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TECHNICAL SPECIFICATION

colour inside

Marine energy – Wave, tidal and other water current converters – Part 300: Electricity producing river energy converters – Power performance assessment

IEC TS 62600-300:2019-09(en)

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

Part 300: Electricity producing river energy converters – Power performance assessment

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Technical Specification are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62600-300, which is a Technical Specification, has been prepared by IEC technical committee 114: Marine energy - Wave, tidal and other water current converters.

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

Draft TS	Report on voting
114/284/DTS	114/300/RVDTS 114/300A/RVDTS

Full information on the voting for the approval of this Technical Specification can be found in the report on voting indicated in the above table.

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 has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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

Part 300: Electricity producing river energy converters – Power performance assessment

1 Scope

This part of IEC 62600 provides:

- A systematic methodology for evaluating the power performance of river current energy converters (RECs) that produce electricity for utility scale and localized grids;
- A definition of river energy converter rated capacity and rated water speed;
- A methodology for the production of power curves for the river energy converters in consideration; and
- A framework for the reporting of results.

Exclusions from the scope of this document are as follows:

- RECs that provide forms of energy other than electrical energy unless the other form is an intermediary step that is converted into electricity by the river energy converter;
- Resource assessment, that will be addressed separately in the River Energy Resource Assessment Technical Specification;
- Scaling of any measured or derived results;
- Power quality issues;
- Any type of performance other than power and energy performance; and
- The combined effect of multiple river energy converter arrays.

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, *Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines*

IEC 60688:2012, *Electrical measuring transducers for converting A.C. and D.C. electrical quantities to analogue or digital signals*

IEC 61400-12-1:2005, *Wind turbines – Part 12-1: Power performance measurements of electricity–producing wind turbines*

IEC 61869-2, *Instrument transformers – Part 2: Additional requirements for current transformers*

IEC 61869-3, *Instrument transformers – Part 3: Additional requirements for inductive voltage transformers*

IEC TS 62600-1:2011, *Marine Energy – Wave, tidal and other water current converters – Part 1: Terminology*

IEC TS 62600-100:2012, *Marine Energy – Wave, tidal and other water current converters – Part 100: Electricity producing wave energy converters – Power performance assessment*

IEC TS 62600-200:2013, *Marine Energy – Wave, tidal and other water current converters – Part 200: Electricity producing tidal energy converters – Power performance assessment*

IEC TS 62600-301:2019, *Marine Energy – Wave, tidal and other water current converters – Part 301: River energy resource assessment*

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

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement,* (GUM:1995)

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 62600-1 as well as 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 ratio
<of a river energy converter> ratio of the flow-facing area of the moving and non-moving parts, to the river cross-sectional area at the test site

3.2
demonstrated performance
<of a river energy converter> portion of device operation for performance assessment that occurs in a river that is representative of sites where the device will be deployed commercially

Note 1 to entry: Refer to Clause 7 for additional information.

Note 2 to entry: This contrasts with the term tested performance.

3.3
energy extraction plane
<of a river energy converter> the plane that is perpendicular to the principal axis of energy capture where device rotation or energy conversion nominally occurs

3.4
equivalent diameter
<of a river energy converter> diameter of a circle with area equal to the device **projected capture area**

3.5
principal axis of energy capture
<of a river energy converter> axis parallel to the design orientation or heading of a River Energy Converter passing through the centroid of the **projected capture area**

3.6
principal flow direction
<of a river current> primary orientation or heading of the **river current**

3.7
power-weighted speed
<of a river energy converter> mean current speed derived with the weighted function of the cube of the speed across the **projected capture area**

3.8
projected capture area
<of a river energy converter> frontal area perpendicular to the **principal flow direction** of the **current energy converter** components hydrodynamically utilized in energy conversion

3.9
rated water speed
<of a river energy converter> lowest mean flow speed at which the river energy converter rated capacity is delivered to its output terminals

3.10
tested performance
<of a river energy converter> portion of device testing that is for the purpose of extending the power curve beyond the range of velocities that is measured in the **demonstrated performance** portion of the test

4 Symbols, units and abbreviated terms

4.1 Symbols and units

Symbol	Description	Unit
A	Projected capture area of the REC	[m^2]
$A_{Channel}$	Channel cross-sectional area at the test site at a particular volumetric flow rate	[m^2]
A_{duct}	Projected capture area of a ducted structure	[m^2]
AEP	Annual energy production	
A_k	Area of kth current profiler bin across the projected capture area	[m^2]
A_{Total}	Cross-sectional area including all support structures	[m^2]
B	Total number of speed bins in the horizontal direction across the projected capture area normal to the principal axis of energy capture	[-]
D_E	Equivalent diameter	[m]
h	Height of the capture area	[m]
i	Index number of the current speed bin	[-]
$i_1, i_2, \ldots i_N$	The set of data point indices, t, in speed bin i	[-]
j	Index number of the time instant when the measurement is performed	[-]
k	Index number of the current profiler bin across the projected capture area	[-]
L_U	Number of current speed data samples in the defined averaging period that produces data point t	[-]
L_P	Number of power data samples in the defined averaging period that produces data point t	[-]
M		
N_i	Number of data points in speed bin i	[-]

