IEC TS 62600-202

Edition 1.0 2022-04

TECHNICAL SPECIFICATION

colour inside

Marine energy – Wave, tidal and other water current converters – Part 202: Early stage development of tidal energy converters – Best practices and recommended procedures for the testing of pre-prototype scale devices

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IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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CONTENTS

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MARINE ENERGY – WAVE, TIDAL AND OTHER WATER CURRENT CONVERTERS –

Part 202: Early stage development of tidal energy converters – Best practices and recommended procedures for the testing of pre-prototype scale devices

FOREWORD

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IEC TS 62600-202 has been prepared by IEC technical committee 114: Marine energy – Wave, tidal and other water current converters. It is a Technical Specification.

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

Draft	Report on voting
114/407/DTS	114/414A/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.

A list of all parts in the IEC 62600 series, published under the general title *Marine energy – Wave, tidal and other water current converters*, can be found on the IEC website.

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.

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- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

To further develop the tidal energy industry, Stage Gates, best practices and recommended procedures for the testing of pre-prototype scale devices must be well understood. This document is a collaborative effort from technology developers, academic researchers and test facility managers.

The purpose of this document is to provide a structured approach in testing and evaluating Tidal Energy Converters. By following a standardised design path, risk will be reduced and stakeholder confidence increased. Through best practise guidance and applicable methodologies this document will ensure consistent, appropriate and comparable data is collected for the characterization and analysis required in the development of a Tidal Energy Converter. Furthermore, the reporting procedures will ensure that the results can be replicated by others.

The core of this document follows a Stage Gate approach; for each stage the program of work is outlined and supporting information relating to test planning and reporting presented. The specific recommendations are provided in a holistic manner guiding the process with respect to test planning, reporting requirements, data acquisition, test environment characterization, and characterization of both rotor and device (motion) performance. Annexes provide the reader with further information on facility selection and instrumentation.

The overall goal of this document is to accommodate the majority of technology developers and facilitate a coherent and structured approach that will accelerate the tidal energy sector in fulfilling its market potential as a renewable energy contributor. However, it is recognised that this document will not cover every eventuality that may be relevant for all users. Therefore, this document assumes that the user is familiar with the subject matter and has access to, and reviews relevant literature, including the literature cited herein.

NOTE This document presently does not describe testing under wave-current interaction, effects of turbulence on tidal energy converters beyond a basic introduction to some turbulence parameters typically reported, and quantification of uncertainty which is covered in other referenced documents.

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MARINE ENERGY – WAVE, TIDAL AND OTHER WATER CURRENT CONVERTERS –

Part 202: Early stage development of tidal energy converters – Best practices and recommended procedures for the testing of pre-prototype scale devices

1 Scope

This document specifies the development stages of Tidal Energy Converters up to the pre-prototype scale (Stages 1 to 3). It includes the hydraulic laboratory test programs, where environmental conditions are controlled so they can be scheduled, and the first scaled system open-water trials, where combinations of tidal currents, wind and waves occur naturally and the programs are adjusted and flexible to accommodate these conditions. Full-scale prototype (Stages 4 and 5) development is not covered in this document.

This document describes the minimum test programs that form the basis of a structured technology development schedule. For each testing campaign, the prerequisites, goals and minimum test plans are specified. This document addresses:

a) Planning an experimental program, including a design statement, technical drawings, selection of scale and facility based on physical laws, site data and other inputs;

b) Device representation and characterization, including the physical device model, power-take-off components, foundation and mooring arrangements where appropriate;

c) Energy resource and environment characterization, concerning either the tank testing facility or the open-water deployment site, depending on the stage of development;

d) Specification of explicit test goals, including power conversion performance and device loads.

Guidance on the measurement sensors and data acquisition packages is included, but not dictated. Providing that the specified parameters and tolerances are adhered to, the device developer is free to select the components and instrumentation.

An important element of testing is to define the limitations and accuracy of the raw data and, more specifically, the results and conclusions drawn from the trials. A methodology of addressing these limitations is presented with each goal so the plan always produces defendable results of defined uncertainty.

It is anticipated that this document will serve a wide audience of tidal energy stakeholders, including device developers and their technical advisors; government agencies and funding councils; test centers and certification bodies; private investors; and environmental regulators and non-governmental organizations.

