SLOVENSKI STANDARD
SIST IEC 60308:1999

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Mednarodna pravila za preskušanje regulacije hitrosti krmilnih sistemov vodnih turbin

Hydraulic turbines - Testing of control systems

Turbines hydrauliques - Essais des systèmes de régulation

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27.140	Vodna energija	Hydraulic energy engineering

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Code international d'essai des régulateurs de vitesse pour turbines hydrauliques

International code for testing of speed governing systems for hydraulic turbines

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INTERNATIONAL CODE FOR TESTING OF SPEED GOVERNING SYSTEMS FOR HYDRAULIC TURBINES

FOREWORD

1) The formal decisions or agreements of the I E C on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.
2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.
3) In order to promote this international unification, the I E C expresses the wish that all National Committees having as yet no national rules, when preparing such rules, should use the I E C recommendations as the fundamental basis for these rules in so far as national conditions will permit.
4) The desirability is recognized of extending international agreement on these matters through an endeavour to harmonize national standardization rules with these recommendations in so far as national conditions will permit. The National Committees pledge their influence towards that end.

PREFACE

This Recommendation has been prepared by I E C Technical Committee No. 4, Hydraulic Turbines.

A first draft was discussed at the meeting held in Madrid in 1959. A new draft was discussed at the meeting held in Aix-les-Bains in 1964, as a result of which a final draft was submitted to the National Committees for approval under the Six Months' Rule in February 1965. Comments received were submitted to the National Committees for approval under the Two Months' Procedure in September 1967.

The following countries voted explicitly in favour of publication:

- Australia
- Austria
- Belgium
- Canada
- Czechoslovakia
- France
- Germany
- Hungary
- Israel
- Italy
- Japan
- Netherlands
- Norway
- Sweden
- Turkey
- Union of Soviet Socialist Republics
- United Kingdom
- United States of America
- Yugoslavia

INTERNATIONAL CODE FOR TESTING OF SPEED GOVERNING SYSTEMS FOR HYDRAULIC TURBINES

INTRODUCTION

Hydraulic turbine governing system requirements have increased greatly in recent years since frequently variables other than turbine speed must be controlled. The governing system must be capable of accepting, in addition to speed, a variety of other signals and combine them to achieve suitable operation in various possible modes. The governing system must be reliable for the safety of the turbine and for the ability to develop power at times when needed. Flexibility is necessary to be able to adapt to changing power system demands.

Many types of governing systems of varying degrees of capability have been built during the past years. Figure 1, page 14, is a block diagram illustrating in a general manner elements common to all governing systems. Speed can be sensed many ways. For governing system applications, the set of flyweights have been the most common method for comparing the actual shaft speed with the desired speed. Electrical methods equally as good have evolved, some based on frequency with others on voltage to arrive at an electrical signal proportional to the turbine speed.

Figure 2, page 14, is a governing system of the tachometric type sensitive to speed deviations of the unit from the set speed value. The signal produced, mechanical or electrical, is then combined with the external command signals and with the permanent speed droop feedback signal proportional to gate servomotor position. The resulting signal, after amplification, moves the distributing valve controlling the main servomotor.

The accelero-tachometric governor of Figure 3, page 15, senses, in addition to speed, the acceleration of the turbine and combines it with the other signals, amplifies and then positions the distributing valve which controls the gate servomotor.

The tachometric governor with temporary speed droop, figure 4, page 15, has a temporary feedback signal proportional to the rate of travel of the servomotor whose effect decays exponentially as a function of time. This temporary droop signal, combined with the speed deviation signal, is amplified to position the main distributing valve to control the main servomotor. It is possible to add to this type of governing system an accelerometric signal, thereby obtaining a combined form of temporary droop and accelero-metric-tachometric governing system.