Symbol	Description	Unit
$\overline{P}_i$	Mean recorded REC active power in speed bin i	[W]
P_j	Magnitude of the total instantaneous active electrical power from the REC	[W]
$\check{P}_i$	Mean REC active power after combining demonstrated data with scaled test data	[W]
$\tilde{P}_t$	Mean recorded REC active power output of the t^{th} data point	[W]
$\overline{Q}_i$	Mean recorded REC reactive power in speed bin i	[var]
Q_j	Magnitude of the total instantaneous reactive electrical power from the REC	[var]
$\tilde{Q}_t$	Mean recorded REC reactive power output of the t^{th} data point	[var]
R	Radius of circular capture area	[m]
S	Total number of current profiler bins normal to the principal axis of energy capture across the projected capture area	[-]
t	Index number of a data point	[-]
T	Number of hours variation from UTC time	[h]
U_i	Current speed of speed bin i	[m/s]
$\overline{U}_i$	Mean current speed in speed bin i	[m/s]
$\hat{U}_j$	The power-weighted current speed in m/s averaged across the projected capture area	[m/s]
$U_{j,k}$	Current speed flowing through current profiler bin k of the projected capture area, at time instant j	[m/s]
$\tilde{U}_t$	Power-weighted mean current speed of the t^{th} data point	[m/s]
$\tilde{U}_{t,k}$	Current speed data point in current profiler bin k over a given averaging period at a specific speed increment	[m/s]
$Ua_{j,k}$	Current speed flowing through the k^{th} current profiler bin of current profiler *a*,	[m/s]
$Ub_{j,k}$	Current speed flowing through the k^{th} current profiler bin of current profiler *b*	[m/s]
$\widetilde{Umean}_{t,k}$	Mean current speed flowing through current profiler bin k at the centroid of the projected capture area	[m/s]
$\overline{Urms}_{i,k}$	RMS fluctuating current speed in current profiler bin k at the centroid of the projected capture area at speed bin i	[m/s]
$\widetilde{Urms}_{t,k}$	RMS fluctuating current speed in current profiler bin k over the specified averaging period	[m/s]
$\overline{Ushear}_{i,k}$	Mean current speed in speed bin i at current profiler bin k	[m/s]
w	Width of the capture area	[m]
$\eta_{system,i}$	REC overall efficiency in current speed bin i	[-]
ΔU	speed bin increment	[m/s]
γ	The test-data power scale factor	[-]
$\theta_{j,k}$	The river current direction of the hub height current profiler bin k	[°]
$\tilde{\theta}_{t,k}$	Mean river current direction of the hub height current profiler bin k over the defined averaging period	[°]
ρ	Fluid density	[kg m^{-3}]

4.2 Abbreviated terms

Abbreviation	Description
AC	Alternating Current
DC	Direct Current
GPS	Global Positioning System
IEC	International Electrotechnical Commission
IHO	International Hydrographic Organisation
ISO	International Organisation for Standardization
REC	River Energy Converter
RMS	Root Mean Square
UTC	Coordinated Universal Time

5 Overview

The primary objective of this document is to quantify the power output of a River Energy Converter (REC) as a function of the current speed inflow in which it is designed to operate, i.e. to quantify the device's "power curve". The accepted approach for accomplishing this is to deploy a device at a representative deployment site, and simultaneously measure the inflow speed to the device and the power output from it over a range of inflow speeds. This approach works well for tidal energy converters and wind turbines (IEC 62600-200, IEC 61400-12), because the inflow speed at representative deployment sites typically varies on a daily basis. Sampling for several days, therefore, provides the range and repetition of inflow speeds that is needed to populate an accurate power curve.

Testing devices in rivers, however, presents a challenge because river flow speed typically varies on timescales of weeks to months. A device test, therefore, may need to last several months before enough data is captured to populate an accurate power curve over the range of speeds that the device is meant to operate. A test of this length may be untenable for many REC device manufacturers, and may be unnecessary for the purpose of sufficiently quantifying the power curve of many RECs.

To minimize the length and cost of REC power performance tests, this document combines the approach of testing a device at a representative site – hereinafter termed "demonstrated performance" – with the option to perform tested performance tests in a controlled scenario, such as a "push" or "pull" test, in a flume, in a tow-tank, or in a tidal-influenced environment. Demonstrated performance assessment is a requirement of this specification. Tested performance assessment is optional for the REC manufacturer for the purpose of providing additional power curve information beyond what is encountered during the demonstrated performance portion of the test. Scaled models may not be used in either the tested performance or demonstrated performance portion of the tests.

Extrapolating results beyond the range measured during either demonstrated or tested performance is not permitted. Data from the tested performance and demonstrated performance portions of the test may not be averaged together. A method for extending the demonstrated power curve using tested performance data—only for the purpose of estimating Annual Energy Production (AEP as described in IEC 62600-301)—is described in Annex B. For all other purposes, results based on data from the demonstrated performance portion shall be presented separately from results based on data from the tested performance portion. For example, figures shall clearly identify and use distinct colours for the two data sets. Discussion and conclusions regarding the REC performance should treat the demonstrated performance data as the higher quality and more reliable dataset.

6 River current energy converter (REC) description

6.1 General

A general description and diagram of the REC is required. Specifically, a description of the system, including components, subsystems and a method of operation for the REC, as well as a description of the expected operating envelope are required. Procedures for satisfying the reporting requirements specified in 10.2 are described in 6.2.

6.2 Operational parameters

As well as a detailed description of the device system and operation method, given in 10.2, the following parameters should be reported:

- REC rated capacity;
- Rated water speed;
- Equivalent diameter (D_E);
- Device width;
- Device height;
- Cut-in water current speed to begin power production;
- Low cut-out water current speed to end power production (if different from the cut-in water current speed);
- Cut-out water current speed (maximum water current speed for REC operation);
- Rotational speed range or period for an oscillating device.

7 Demonstrated performance

7.1 General

This clause describes the methods for measuring REC performance on site or in a river that is similar to the anticipated deployment locations. This demonstrated performance data should be considered more representative of performance in other locations than the "tested performance" data collected per Clause 8, and should be clearly emphasized in all reports as such. 7.5 details methods for measuring REC performance in a tidal influenced river site such as tidal channel or estuary.

7.2 Site and test conditions

7.2.1 General

The REC test site should be characterized in detail and reported prior to any assessment of power performance. Specifically, the bathymetry and flow conditions should be clearly identified. Guidance for satisfying the reporting requirements in 10.3 are described in this section.

A test site should be a region where bathymetric changes (e.g. water depth and riverbank) are small compared to the dimensions of the device. A test site should be on a straight section of a river; locations that are up- or down-stream of large sandbars, sharp bends, or other significant obstructions that alter the flow from a steady and uniform distribution should be avoided. Whenever possible, the path of the thalweg should not change by more than 30° for at least 3 river widths upstream of the test site. A test site should be a location where river bathymetry and riverbank do not change significantly during the test. Bathymetric features that do exist should be clearly documented.

7.2.2 Bathymetry

The bathymetry of the REC test site should be surveyed to ensure that it is free from obstacles and topography that could affect the performance of the REC or the local quality of the flow. It is recommended that the REC test site be surveyed 10 D_E upstream and downstream of, and 5 D_E on either side of, the REC location according to IHO Order 1a hydrographic survey standard. A depth transect through the test site and across the entire river should also be obtained to quantify the cross-sectional area of the river at the test site. The riverbed and riverbank material (sand, clay, gravel, vegetation, etc.) should be documented.

Any significant variation in the local bathymetry should be clearly identified and characterized in detail. There should be no local bathymetric disturbances present that could lead to a serious local variation in the quality and reliability of the incident resource, and thus, a misrepresentation of the REC power performance.

Any known seasonal and inter-annual variability in bathymetry should be noted, and locations where significant bathymetric changes occur should be avoided. For sites that are prone to sedimentation or deposition (shifting bathymetry), the bathymetry survey should be completed less than 30 days prior to the test. It is recommended that cross-stream bathymetry transects through the test site be completed several (>3) times throughout the test period to confirm that bathymetric changes during the test – relative to the full-sweep detailed bathymetric survey – are minimal.

7.2.3 Flow conditions

7.2.3.1 General

It is necessary to characterize the general flow conditions of the REC test site to provide context for the power performance assessment. Guidance is provided here for the assessment of the following flow conditions: principal flow direction, lateral shear (the variation of the mean stream-wise current speed in the cross-stream direction), and vertical shear (the variation of the mean stream-wise current speed in the vertical direction).

It is important to take baseline measurements of the lateral and vertical shear at a test site because significant shear can affect power performance measurements. The presence of the river bottom creates vertical shear. Sites with large lateral shear should be avoided if possible because meandering of this lateral shear across the energy-extraction plane during testing will dramatically reduce the accuracy of device performance estimates. It is important to measure principal flow direction because this indicates where the current profiler should be placed relative to the REC during testing.

The flow conditions should be assessed as a set of at least 5 vertical profiles of current speed. The vertical profile locations should be determined according to the following guidelines:

- they should be evenly spaced in a line across the river that either:
- passes through the anticipated REC test site, or
- if the REC is deployed at the test site, is 2 to 5 D_E upstream of the REC location;
- they should span a distance of twice the REC width, or the entire channel width, whichever is smaller;
- the spacing between profiles should be no more than twice the water depth;
- one of the profiles should be centred on the REC principal axis;
- at least one profile should be available on either side of the REC projected capture area.

The principal flow direction at the centroid of the projected capture area of the anticipated REC deployment location should be calculated and provided. The lateral and vertical shear