the steady-state frequency band after a sudden specified load change and the permanent re-entry of the frequency into the specified steady-state frequency tolerance band (see Figure 4).                                                                                                                                             |
| 5.3.6 | Steady-state frequency tolerance band                                                                               | $\Delta f$                 | 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.                                                                                                                                                                                                                     |
|       | Related frequency tolerance band                                                                                    | $\alpha_f$                 | This tolerance band usually is expressed as a percentage of the rated frequency:<br><br>$\alpha_f = \frac{\Delta f}{f_r} \times 100$                                                                                                                                                                                                                                               |

## 6 Overfrequency characteristics

The terms, symbols and definitions for overfrequency characteristics are given in 6.1 to 6.4.

| No. | Term                                                              | Symbol                  | Definition                                                                                                                                                                                                                                                             |
|-----|-------------------------------------------------------------------|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6.1 | Maximum permissible frequency <sup>a</sup>                        | $f_{\max}$              | A frequency specified by the generating set manufacturer which lies a safe amount below the frequency limit (see also ISO 8528-2:1993, 6.5.1).                                                                                                                         |
| 6.2 | Setting frequency of overfrequency limiting device                | $f_{\text{ds}}$         | The frequency of the generating set, the exceeding of which activates the overfrequency limiting device.<br>NOTE In practice, instead of the value for the setting frequency, the value for the permissible overfrequency is stated (see also ISO 8528-2:1993, 6.5.2). |
| 6.3 | Overfrequency setting ratio                                       | $\delta f_{\text{lim}}$ | Difference between the setting frequency of the overfrequency limiting device and the rated frequency divided by the rated frequency, expressed as a percentage:<br>$\delta f_{\text{lim}} = \frac{f_{\text{ds}} - f_r}{f_r} \times 100$                               |
| 6.4 | Operating frequency of overfrequency limiting device <sup>b</sup> | $f_{\text{do}}$         | The frequency at which, for a given setting frequency, the overfrequency limiting device starts to operate.                                                                                                                                                            |

<sup>a</sup> The frequency limit (see also ISO 8528-2:1993, Figure 3) is the calculated frequency which the engine and generator of the generating set may sustain without risk of damage.

<sup>b</sup> For a given generating set the operating frequency depends on the total inertia of the generating set and the design of the overfrequency protection system.

## 7 Voltage characteristics (see Figure 5)

The generating set voltage characteristics are determined mainly by the inherent design of the a.c. generator and the performance of the automatic voltage regulator. Both the steady-state and the transient frequency characteristics may also influence the generator voltage.

The terms, symbols and definitions of voltage characteristics are given in 7.1 to 7.3.

### 7.1 Steady-state voltage behaviour

| No.   | Term                           | Symbol                 | Definition                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------|--------------------------------|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7.1.1 | Rated voltage                  | $U_r$                  | Line-to-line voltage at the terminals of the generator at rated frequency and at rated output.<br>NOTE Rated voltage is the voltage assigned by the manufacturer for operating and performance characteristics.                                                                                                                                                                                                   |
| 7.1.2 | Set voltage                    | $U_s$                  | Line-to-line voltage for defined operation selected by adjustment.                                                                                                                                                                                                                                                                                                                                                |
| 7.1.3 | No-load Voltage                | $U_0$                  | Line-to-line voltage at the terminals of the generator at rated frequency and no-load.                                                                                                                                                                                                                                                                                                                            |
| 7.1.4 | Steady-state voltage deviation | $\delta U_{\text{st}}$ | Maximum deviation from the set 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. The steady-state voltage deviation is expressed as a percentage of the rated voltage:<br>$\delta U_{\text{st}} = \pm \frac{U_{\text{st,max}} - U_{\text{st,min}}}{2U_r} \times 100$ |
| 7.1.5 | Voltage unbalance              | $\delta U_{2,0}$       | Ratio of the negative-sequence or the zero-sequence voltage components to the positive-sequence voltage components at no-load. Voltage unbalance is expressed as a percentage of rated voltage.                                                                                                                                                                                                                   |