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 TS 62600-1, *Marine energy – Wave, tidal and other water current converters – Part 1: Vocabulary*

IEC TS 62600-101, *Marine energy – Wave, tidal and other water current converters – Part 101: Wave energy resource assessment and characterization*

IEC TS 62600-103:2018, *Marine energy – Wave, tidal and other water current converters – Part 103: Guidelines for the early stage development of wave energy converters – Best practices and recommended procedures for the testing of pre-prototype devices*

IEC TS 62600-200, *Marine energy – Wave, tidal and other water current converters – Part 200: Electricity producing tidal energy converters – Power performance assessment*

IEC TS 62600-201:2015, *Marine energy – Wave, tidal and other water current converters – Part 201: Tidal energy resource assessment and characterization*

IEC TS 62600-300:2019 *Marine energy – Wave, tidal and other water current converters – Part 300: Electricity producing river energy converters – Power performance assessment*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC 17025:2017, *General requirements for the competence of testing and calibration laboratories*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 62600-1 and the following apply:

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
blockage
<of a tidal energy converter under test in a specific test facility> ratio of the tidal energy converter projected area to the facility test section cross-sectional area

Note 1 to entry: There is a constraining effect exaggerating performance data when this ratio is too high, which is typically observed for ratios greater than 5 %.

3.2
Stage 1
small-scale testing in the laboratory

Note 1 to entry: Stage 1 is equivalent to Technology Readiness Level (TRL) 2-3.

3.3
Stage 2
medium-scale testing in the laboratory

Note 1 to entry: Stage 2 is equivalent to Technology Readiness Level (TRL) 4.

3.4
Stage 3
large-scale testing in open water

Note 1 to entry: Stage 3 is equivalent to Technology Readiness Level (TRL) 5-6.

3.5
turbulence intensity
<in a tidal flow> ratio of the tidal current speed standard deviation to the mean tidal current speed.

Note 1 to entry: It is also referred to as turbulence level, and is a very simplified description of how turbulent the flow at a tidal site or in a facility is.

Note 2 to entry: Turbulence intensity is to be determined from the same set of measured data samples of tidal current speed, and taken over a specified period of time.

4 Symbols and abbreviated terms

ADCP	Acoustic Doppler Current Profiler
ADV	Acoustic Doppler Velocimeter
AEP	Annual Energy Production as defined in IEC TS 62600-1
AD	Analogue to Digital
CoG	Centre of Gravity
COTS	Commercial off-the-shelf
DAQ	Data Acquisition
DoF	Degrees of Freedom as defined in IEC TS 62600-1
EEP	Energy Extraction Plane as defined in IEC TS 62600-1
FMECA	Failures Mode, Effects and Criticality Analysis
MLW	Mean Low Water
MHW	Mean High Water
PDF	Probability Density Function
RAO	Response Amplitude Operator
PTO	Power-Take-Off as defined in IEC TS 62600-1.
SCADA	Supervisory Control and Data Acquisition System
TEC	Tidal Energy Converter as defined in IEC TS 62600-1
TEOS-10	The Thermodynamic Equation of Seawater – 2010
TRL	Technology Readiness Level
TSR	Tip Speed Ratio
ULS	Ultimate Limit State in the context of structural engineering

5 Staged development approach

5.1 General

This clause introduces the staged development approach to the design and evaluation of a TEC through physical model testing. Each stage of development is motivated by risk reduction. The primary goals for each stage address elements that should be completed before proceeding through the user's pre-defined Stage Gate for that stage. Each stage corresponds to technology readiness levels (TRL) that measure the progress of technology advancement.

Scaled tidal flow conditions produced in the test tank should be representative of anticipated full-scale tidal flow conditions at the expected deployment sites; namely depth-limited turbulent open channel flows, such as those produced in large flumes. Departures from these conditions due to test facility limitations or differences, e.g., absence of velocity gradients, ambient turbulence and other unsteady flow characteristics over the energy extraction plane, for example in towing tanks, should be documented, and the anticipated effects on test results should be described.

Table 1 shows an overview of the Stage Gate framework and process from the early design concept to the deployment of the first limited device number array, Stage 1 to 5. For each Stage Gate, Table 1 includes the relevant model-test description, typical geometric scale range, test objectives, and Stage Gate success metrics used in the go/no-go analysis.