Another possible arrangement may be seen in figure 5, page 16, which is an accelerometric-tacho-metric governing system. The distinguishing feature is that the power amplification occurs between the pilot servomotor and the main servomotor. The permanent droop can be obtained by feeding back a signal from the main servomotor instead of the pilot servomotor. Figure 6, page 16, finally shows a governor arrangement of the temporary speed droop type where the speed droop signals are derived from the pilot servomotor. In this case also the permanent speed droop could alternatively be derived from the main servomotor.

There are four modes of governing system operation. They are as follows:

1. steady state;
2. small transient conditions;
3. large transient conditions;
4. blocked gate.

Steady state operation in general occurs when all variables of the controlled system and the governing system are at rest. The unit is operating under constant load, command signal and head. During steady state operation, measurements of importance deal mainly with the accuracy and the range of operation of the system. Drift or wander should be minimized to the degree capable by the governing system.

The second mode is when the combined system, controlled and governing, is subject to small changes such as generator load fluctuations, command signal changes, etc. The changes are sufficiently small that none of the governing system elements reach limits. Good operation in this mode is characterized by the system returning to a steady state condition without unreasonable deviation or time interval and to settle out with a minimum of swings (adequate damping). It is in this operation that stability concepts are predominant. Various parameters of the governing and the controlled systems (time constants and gain coefficients) are sufficient to establish whether the desired operation can be obtained. Criteria exist in terms of these measurable parameters, often specified, which nearly assure a stable system.

The third mode occurs when either load or command signal changes are of sufficient size to cause any of the internal portions of the governing system to reach some limit as evidenced by nonlinear or saturated performance. In hydraulic turbine governing systems, this usually occurs due to a planned restriction of flow of hydraulic fluid to the main servomotors to establish the servomotor timing. Here of importance is the size of deviation required to cause saturation and the time required to reach saturation. The timing of the main servomotors, the governor dead time and the cushioning time are normal measurements in this condition. Further, it is important to know how the system settles out following the saturated performance. Maximum pressure change in the penstock and maximum speed change for this type of performance need to be known for safety reasons and are usually determined in conjunction with turbine tests.

The fourth mode is probably the simplest situation in that the main servomotor is restrained from movement in one or both directions with the result that the machine supplies a predetermined amount of power to its connected system without regard for small speed fluctuations.

The present code concerns tests about control of the speed of a hydraulic turbine. The object of these tests is to verify the fulfilment of certain technical guarantees appropriate to a given installation. The code, therefore, deals with the methods of measuring those quantities which most frequently are the basis for technical guarantees.

In practice the guarantees relate to:

— the speed governing system, defined as a control system in which the output quantity is the position of the main servomotor and the input quantities are the turbine speed of rotation and external command signals;

— and/or the quality of the frequency control of an electric network fed by the generating unit, which is equipped with the speed governing system considered;

— and/or the consequences (variations of pressure and speed) of a sudden large-amplitude load variation.

In the first case, the most common methods of specification at the present time consist of indicating the operating principle of the governor (i.e. accelero-tachometric or temporary speed droop) and the required numerical values of the main characteristic parameters.

The main purpose of the acceptance tests in this case is to determine experimentally the effective numerical values of these parameters. The present code, therefore, defines the nature of these characteristic parameters and outlines methods of their measurement. Many methods are available to the test engineer to determine the static and dynamic characteristics of the governing system. The present code has attempted to cite the most common and most used test procedure applicable to all governing systems. Step response type of tests are described where deemed appropriate. Another method, known as harmonic response, at present little used, is described in the Appendix. Statistical techniques can be used, but are not discussed in this code.

In the second case, that is when the quality of the frequency control forms the basis of technical specifications, the tests on the governing system itself may not have contractual significance.

On the other hand, the supplier of the governing system can undertake to obtain a certain quality of the frequency control only if the conditions in which the governing system will operate are clearly defined. These conditions concern firstly the nature of the load variations which will be considered when judging the quality of frequency control. They also concern the characteristics of the controlled system (water passages, turbine, alternator, voltage regulator, network).

The present test code therefore defines certain characteristic parameters of the controlled system and outlines methods of their measurement.

It is important to draw the attention to the difficulties of experimental determination of certain characteristics of the controlled system and therefore such measurements should be limited to the cases when serious control difficulties occur and cannot be remedied by modification of the adjustable parameters of the governor. It then becomes necessary to ascertain the actual values of certain controlled system characteristics and to see in what measure they differ from those originally given to and used by the manufacturer of the governing system for selecting and adjusting the governor.

In the third case, that is when the technical guarantees cover the maximum value reached by speed and pressure variations in case of a sudden load variation, the tests on the speed governing system itself again may not have contractual significance. This case, therefore, is complementary to the second case mentioned above, and the supplier of the speed governing system may undertake to give contractual limit values of speed and pressure variations only if the hydraulic installation characteristics which he deems necessary for fixing the governing systems characteristics have been given to him and prove to be correct.

A definition problem arises because of two situations. The first is when the governing system manufacturer and the hydraulic turbine manufacturer are the same. The second is where the governing system manufacturer provides his equipment to either the turbine manufacturer or to the engineers responsible for controlled system. Therefore, it is possible, from the wording of the code, for the purchaser of the governing system to be a division of the same manufacturer of the hydraulic turbine. The word purchaser, therefore, refers to the group that has entered into contract directly with the manufacturer of the governing system.

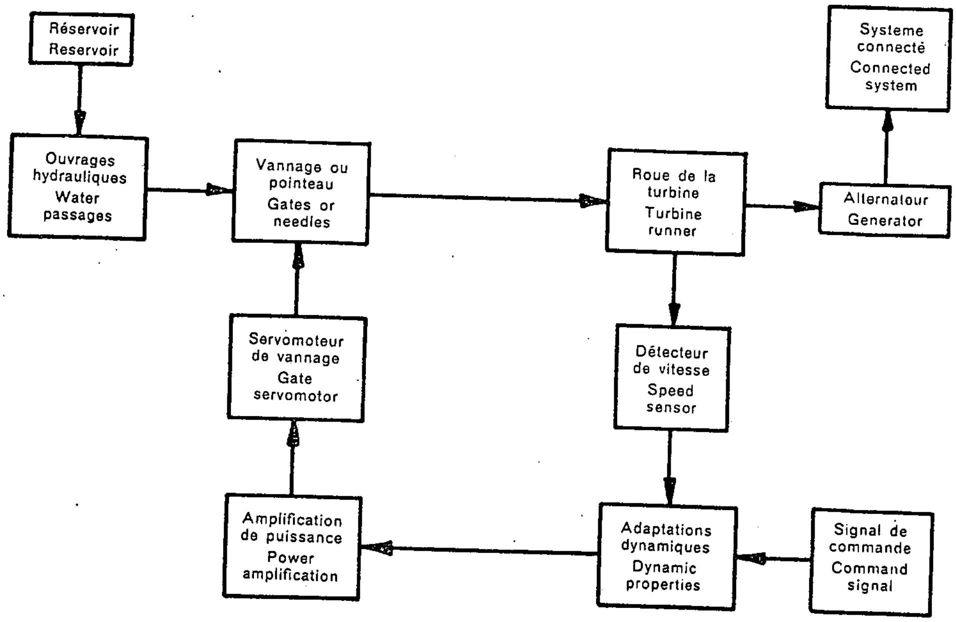

FIG. 1. — Schéma de principe du système réglé et du régulateur.
Diagram of controlled and governing system.

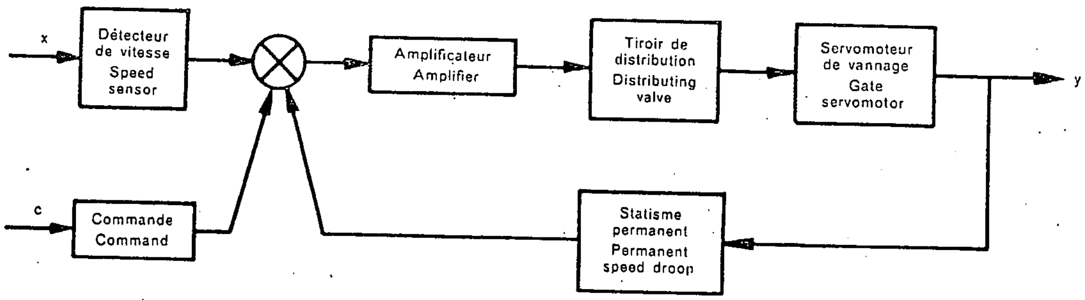

FIG. 2. — Régulateur de type tachymétrique.
Tachometric type governing system.

