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TECHNICAL SPECIFICATION

colour inside

Marine energy – Wave, tidal and other water current converters – Part 200: Electricity producing tidal energy converters – Power performance assessment

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 200: Electricity producing tidal energy converters – Power performance assessment

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

IEC 62600-200, which is a technical specification, has been prepared by IEC technical committee TC 114: Marine energy – Wave, tidal and other water current converters.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
114/93/DTS	114/101A/RVC

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.

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

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

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication 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- withdrawn,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 200: Electricity producing tidal energy converters – Power performance assessment

1 Scope

This Technical Specification provides:

- a systematic methodology for evaluating the power performance of tidal current energy converters (TECs) that produce electricity for utility scale and localized grids;
- a definition of TEC rated power and rated water velocity;
- a methodology for the production of the power curves for the TECs in consideration;
- a framework for the reporting of results.

Exclusions from the scope of this Technical Specification are as follows:

- tidal energy converters (TECs) that provide forms of energy other than electrical energy unless the other form is an intermediary step that is converted into electricity by the TEC;
- resource assessment. This will be carried out in the tidal energy resource characterization and assessment Technical Specification (future IEC/TS 62600-201);
- scaling of any measured or derived results;
- power quality issues;
- any type of performance other than power and energy performance;
- the combined effect of multiple TEC arrays.

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 60688:2012, *Electrical measuring transducers for converting AC and DC 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 61869-2:2012, *Instrument transformers – Part 2: Additional requirements for current transformers*

IEC 61869-3:2011, *Instrument transformers – Part 3: Additional requirements for inductive voltage transformers*

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

ISO/IEC 17025:2005, *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)*

International Hydrographic Organisation: 2008, *IHO standards for hydrographic surveys, Special publication No. 44. 5th edition* (http://www.iho-ohi.net/iho_pubs/standard/S-44_5E.pdf)

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. General terms and definitions regarding marine energy found in IEC 62600-1 also apply.

3.1
acoustic current profiler
an instrument that produces a record of water current velocities for specified depth and time intervals over a pre-determined distance through the water column

Note 1 to entry: Current profilers can be configured in many ways: downward facing, mounted on boats or moorings, installed on the seabed facing upwards, or mounted on a TEC oriented in any direction desired for tidal current and wave studies. Detailed specifications for the use of acoustic current profilers are provided in this technical specification.

3.2
averaging period
the period of time, in minutes, over which data samples are averaged to calculate a data point

3.3
current profiler bin
a distance interval, typically vertically on the order of 1 m or less, that is used to group data samples and data points for calculation of certain parameters according to their corresponding distance above the seabed or below the surface

Note 1 to entry: Mean current velocity, $\overline{\mathrm{Ushear}}_{i,k,n}$, is an example of a parameter that is grouped by current profiler bins.

3.4
cut-in water velocity
water speed during the accelerating part of the tidal cycle, above which there is power production

3.5
cut-out water velocity
the maximum flow speed above which the TEC cannot continue operation

3.6
data point
a single measurement used to populate bins and obtained from averaging instantaneous data samples over the specified averaging period

Note 1 to entry: $U_{i,n}$, $P_{i,n}$ and $Q_{i,n}$ are all examples of data points.

3.7
data sample
a single measurement obtained at a minimum sampling frequency of 1 Hz used in the subsequent calculation of a data point

Note 1 to entry: $U_{i,j,k,n}$, $P_{i,j,n}$ and $Q_{i,j,n}$ are all examples of data samples. A data sample may consist of one or multiple current profiler 'pings' depending on the setting of the device.

3.8
data set
the collection of data points calculated during a specific portion of the test period, and is a subset of the test data

Note 1 to entry: For example, all data points collected during a flood tide would be considered a data set.

3.9
energy extraction plane
the plane that is perpendicular to the principal axis of energy capture where device rotation or energy conversion nominally occurs

Note 1 to entry: Refer to Figures 2 and 3 for a simplified illustration of the energy extraction plane. For devices with multiple extraction planes, an appropriate upstream energy extraction plane on both ebb and flood tides should be identified.

3.10
equivalent diameter
a common method used to transform a TEC that is non-circular in cross-section, where the cross-section is parallel to the energy extraction plane, into an equivalent device with a circular cross-section

$$D_E = \sqrt{\frac{4A}{p}}$$

where:

A is the projected capture area

Note 1 to entry: Examples of the calculation of equivalent diameter for various TEC projected capture areas are provided in Figure 1.