This Stage Gate framework is designed to be consistent with TEC development and evaluation guidance and protocols developed by the International Energy Agency, Ocean Energy Systems (IEA OES) under Annex II (Bahaj, Blunden, and Anwar 2008; Nielsen 2010).

Each stage is based on a different physical scale range carefully selected to achieve a set of specific design objectives prior to advancing the device trials to the next stage. This clause outlines the scope and Stage Gates for Stages 1, 2 and 3, guiding the development process from TRL 1 to 6. Stages 4 and 5 concern full scale (or near full scale) testing and are not covered in this document.

This document does not dictate a scale for each of the Stages 1-3. The model testing scale heavily depends on the test objective, size of full-scale TEC, governing scaling laws to achieve dynamic similitude, and the fidelity of the available instrumentation. The scales provided in Table 1 are included as indicators based on previous TEC development efforts.

Every type of TEC will have slightly different requirements so a customized program should be drawn up around these basic testing requirements. Different physical models may be prepared to evaluate specific subsystems or design features. The necessary and recommended goals and experimental activities for Stages 1 to 3 are described in detail in Clauses 6 through 13. Activities are to be defined in the context of best engineering practice, where factors of safety, reliability or other design philosophies are followed.

A Stage Gate process shall be applied after each set of trials to evaluate if the TEC has achieved the required experimental objectives before advancing to the next stage.

A set of Stage Gate criteria for the evaluation of the TEC response and performance at the end of each testing period are defined for Stages 1 to 3 in 5.2 to 5.4. These criteria shall be addressed before advancing to the next stage. These criteria (5.2 to 5.4) are currently defined as a general framework and allow for a high degree of flexibility to suit the design requirements.

At Stage 1, it should be anticipated that several iterations of a device would be required to optimize its performance, reliability, safety and economics. More than one iteration may still be required at Stage 2, and a single implementation should normally suffice at Stage 3.

Table 1 – Staged development approach

Stage	Model test description	TRL	Typical range of scales	Test objectives	Go/No-Go analysis Stage Gate success thresholds
1	Concept model	2-3	1:15-100	Concept verification: Turbine rotor: Demonstrate power energy conversion Platform: Test initial design choices and select most favorable design configuration. Characterize design loads and motions for operational reliability and survival.	Rotor power conversion demonstrated. Loads characterized for normal operating and extreme conditions. A favorable design configuration is found.
2	Design model	4	1:3-10	Design verification: Demonstrate power performance and survival in simulated tidal flow environment at a physical scale that minimizes scale effects (chord Reynolds number dependency). Demonstrate component PTO. Demonstrate other component or subsystem, e.g., controls.	Power performance equals or exceeds target based on numerical model. Loads characterized for normal operating and extreme conditions. PTO operates as designed and at expected efficiency. Control or other subsystem operates as designed.
3	Subsystems model	5-6	1:1-5	Sub-system model verification: Assess energy production in real tideways. Demonstrate subsystem integration. Fully operational TEC tideway trials.	Power performance equals or exceeds target based on numerical model. Loads characterized for normal operating conditions. PTO operates as designed and at expected efficiency. Control or other subsystem operates as designed.
4	Solo-device proving – near to full scale testing of prototype device.	7-8	1:1-2	Technical/operational evaluation of near-full size to full size power plant deployment. Advance pre-production to pre-commercial unit.	Operations analysis: Demonstrate operability, maintainability, access, health and safety.
5	Multi-device proving – Commercial demonstrator tested at sea for an extended period.	9	1:1	Economic evaluation of final commercial unit. Small farm trials, 3-5 units.	Economic analysis: Demonstrate levelized cost of energy (LCOE) target met.

After each stage of TEC model testing, an evaluation procedure should be instigated to assess the overall performance of the TEC. The appraisal should include a technical and economic review based on three elements of the proposed device design:

a) Analysis of the results from the appropriate preceding test program;

b) A comparison with the related TEC design statement produced at the beginning of the stage;

c) An overall design review, preferably by a third party, independent, established engineering company.

The review shall follow the same set of evaluation criteria at each stage which are based on the test goals specified for each stage. As the test article physical scale increases, the complexity of the model and trials increases to generate more accurate results with less uncertainty in the prototype extrapolation. The Stage Gate evaluation criteria reflect this decreasing uncertainty.