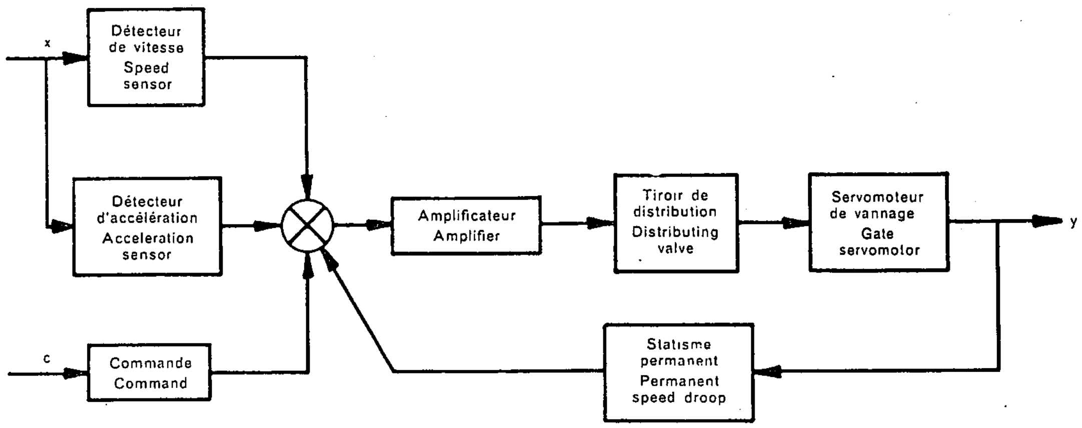

FIG. 3. — Régulateur accélérotachymétrique.
Accelero-tachometric governing system.

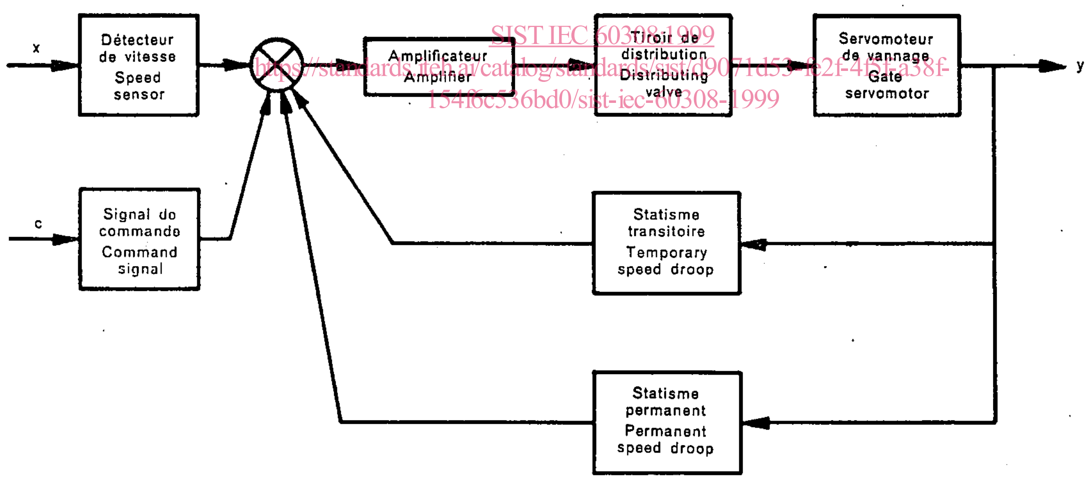

FIG. 4. — Régulateur à statisme transitoire.
Tachometric governor with temporary droop.

