IEC/TS 62600-100

Edition 1.0 2012-08

TECHNICAL SPECIFICATION

colour inside

Marine energy – Wave, tidal and other water current converters –
Part 100: Electricity producing wave energy converters – Power performance assessment

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

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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Part 100: Electricity producing wave energy converters – Power performance assessment

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- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

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

IEC 62600-100, 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:

Enquiry draft	Report on voting
114/87/DTS	114/95/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 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.

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- withdrawn,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.

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

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The contents of the corrigendum of April 2017 have been included in this copy.

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IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This part of IEC 62600, which is a Technical Specification, provides performance assessment methods for Wave Energy Conversion Systems (WECS). A Wave Energy Converter (WEC) is a device which generates electricity using the action of water waves and delivers electricity to an electrical load.

Wave energy industry development is transitioning from preliminary stages to commercial production stages. Validated data gathering and processing techniques are important to improve existing technologies. This technical specification will be subject to changes as data are collected and processed from testing of WECS.

The expected users of the specification include:

- device developers who want to validate the performance of their WEC;
- investors who want to assess the performance of a device developer's WEC;
- project developers who want to assess the performance of their project against manufacturer's claims;
- surveyors contracted to carry out the assessment.

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

Part 100: Electricity producing wave energy converters – Power performance assessment

1 Scope

This part of IEC 62600, which is a Technical Specification, provides a method for assessing the electrical power production performance of a Wave Energy Converter (WEC), based on the performance at a testing site.

The scope of this Technical Specification includes:

a) all WECs that produce electrical power from wave energy;

b) all sea resource zones (near and offshore, deep and shallow water);

c) the specification applies to commercial scale WECs that are:

   1) compliantly moored,

   2) tautly moored,

   3) bottom mounted,

   4) shore mounted.

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The scope of this Technical Specification does not include:

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a) WECs that produce other forms of energy unless this energy is converted into electrical energy;

b) resource assessment;

c) scaled devices in test facilities (tank or scaled sea conditions) where any scaling would need to be carried out to extrapolate results for a full scale device;

d) power quality issues;

e) environmental issues;

f) power matrix transposition from one location to another.

This Technical Specification provides a systematic method which includes:

– measurement of WEC power output in a range of sea states;

– WEC power matrix development;

– an agreed framework for reporting the results of power and wave measurements.

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 60044-1, *Instrument transformers – Part 1: Current transformers*

IEC 60688, *Electrical measuring transducers for converting a.c. electrical quantities to analogue or digital signals*

IEC 61000-3 (all parts), *Electromagnetic compatibility (EMC) – Part 3: Limits*

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

ISO/IEC Guide 98-1:2009, *Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement*

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

ISO 8601, *Data elements and interchange formats – Information interchange – Representation of dates and times*

EquiMar: Protocols for the equitable assessment of marine energy converters, Part II, Chapters I.A.1 through I.A.5., Editors: David Ingram, George Smith, Claudio Bittencourt Ferreira, Helen Smith. European Commission 7th framework programme grant agreement number 213380, First Edition 2011

NDBC:2009, Technical Document 09-02, *Handbook of automated data quality control checks and procedures.* National Data Buoy Center, August 2009

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3 Symbols and units

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For the purposes of this document, the symbols and units listed in Table 1 apply.

Table 1 – Symbols and units

Symbol	Definition	Units
$f\text{cell}_i$	Frequency of occurrence in the i^{th} bin	Hz
C_{cable}	Total positive sequence line-to-line capacitance of subsea cable	farad
c_g	Group velocity	m/s
f	Frequency	Hz
f_i	Frequency at component i	Hz
$G(\theta,f)$	Energy at f distributed with angle θ NOTE $\int_{-\pi}^{+\pi} G(\theta,f)\cdot d\theta = 1$	1/rad
h	Water depth	m
H_{m0}	Spectral estimate of significant wave	m
H_s	Significant wave height	m
I_{meas}	Line current	A
J	Omnidirectional measured wave energy flux	W/m
J_i	Omnidirectional measured wave energy flux per bin	W/m
L	Capture length	m
L_i	Capture length per bin	m

Symbol	Definition	Units
M	Number of data sets in a bin	-
MAEP	Mean Annual Energy Production	Wh
m_n	Frequency n^{th} order moments of the variance spectrum	-
n	Number of sea states	-
N	Number of bins	-
P	Measured power output	W
P_i	Measured power output per bin	W
P_{meas}	Real power	W
PF_{meas}	Power factor	-
Q_{meas}	Reactive power	W
R_{cable}	Total positive sequence resistance of subsea cable	Ω
S	Spectral density	$\frac{m^2}{Hz}$
$S(f)$	Spectral density as function of frequency	$\frac{m^2}{Hz}$
$S(f)_{WEC}$	Spectral density at WEC Equals $T(f,t,\theta,h,..)\cdot S(f)_{WMI}$	$\frac{m^2}{Hz}$
$S(f)_{WMI}$	Spectral density at WMI	$\frac{m^2}{Hz}$
$S(f, \theta)$	Directional spectrum $S(f)\cdot G(\theta,f)$	$\frac{m^2}{Hz \cdot rad}$
S_i	Spectral density at frequency component i	$\frac{m^2}{Hz}$
S_p	Standard deviation	-
t	Time lag or shift between the WMI and the WEC	s
T	Operational hours per record	h
T_e	Energy period	s
$T(f, t, \theta, h,\ldots)$	Spatial transfer model, for correction of the spectral density measured at the WMI to the WEC NOTE Not all the variables are listed. The correction depends on the test site.	-
U	Line-to-line voltage	V
U_{meas}	Line-to-line r.m.s. voltage	V
V_{p1+}, V_{p1-}	WEC side positive sequence voltage	V
V_{p2}, V_{p2-}	Shore side positive voltage	V
X_{cable}	Total positive sequence reactance of subsea cable	Ω
Δf_i	Frequency spacing	Hz
ρ	Fluid density	$\frac{g}{m^3}$
θ	Wave direction	°
φ	Phase angle	°

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4 Sequence of work

Figure 1 shows the sequenced of work for the assessment as described in this technical specification. The pre-test sections shall be conducted prior to the testing period. Following the testing period the post-test sections shall be conducted.