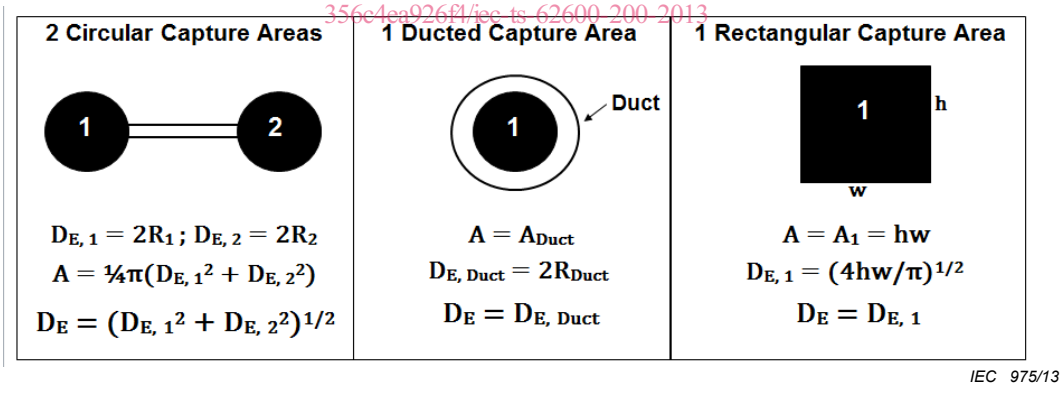

Figure 1 – Equivalent diameter calculations for various TEC projected capture areas

3.11
free-stream condition
boundary condition description for a TEC operating in a sufficiently large channel and without external influence such that its performance is equivalent to a TEC operating in a channel having a cross-section of infinite width and depth

3.12
hub height
distance from the centroid of the TEC projected capture area to the sea floor

3.13
low cut-out water velocity
water velocity during the decelerating part of the tidal cycle below which a TEC does not produce power

3.14
method of bins
a method of data reduction that groups test data for a certain parameter into sub-sets typified by an independent underlying variable that can be applied both spatially (current profiler bins) and by tidal current speed (velocity bins)

3.15
net electrical power output
the net active power at the output terminals, excluding any power generated by on-board ancillary generators or imported via separate cables

Note 1 to entry: Additional information on this term is provided in 8.8.4.

3.16
power weighted velocity
mean velocity derived with a power weighted (velocity cubed weighted) function to ensure that it is representative of the value of the incident power across the projected capture area as a standard mean of the velocity would underestimate the incident power

Note 1 to entry: A more specific definition can be found in formula (1).

3.17
principal axis of energy capture
an axis parallel to the design orientation or heading of a TEC passing through the centroid of the projected capture area

Note 1 to entry: Refer to Figure 2 for a simplified example of the principal axis of energy capture.

3.18
principal flow direction
the primary orientation or heading of the tidal current

Note 1 to entry: The primary flow directions for flood and ebb tides are nominally 180° apart; however, the exact difference between these two directions is determined by site specific factors, such as bathymetry.

Note 2 to entry: Refer to Figure 2 for a simplified example of the principal flow directions.

3.19
projected capture area
the frontal area of the TEC, or swept area in the case of an oscillating TEC, including the duct or other structures which contribute to the power extracted by the device perpendicular to the principal axis of energy capture

Note 1 to entry: If the upstream and downstream areas of the device are different, the larger area should be used in the calculation of $\eta_{System,i}$.

Note 2 to entry: The definition of projected capture area is further clarified in Figure 7.

3.20
rated water velocity
the lowest mean flow speed at which the TEC rated power is delivered to its output terminals

Note 1 to entry: Different rated water velocities may result for ebb and flood conditions depending on device design.

3.21
r.m.s. fluctuating velocity
the root-mean square of the current speed variations in each current profiler bin

Note 1 to entry: Additional details can be found in 9.5.

3.22
shear profile
the vertical variation of the mean current velocity across all measured current profiler bins

3.23
TEC annual energy production
an estimate of the total energy production of a TEC during a one-year period obtained by applying the measured flood and ebb power curves to a set of tidal current predictions, at a stated test availability

3.24
TEC footprint
the area described by the intersection of the energy extraction plane and the principal axis of energy capture for a floating TEC that is free to move on a compliant mooring

Note 1 to entry: Refer to Figure 6 for further details and an illustration on TEC footprint.

3.25
TEC output terminals
the node of a TEC power generation circuit where the output is available as an AC signal at the grid network frequency

Note 1 to entry: In the case of a DC output TEC, the output terminals are defined as the node where output power is available for battery charging or connection directly to the load.

Note 2 to entry: A full description of output terminal for both AC and DC cases is provided in 8.8.1.

3.26
TEC overall efficiency
ratio of the net power produced by the TEC at its output terminals to the power of an undisturbed flow of water with the same projected capture area as the TEC

3.27
TEC rated power
the maximum continuous electrical power measured at the TEC output terminals which the TEC is designed to achieve under normal operating conditions

3.28
TEC test site
the location of the TEC under test and the surrounding area

Note 1 to entry: A full description of TEC test site requirements is provided in Clause 5.

3.29
test availability
the ratio of the total number of hours during a test period where all test conditions are met, to the total number of hours of the test period

3.30
test data
all data points collected during the test period

3.31
test period
the period between first data collection and last data collection, for the purpose of TEC power performance assessment

Note 1 to entry: Refer to 8.3 for additional information.

3.32
tidal ellipse
a graphical representation of a tidal current in which the velocity of the current at different hours of the tidal cycle is represented by radial vectors and angles

Note 1 to entry: A line joining the extremities of the vectors will form a curve roughly approximating an ellipse.

3.33
tidal energy converter
any device which transforms the kinetic energy of tidal currents into electrical energy

3.34
velocity bin
a velocity magnitude interval, typically in the order of 0,1 m/s or less, that is used to group data samples and data points for calculation of certain parameters according to their corresponding velocity value

Note 1 to entry: Total instantaneous active electrical power, $P_{i,j,n,}$ is an example of a parameter that is grouped by velocity bins.

4 Symbols, units and abbreviations

NOTE SI units are assumed for all terms in this technical specification unless otherwise noted.

4.1 Symbols and units

A	Projected capture area of the TEC	[m^2]
A_k	Area of current profiler bin k across the projected capture area	[m^2]
D_E	Equivalent diameter	[m]
η_{System}	TEC overall efficiency	
$\eta_{System,i}$	TEC overall efficiency in velocity bin i	
h	Vertical dimension of the projected capture area	[m]
i	Index number defining the velocity bin	
j	Index number of the time instant at which the measurement is performed	
k	Index number of the current profiler bin across the projected capture area	
L	Number of samples in the defined averaging period which produces data point n	
n	Index number defining an individual data point in a velocity bin	
N_B	Number of measurement data bins	
N_i	Number of data points in velocity bin i	
N_k	Number of data points in current profiler bin k	
$\overline{P}_i$	Mean recorded TEC active power in velocity bin i	[W]
$\overline{P}_{i,n}$	Mean recorded TEC active power in velocity bin i for data point n	[W]
$P_{i,j,n}$	Magnitude of the total instantaneous active electrical power from the TEC	[W]
$\overline{Q}_i$	Mean recorded TEC reactive power in velocity bin i	[VAr]
$\overline{Q}_{i,n}$	Mean recorded TEC reactive power in velocity bin i for data point n	[VAr]
$Q_{i,j,n}$	Magnitude of the total instantaneous reactive electrical power from the TEC	[VAr]

R	Radius	[m]
S	Total number of current profiler bins across the projected capture area, normal to the principal axis of energy capture	
T	Time zone shift relative to UTC	[h]
$\overline{U}_i$	Mean power weighted tidal current velocity in velocity bin i	[m/s]
$\overline{U}_{i,n}$	Mean power weighted tidal current velocity in velocity bin i for data point n	[m/s]
$\widehat{U}_{i,j,n}$	Instantaneous power weighted tidal current velocity across the projected capture area	[m/s]
$U_{i,j,k,n}$	Magnitude of instantaneous tidal current velocity, time j, at current profiler bin k, in velocity bin i, for data point n	[m/s]
$\overline{Uellipse}_{i,k,n}$	Mean tidal current velocity in velocity bin i, for current profiler bin k at hub-height, for data point n	[m/s]
$Urms_{i,k}$	RMS fluctuating tidal current velocity in velocity bin i at current profiler bin k	[m/s]
$Urms_{i,k,n}$	RMS fluctuating tidal current velocity in velocity bin i, at current profiler bin k, for data point n	[m/s]
$\overline{Ushear}_{i,k}$	Mean tidal current velocity in velocity bin i at current profiler bin k	[m/s]
$\overline{Ushear}_{i,k,n}$	Mean tidal current velocity in velocity bin i, at current profiler bin k, for data point n	[m/s]
w	Horizontal dimension of the projected capture area	[m]
ρ	Density of water	[kg/m^3]
$\bar{\theta}_{i,k,n}$	Mean tidal current direction in velocity bin i, at current profiler bin k, for data point n	[deg]
$\theta_{i,j,k,n}$	Magnitude of the instantaneous tidal current direction, time j, at current profiler bin k, in velocity bin i, for data point n	[deg]

4.2 Abbreviations

AC	Alternating Current
AEP	Annual Energy Production
CD	Committee Draft
CT	Current Transformer
DAQ	Data Acquisition System
DC	Direct Current
EXT	Extrapolated
GPS	Global Positioning System
HAT	Highest Astronomical Tide
HV	High Voltage
IEC	International Electrotechnical Commission
IHO	International Hydrographic Organisation (Monaco)
INT	Interpolated
ISO	International Standards Organization
LAT	Lowest Astronomical Tide
LV	Low Voltage
MHW	Mean High Water
MLW	Mean Low Water