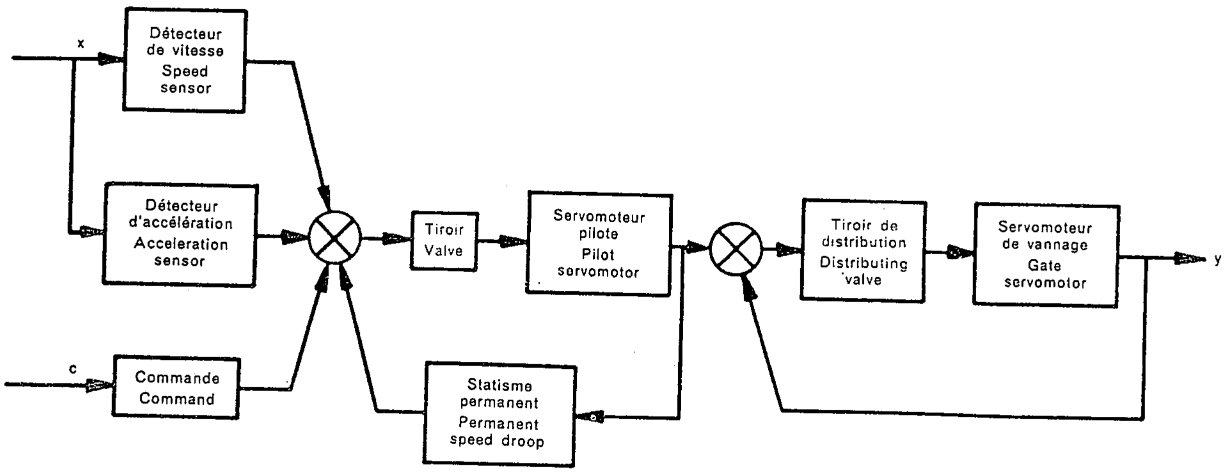

FIG. 5. — Régulateur accélérotachymétrique avec servomoteur pilote.
Accelero-tachometric governor with pilot servomotor.

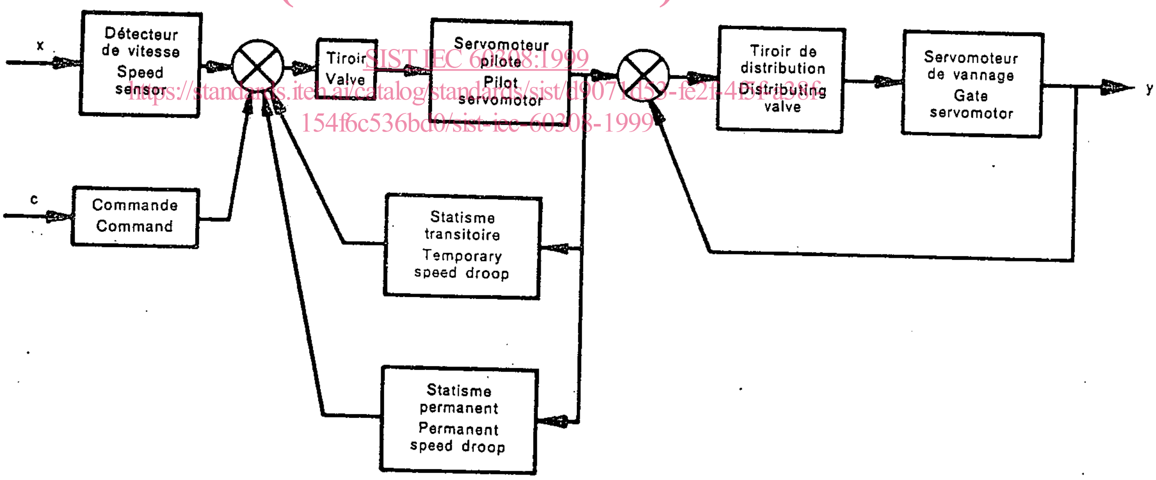

FIG. 6. — Régulateur à statisme transitoire provenant d'un servomoteur pilote.
Governor with temporary droop derived from a pilot servomotor.

