

BS EN 61362:2012



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Guide to specification of hydraulic turbine governing systems

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National foreword

This British Standard is the UK implementation of EN 61362:2012. It is identical to IEC 61362:2012. It supersedes BS EN 61362:1998 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MCE/15, Hydraulic turbines.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English version

Guide to specification of hydraulic turbine governing systems (IEC 61362:2012)

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de régulation des turbines hydrauliques
(CEI 61362:2012)

Leitfaden zur Spezifikation der
Regeleinrichtung von Wasserturbinen
(IEC 61362:2012)

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Foreword

The text of document 4/270/FDIS, future edition 2 of IEC 61362, prepared by IEC/TC 4 "Hydraulic turbines" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61362:2012.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2013-02-28
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2015-05-25

This document supersedes EN 61362:1998.

EN 61362:2012 includes the following significant technical changes with respect to EN 61362:1998:

This technical revision takes into account the experience with the guide during the last decade as well as the progress in the state of the art of the underlying technologies.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 61362:2012 was approved by CENELEC as a European Standard without any modification.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-351	2006	International Electrotechnical Vocabulary (IEV) - Part 351: Control technology	-	-
IEC 60068-2-6	2007	Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)	EN 60068-2-6	2008
IEC 60068-2-27	2008	Environmental testing - Part 2-27: Tests - Test Ea and guidance: Shock	EN 60068-2-27	2009
IEC 60308	2005	Hydraulic turbines - Testing of control systems	EN 60308	2005
IEC 61000-4-1	2006	Electromagnetic compatibility (EMC) - Part 4-1: Testing and measurement techniques - Overview of IEC 61000-4 series	EN 61000-4-1	2007
CISPR 11 (mod)	2009	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement	EN 55011	2009
ISO 3448	1992	Industrial liquid lubricants - ISO viscosity classification	-	-

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INTRODUCTION

While a standard for the testing of hydraulic turbine governing systems had been existing for a very long time (IEC 60308 published in 1970)¹, a guide for the specification of hydraulic turbine governing systems was missing until 1998. The need for such a guide became more and more urgent with the fast development and the new possibilities especially of the digital components of the governor.

The current second edition of the guide takes into account the experience with the guide during the last decade as well as the progress in the state of the art of the underlying technologies.

While the first edition was written more or less as a supplement to the already existing guide for testing, the objective of the second edition is to be the leading guide with respect to turbine governing systems.

¹ IEC 60308:1970, *International code for testing of speed governing systems for hydraulic turbines*. This publication was withdrawn and replaced by IEC 60308:2005.

GUIDE TO SPECIFICATION OF HYDRAULIC TURBINE GOVERNING SYSTEMS

1 Scope

This International Standard includes relevant technical data necessary to describe hydraulic turbine governing systems and to define their performance. It is aimed at unifying and thus facilitating the selection of relevant parameters in bidding specifications and technical bids. It will also serve as a basis for setting up technical guarantees.

The scope of this standard is restricted to the turbine governing level. Additionally some remarks about the control loops of the plant level and about primary and secondary frequency control (see also Annex B) are made for better understanding without making a claim to be complete.

Important topics covered by the guide are:

- speed, power, water level, opening and flow (discharge) control for reaction and impulse-type turbines including double regulated machines;
- means of providing actuating energy;
- safety devices for emergency shutdown, etc.

To facilitate the setting up of specifications, this guide also includes data sheets, which are to be filled out by the customer and the supplier in the various stages of the project and the contract.

Acceptance tests, specific test procedures and guarantees are outside the scope of the guide; those topics are covered by IEC 60308.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-351:2006, *International Electrotechnical Vocabulary – Part 351: Control technology*

IEC 60068-2-6:2007, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-27:2008, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60308:2005, *Hydraulic turbines – Testing of control systems*

IEC 61000-4-1:2006, *Electromagnetic compatibility (EMC) – Part 4-1: Testing and measurement techniques – Overview of IEC 61000-4 series*

CISPR 11:2009, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

ISO 3448:1992, *Industrial liquid lubricants – ISO viscosity classification*

3 Terms, definitions, symbols and units

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

NOTE This guide uses as far as possible the terms and definitions of IEC 60050-351. For clarification, the simplified differential equations and transfer functions of the idealized PID-controllers as used in this guide are given in Annex A. Additional reference is made to IEC 60308 for purposes of tests of governing systems.

3.1 General terms and definitions

3.1.1

turbine governing system

technical equipment governing the opening (guide vane, runner blade, needle, deflector position) of hydraulic turbines

Note 1 to entry At the present state of the art, the turbine governing system consists of an oil hydraulic and an electronic part, the "oil hydraulic governor" and the "electronic governor".

3.2 Terms and definitions related to control levels and control modes

3.2.1

turbine governing level

control functions directly related to the governing system of a single turbine

Note 1 to entry The following control modes are related to the turbine governing level:

- speed control;
- power output control;
- water level control;
- opening control;
- flow control (the term flow used in this guide has the same meaning as the term discharge).

Note 2 to entry The scope of this standard is restricted to the turbine governing level. Additionally some remarks about the control loops of the plant level and about primary and secondary frequency control (see Annex B) are made for better understanding without making a claim to be complete.

3.2.2

unit control level

control functions directly related to the overall control of a single unit (turbine, generator, unit auxiliaries) including turbine governing, voltage regulation, start-stop-sequencing etc.

3.2.3

plant control level

control functions related to the overall control of a whole plant including the control of several units

Note 1 to entry In automatic unit and plant control operation, the turbine governing system gets its modes and setpoints from the unit and plant control level.

3.2.4

grid control level

control functions related to the overall control of the grid as a whole

Note 1 to entry If required the turbine governing system participates in grid control over the primary and/or secondary frequency control mode (see Annex B).

3.3 Terms and definitions from control theory

3.3.1

differential equation

equation describing the dynamic system behavior in the time-domain, as shown in Annex A

3.3.2

transient response

system response (output) to a step change of the input

3.3.3

frequency response

dynamic response of the linearized system to a sinusoidal change of the input signal derived from the differential equation by applying the Fourier transformation

3.3.4

transfer function

dynamic response of the linearized system to an arbitrary variation of the input signal derived from the differential equation by applying the Laplace transformation

3.4 Subscripts and prefixes

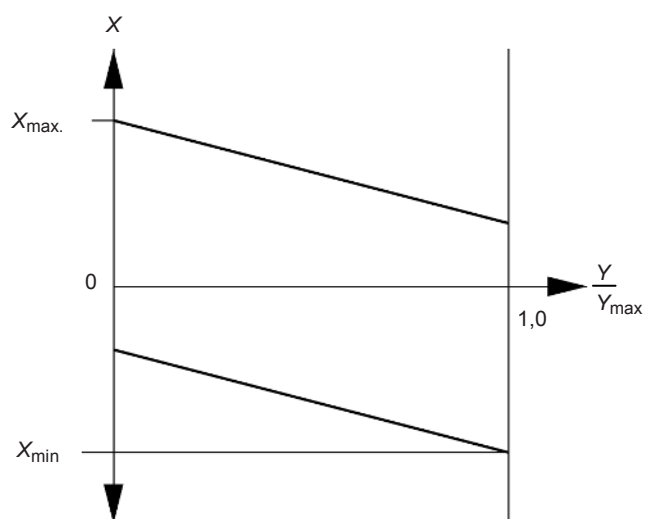
Sub-clause	Term	Definition	Symbol	Unit
3.4.1	rated	subscript indicating the rated operation point of the system	r	–
3.4.2	maximum minimum	subscript indicating maximum or minimum values of any term	max. min.	–
3.4.3	deviation	deviation of any term from a steady-state value	Δ	–
3.4.4	guide vanes	subscript associating a quantity to guide vane position	ga	–
3.4.5	runner	subscript associating a quantity to runner blade position	ru	–
3.4.6	nozzle	subscript associating a quantity to needle position	ne	–
3.4.7	Deflector	subscript associating a quantity to deflector position	de	–

3.5 Terms and definitions related to the plant and the machines

Sub-clause	Term	Definition	Symbol	Unit
3.5.1	specific energy of machine	specific energy of hydraulic water available between the high- and low-pressure side sections of the machine	E	$\text{J} \cdot \text{kg}^{-1}$
3.5.2	turbine head	$H = E/g$ definition of E , see 3.5.1 g = acceleration due to gravity = $9,81 \text{ m} \cdot \text{s}^{-2}$ (at sea level)	H	m
3.5.3	flow	volume of water per unit time flowing through any section in the system	Q	$\text{m}^3 \cdot \text{s}^{-1}$
3.5.4	rotational speed	number of revolutions per unit time	n	s^{-1} ^a
3.5.5	frequency	cycles per second	f	Hz
3.5.6	generator power output	generator power measured at generator terminals	P_G	W
3.5.7	moment of inertia of mass	moment of inertia for calculation of fly-wheel effect. $I = M D^2/4 = MR^2$ (M = mass, D = diameter of gyration, R = radius of gyration)	I	$\text{kg} \cdot \text{m}^2$
^a The unit rpm is frequently used.				

3.6 Terms and definitions relating to the governing system

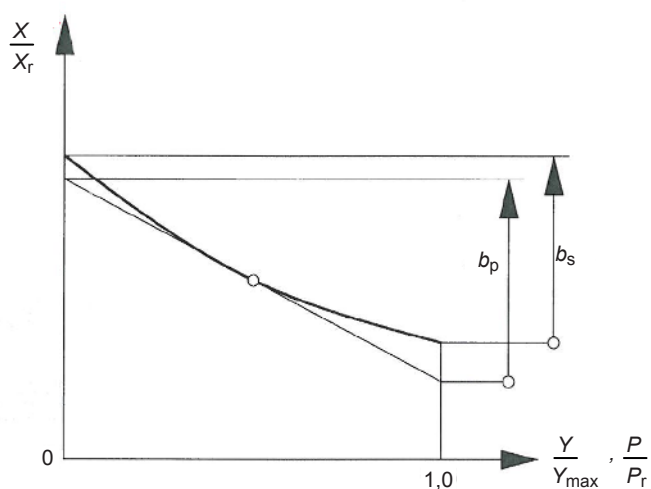
Sub-clause	Term	Definition	Symbol	Unit
3.6.1	controlled variable	variable which has to be controlled as speed n , output P_G , water level h , servoposition opening y , flow Q : – absolute, dimensional value – relative deviation from a steady-state value, $x = \Delta X/X_r$ rotational speed power output water level opening flow	X x x_n x_p x_h x_y x_q	var. – – – – – –
3.6.2	command signal	a signal which can be set by an external adjustment: – absolute, dimensional value – relative deviation from a steady-state value, $c = \Delta C/C_r$ rotational speed power output water level opening flow	C c c_n c_p c_h c_y c_q	var. – – – – – –
3.6.3	servomotor stroke	stroke of the main servomotor which moves the guide vane/runner blades/needles/deflectors – absolute value – relative deviation from a steady-state value, $y = \Delta Y/Y_{\max}$ Note 1 to entry The effective max. servomotor stroke $Y_{\max}$ has to be defined between customer and supplier.	Y y	m –
3.6.4	controlled variable range	adjusting range for the setting of a controlled variable (rotational speed in speed control, or water level in level control) with an average setting of the permanent droop, if applicable (see 3.6.8 and 5.3.2): – maximum value of the controlled variable for $Y/Y_{\max} = 0$ – minimum value of the controlled variable for $Y/Y_{\max} = 1,0$ SEE: Figure 1	$X_{\max}$ $X_{\min}$	– –



IEC 383/12

Figure 1 – Controlled variable range

Sub-clause	Term	Definition	Symbol	Unit
3.6.5	electronic governor output signal	output signal at the electronic governor = input signal of the following servo-positioner Relative deviation from a steady-state value	s	–
3.6.6	output signal of a pilot servo-positioner	output signal of a pilot servo-positioner = input signal of the following main servo-positioner Relative deviation from a steady-state value	s_v	–
3.6.7	droop graph	a graph showing the relationship between a relative controlled variable (speed n/n_r , or in some cases water level H/H_r) as a function of the relative servomotor stroke or the relative power output under steady-state conditions SEE: Figure 2		



IEC 384/12

Figure 2 – Permanent droop

Sub-clause	Term	Definition	Symbol	Unit
3.6.8	permanent droop	slope of the droop graph (see Figure 2): – at a specific point of operation, – defined by the end values of the droop graph	b_p b_s	% %
3.6.9	proportional action coefficient^a	proportional amplification, defined by the step response of an idealized PID-controller with $b_p = 0$, $K_D = 0$ and input signal $x = 1$ SEE: Figure 3	K_p	–
^a In accordance with IEC 60050-351.				

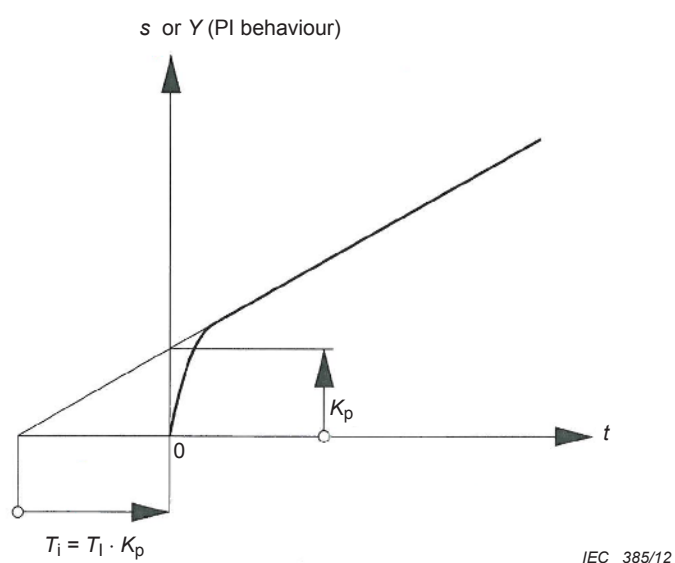


Figure 3 – Proportional action coefficient and integral action time

Sub-clause	Term	Definition	Symbol	Unit
3.6.10	integral action time^a	time constant of the integral action of an idealized PID-controller. The reset time T_i in parallel structured PID-controllers is defined by $T_i = T_1 \cdot K_p$ and K_p/T_i corresponds to the slope of the controller step response curve with $b_p = 0$, $K_D = 0$ and input signal $x = 1$ SEE: Figure 3	T_i	s
3.6.11	derivative^b action time	time constant of the derivative action of an idealized PID-controller. The transfer function ($T_D \cdot p$) can practically be realized only approximately by a DT_1 transfer function, i.e. a derivative term multiplied by a first-order lag element ^c : $\frac{K_{1D} \cdot T_{1D} \cdot p}{1 + T_{1D} \cdot p}$ The step response of such a transfer function of an idealized PID-controller, the proportional and integral term being zero, is shown in Figure 4. For small values of T_{1D} the following approximation applies: $T_D = K_{1D} \cdot T_{1D}$	T_D	s

^a Reset time can also be defined by $T_i = K_p/K_I$ with integral action coefficient $K_I = 1/T_i$ (see IEC 60050-351).

^b Rate time is defined in parallel structured PID-controllers by $T_d = K_D/K_p$, with derivative action coefficient $K_D = T_D$ (see IEC 60050-351).

^c Realization also by second-order lag element possible.

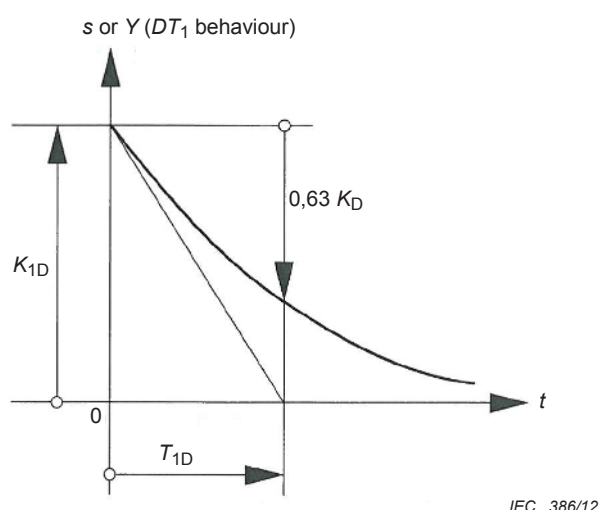
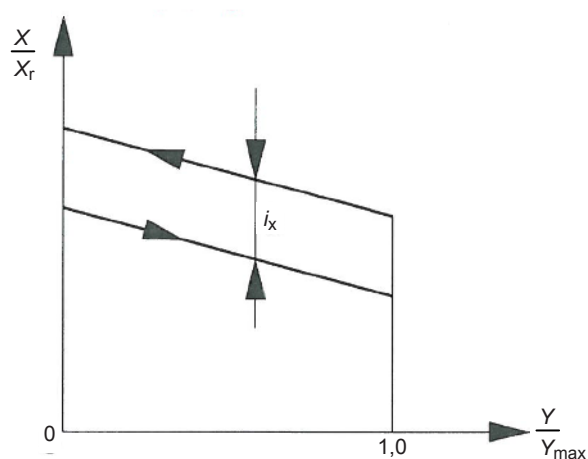


Figure 4 – Derivative time constant

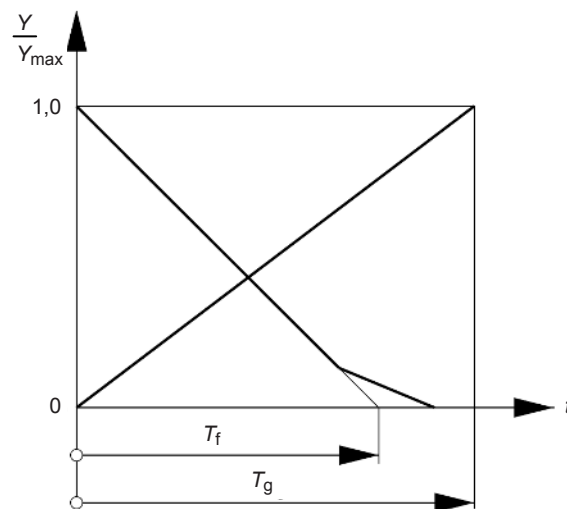
Sub-clause	Term	Definition	Symbol	Unit
3.6.12	dead band	the maximum band between two values inside of which the variation of the controlled variable does not cause any governing action SEE: Figure 5	i_x	–
3.6.13	insensitivity	one-half of the dead band	$i_x/2$	–



IEC 387/12

Figure 5 – Dead band

Sub-clause	Term	Definition	Symbol	Unit
3.6.14	minimum servo-motor opening/closing time	the opening/closing time for one full servo-motor stroke at maximum velocity, cushioning times disregarded SEE: Figure 6 Note 1 to entry Minimum servomotor opening and closing times are the result of hydraulic transient calculations.	T_g, T_f	s

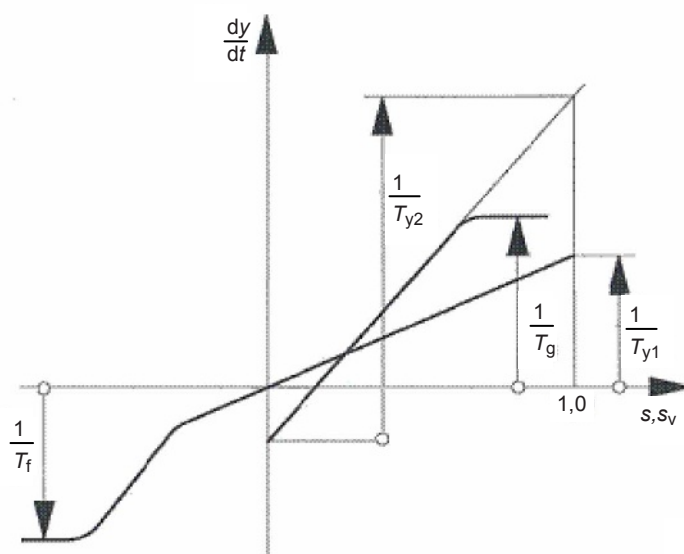


IEC 388/12

NOTE In case of stepped opening/closing velocities a diagram may be provided.

Figure 6 – Minimum servomotor opening/closing time

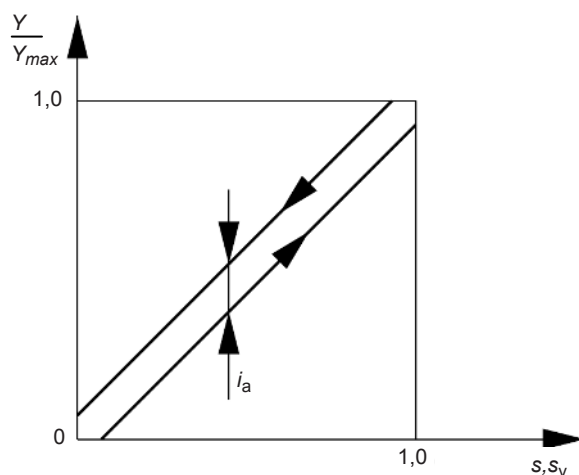
Sub-clause	Term	Definition	Symbol	Unit
3.6.15	time constant of the servo-positioner	the reciprocal value of the slope of the curve showing the servomotor velocity dy/dt as a function of the relative deviation of the position of the control valve, s, s_v , from the zero position related to $s, s_v = 1$ ($s, s_v = 1$ theoretical relative spool stroke in the absence of feedback) SEE: Figure 7	T_y	s



IEC 389/12

Figure 7 – Time constant of the servo-positioner

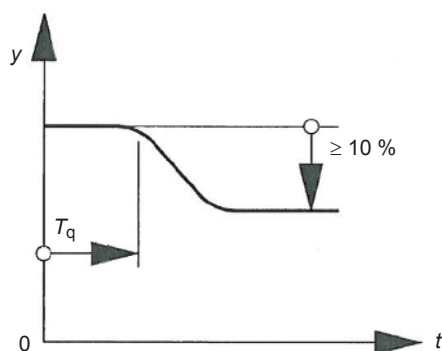
Sub-clause	Term	Definition	Symbol	Unit
3.6.16	servo-positioner inaccuracy	the maximum possible change in the servomotor position which can occur for a given constant value of the input signal of the servo-positioner SEE: Figure 8	i_a	–



IEC 390/12

Figure 8 – Servo-positioner inaccuracy

Sub-clause	Term	Definition	Symbol	Unit
3.6.17	control system dead time	time interval between a specified change in speed or command signal and the first detectable movement of the servomotor SEE: Figure 9	T_q	s



IEC 391/12

Figure 9 – Control system dead time

Sub-clause	Term	Definition	Symbol	Unit
3.6.18	actuating energy	required energy for one servomotor stroke under the minimum required pressure $p_R = E_R/V_S$	E_R	N · m
3.6.19	servomotor volume	oil volume of the servomotors	V_S	m ³
3.6.20	tripping oil volume	oil volume of the pressure tank at the tripping point (between p_T and p_R , see Figure 20)	V_T	m ³
3.6.21	usable oil volume (Figure 20)	usable oil volume between $p_{o \min}$ and p_R	V_u	m ³
3.6.22	residual (not usable) oil volume (Figure 20)	oil volume of the pressure tank after a full-load shut-down from the tripping point	V_{res}	m ³
3.6.23	design oil pressure	design pressure of the oil pressure tank	p_D	Pa ^a
3.6.24	operating oil pressure	operating oil pressure under normal operating condition	p_o	Pa ^a
3.6.25	tripping oil pressure	when the tripping pressure p_T is reached a shutdown is released, this implies $p_R < p_T < p_o < p_D$	p_T	Pa ^a
3.6.26	minimum required pressure	minimum required pressure in the oil servo system	p_R	Pa ^a
^a The unit bar is also used.				

4 Control structure

4.1 General

In the hydraulic turbine control, various tasks can be specified with varying priority. Realization leads to certain typical control system structures and in turn to some basic rules to be adhered to.

Such typical arrangements are compiled for clarification.

4.2 Main control functions

4.2.1 General

In hydraulic turbine control, these major control functions can be distinguished:

- speed control;
- power output control;
- water level control;
- opening, and
- flow control.

In some systems, combinations of these control functions also occur.

4.2.2 Speed control

The purpose of the speed control basically is to maintain constant frequency. In the various modes of operation this means that:

- in the isolated network mode with only one unit (small network), the actual speed and therefore the frequency corresponds to the command signal setting; in the isolated network mode with more than one unit (medium network), the speed control contributes to the frequency control through the permanent droop avoiding oscillation between the units;
- in the operation on the grid, where the speed is determined by the network frequency, the speed control contributes to the network frequency control through the permanent droop and the dynamic characteristics of the controlled system;
- in the no load mode (before synchronization and after separation from the network), the actual speed corresponds to the command signal or the existing network frequency with some small deviation.

4.2.3 Power output control

The power output control with a separate power controller is applied with the unit connected to the grid, its purpose is to control the power output of the unit according to a power command signal irrespective of head variations. Any frequency variations influence the power level additionally via the permanent droop.

It is noted that in the cases where head variations can be ignored, a closed loop power output control, i.e., a power output controller, may not be necessary. In such a case, the calculation of the appropriate opening via a linearization may suffice (see 4.3.2). In this case also, any frequency variations influence the power level additionally via the permanent speed droop.

4.2.4 Opening control

The opening control serves to position the opening of the servomotor according to an opening command signal, either as a follow-up control in master control operations (for example speed control) or as a specific operating mode in grid control. In that last case, the usual configuration includes the permanent speed droop, which creates the relationship between the frequency of the grid and the opening of the servomotor, around the opening set-point from the unit control system; it is an alternative solution for power control with frequency influence, which is the preferred solution using modern digital controllers.

4.2.5 Water level control

For run-of-the-river hydropower plants, it is often required to control the water level of the upper part of the river, in order to keep it relatively constant or inside a specified range around a fixed value. The corresponding water level control is usually operated by an external controller of the power plant control system. But in some cases, it can also be managed by the turbine governing system itself, especially if there is no need of grid frequency control.

In the first case, by using an external water level control, the water level controller operates as a secondary controller. For that, it compares a water level measurement with a level set-point or level limit values, and by a specific algorithm, modifies the command signal of the main controller of the turbine governing system (speed or opening or power controller), in order to control the water level. Attention should be paid, in case of participation of the unit to the frequency control of the grid, that time constant of the water level control has to be enough long, in order to allow the action of the primary frequency control, with a duration as required by the TSO (transmission system operator) according to the corresponding grid code.

In the second case, the internal water level controller also compares the level measurement with the level set-point or level limit values, and modifies the command signal to the servopositioners, or to the opening limiter of the speed controller. If there are several units in the