IEC TS 63111

Edition 1.0 2025-10

TECHNICAL SPECIFICATION

Hydraulic turbines, storage pumps and pump-turbines – Hydraulic transient analysis, design considerations and testing

ICS 27.140

ISBN 978-2-8327-0605-3

IEC TS 63111:2025-10(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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The text of this Technical Specification is based on the following documents:

Draft	Report on voting
4/525/DTS	4/531/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,
– withdrawn, or
– revised.

INTRODUCTION

Proper treatment of hydraulic transients is important for utilities, equipment owners, producers, as well as equipment suppliers. During transient operational modes, hydro power equipment can be exposed to large dynamic loads that, in extreme cases, can lead to catastrophic events. Insufficient understanding of basic transient phenomena and related modelling can lead to inadequate design safety factors that can put both equipment and related plant personnel at risk.

The occurrence of transient phenomena during hydro power production is unavoidable. Simulation and testing of hydraulic transients provide critical values throughout the project development that should be used to establish and validate guarantees for maximum and minimum allowable pressures, rotational speeds, torques, etc. The primary goal of a hydraulic transient analysis is to support the safety of the hydroelectric equipment and any personnel directly related to the environment produced by a hydraulic transient event.

1 Scope

This Technical Specification (1) describes hydraulic transient phenomena of hydro turbines, storage pumps and pump-turbines and the factors that affect them, (2) provides modelling and measurement best practice guidelines and resulting limitations (3) defines relevant equipment design criteria, and (4) identifies potential mitigation solutions. Definitions of the relevant terms and quantities are provided along with descriptions of the system components that are considered.

Various types of hydraulic transient phenomena are covered in the current specification, including waterhammer, surge tank mass oscillation, and speed variation of the hydraulic machine for operational modes such as start-up, normal shutdown, emergency shutdown, and load rejection and acceptance. Combinations of the individual transient modes are also considered. The links between these transient characteristics and operation across the relevant quadrants for each machine type are illustrated. Methods for mitigating extreme transient values of pressure, surge tank water levels, and unit rotational speed are suggested.

In this Technical Specification, abnormal transient phenomena are also defined and described, including component malfunction and catastrophic events like component rupture. The probability of the occurrence of these extreme events and how this can influence the relevant safety margin is described.

Different stages of hydroelectric development correspond to unique sets of available data with differing levels of detail and uncertainty. The various stages of project development are described in relation to transient analysis. The corresponding uncertainty margins associated with each stage and analysis technique are discussed.

This Technical Specification provides guidelines and commonly accepted practices to model and compute transient conditions. It provides a summary of the basic hypotheses and equations, together with relevant characteristic quantities and system time constants. Accepted methods of modelling hydraulic components, and related numerical simulation methods are identified. This specification details the input data, including best practices for model testing of hydraulic machines, valves, gates, etc. to acquire reliable transient modelling.

Different calculation methods with different levels of uncertainty are described so that the most suitable approach for the available data or project stage can be selected. Limitations of one-dimensional modelling methods are described. Additional means of investigation, such as physical model tests or CFD computation, can be used to improve the simulation results.

For various configurations of equipment and operating regimes, typical scenarios for consideration are defined.

Procedures to determine uncertainty margin, with respect to the modelling and computation methods and available input data are described.

Finally, this Technical Specification describes methodologies for on-site measurements with respect to transient such as load rejection tests, runaway tests, etc. Recommendations are provided for quantities to be monitored during these tests, with related instrumentation, calibration and data acquisition systems. Procedures for comparing on-site measurements with numerical simulation results are proposed.

Note that the following aspects influence hydraulic transients and are therefore introduced; however, the associated modelling and related design guidelines will not be addressed in the Technical Specification:

- waterway design and optimization;
- upstream and downstream free surface flows;
- fluid structure interactions;
- cavitation and water column separation;
- unsteady friction and viscoelasticity;
- two phase flows;
- turbine governor design;
- flow induced pressure fluctuations.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60041:1991, *Field acceptance test to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines*

IEC 60193:2019, *Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests*

IEC 60545:2021, *Guidelines for commissioning and operation of hydraulic turbines, pump-turbines and storage pumps*

IEC 60994:1991, *Guide for field measurement of vibrations and pulsations in hydraulic machines (turbines, storage pumps and pump-turbines)*

IEC 62884 (all parts), *Measurement techniques of piezoelectric, dielectric and electrostatic oscillators*