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CHAPTER I — OBJECT AND SCOPE

The object of this code is to define the terms and quantities necessary to describe the regulating behaviour of the speed governing system. This code will establish methods of testing and ways of measuring the quantities involved so that the performance and behaviour of the governing system can be ascertained and the guarantees verified.

1. Types of governor and controlled system

In general this code applies to any speed governing system for hydraulic turbines. It is also concerned with the controlled system consisting of the hydraulic turbine, water supply, discharge passages, generator, voltage regulator and connected electric power network.

2. Acceptance tests

This code covers the arrangements for tests on the speed governing system, both in the shops of the manufacturer and when installed at the site to determine the attainment of governor guarantees given by the supplier. This code covers the arrangements for tests on the controlled system at site to determine the validity of the controlled system characteristic values given by the purchasers upon which the system performance has been guaranteed.

This code deals with the way in which the results are to be computed along with the accuracies and range of measurement considered acceptable. The code gives guidance as to the content and style of the final report.

Only those tests should be performed which are necessary to verify the guarantees stipulated in the contract or such tests as set forth in a written agreement between the parties to the test for purposes of obtaining supplementary information about either the governing system or the controlled system.

3. Excluded topics

This code excludes all matters of purely commercial interest and enterprise, except those inextricably bound up with the successful issue of the acceptance tests.

3.1 It is not concerned with structural details of governors nor with the mechanical or electrical properties of their components. It is not concerned with the conditions prevailing in the oil pressure system, except that the maximum and minimum pressure levels must be as specified, the oil quality and temperature observed (see Sub-clauses 14.2.1 and 14.2.2) and the tolerances recognized.

3.2 The testing of various auxiliary protective and supervisory devices is not within the scope of this code, unless otherwise agreed or found necessary.

CHAPTER II — TERMS, DEFINITIONS, SYMBOLS AND UNITS

4. Units

The international system of units is adopted throughout this code for measurement but other systems consistent with the contract specifications shall be allowed if preferred. Dimensionless relative values of variables are used for calculating and reporting the results.

5. Terms

The terms, definitions, symbols and terminal markings adopted in this document conform as closely as possible with the Special I E C Publications on terms, definitions, symbols and terminal markings. Where this is not so, they are not to be regarded as official recommendations of the I E C, but only as an aid to express the meaning of the present document.

In general, it is preferred that symbols referring to the governing system be denoted by the letter b and those referring to the controlled system be denoted by the letter e. All coefficients with dimension of time are denoted by the capital letter *T*.

	Term	Definition	Symbol for the Quantity	Symbol for the Unit	Symbol for the Relative quantity
5.1	*General definitions*				
5.1.1	Governing system	The combination of devices and mechanisms which detect the speed deviation and convert it into the main servomotor stroke deviation in a characteristic manner.			
5.1.2	Speed	The speed of rotation of the turbine.	n ω f	rev/min rad/s Hz	n/n_N ω/ω_N f/f_N
5.1.3	Guarantee speed	The speed for which the turbine is ordered.	n_N ω_N f_N	rev/min rad/s Hz	
5.1.4	Speed deviation	At a considered instant, the difference between the actual speed of rotation and a reference speed.	Δn $\Delta\omega$ Δf	rev/min rad/s Hz	x
5.1.5	Command signal	A reference quantity which can be set by external adjustment of the governing system.	C		
5.1.5.1	Command signal deviation	The difference between the actual command signal (C) and a reference value (C_o), where C_o is the value of the command signal when the turbine rotates at guarantee speed under no load and guarantee conditions of water supply.	ΔC		c
5.1.5.2	Command signal proportionality factor	The slope of the curve representing the rotational speed versus the command signal at a given steady state servomotor position.			b_c