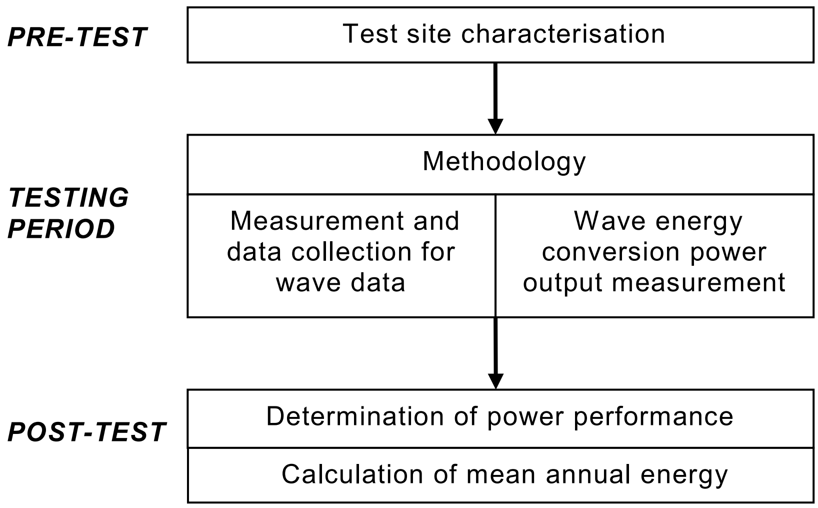

Figure 1 – Timeline of assessment

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5 Test site characterization

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5.1 General

An analysis of the prospective test site shall be undertaken to ensure that it is suitable for power assessment of a WEC. The incident wave climate shall be evaluated to ensure the power performance matrix can be populated. In order to infer the incident wave power at the location of a WEC, the effect of bathymetry and marine currents on the incident wave climate shall be sufficiently analyzed to determine whether a transfer model between the Wave Measurement Instrument (WMI) and WEC will be required. If a transfer model is required, the analysis shall support the development of a suitable transfer model.

5.2 Measurements

5.2.1 Wave measurement for wave power

A WMI shall be deployed at the proposed WEC location prior to WEC deployment. A second WMI shall be deployed simultaneously at the proposed post-deployment wave measurement location. The WMIs shall be deployed for a minimum of 3 months prior to WEC deployment and it is recommended the WMIs record data for 12 months prior to WEC deployment to account for seasonal variations.

The spectral data shall be calculated from WMI time series data. Estimates of the significant wave height estimate and energy period shall be calculated from the spectral data. The following parameters, to be used to determine the power matrix, shall be included in the determination of the power matrix:

a) spectral shape;

b) directionality of waves;

c) directional frequency spectrum;

d) water depth including tidal effect;

e) tidal and marine current, direction and velocity;

f) wind speed and direction;

g) density of water;

h) occurrence and thickness of ice.

Parameters from the above list that have not been recorded, and thus not included in the development the power matrix, shall be identified and the rationale for their exclusion justified.

5.2.2 Current measurement

Marine currents at the test site shall be recorded and documented. The current speed and direction data shall be measured simultaneously with the wave measurement and shall extend over a minimum of 30 days. The sampling period shall be a maximum of 10 minutes. At least one current speed and direction record will be taken from the upper half of the water column during the deployment period. The primary purpose of current records is to facilitate the development of a marine current model of the area. Tidal and non-tidal currents shall be estimated and differentiated.

It is recommended, however, to measure current velocity and directions at different points of the water column in order to adequately describe the velocity profile at the site.

5.2.3 Tidal measurement

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Tidal heights shall be recorded at the test site. The measurements shall extend over at least 30 days and shall be analysed to estimate tidal ranges.

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5.2.4 Bathymetric survey

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The boundary of the test site shall be defined and documented. A bathymetric survey of the area shall be undertaken and documented. The resolution of the bathymetric survey shall be as needed to support the wave spatial transfer model, see 5.2.5.

The survey should provide the details on the bottom profile.

5.2.5 Calculation of wave spatial transfer model

The sea state at the location of the WMI shall be representative of the sea state at the location of the WEC. If the difference between the energy flux at the WMI and the WEC – as determined by the deployment of a minimum of two WMIs, one at the wave measurement location and one at the WEC location – is less than 10,0 % for 90,0 % of the records then it can be assumed that the wave field is statistically equivalent.

NOTE It is expected that this will be the case for a well-chosen deep-water test site.

If the above condition is not met then a spatial transfer model shall be generated and validated. The spatial transfer model can either be an existing modelling program or a custom modelling program. The modelling program shall be validated. The accuracy of the model shall be determined as shown in Annex D.

5.2.6 Modelling of the test site

The spatial transfer model shall predict the spectrum at the WEC based on the spectrum at the WMI. The test site should be modelled to assist in the development of a spatial transfer model. The spatial transfer model shall be acceptable if it predicts the energy flux at the WEC to within 10,0 % of the measured energy flux for 90,0 % of the of the data recorded according to 5.2.1.

NOTE The spatial transfer model would generally be in the form: