

TECHNICAL SPECIFICATION



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

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INTERNATIONAL
ELECTROTECHNICAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**MARINE ENERGY –
WAVE, TIDAL AND OTHER WATER CURRENT CONVERTERS –****Part 100: Electricity producing wave energy converters –
Power performance assessment**

FOREWORD

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IEC TS 62600-100 has been prepared by IEC technical committee 114: Marine energy – Wave, tidal and other water current converters. It is a Technical Specification.

This second edition cancels and replaces the first edition published in 2012. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Incorporation of IEC TS 62600-102 as a series of annexes in this document
- b) Removal of the computation of annual energy production. This has been moved to IEC TS 62600-101.

- c) Modification to the list of terms definitions, symbols and units.
- d) Modification of the reporting section to align with IEC TS 62600-200

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

Draft	Report on voting
114/537/DTS	114/554/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.

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 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- withdrawn, or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.

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INTRODUCTION

This part of IEC 62600, which is a Technical Specification, provides performance assessment methods for wave energy converters. A wave energy converter 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 document will be subject to changes as data are collected and processed from testing of wave energy converters.

The expected users of the document include:

- Device developers who want to validate the performance of their wave energy converter.
- Investors who want to assess the performance of a device developer's wave energy converter.
- Project developers who want to assess the performance of their project against manufacturer's claims.
- Surveyors contracted to carry out the assessment.
- Conformity assessment, test laboratories, and certification.
- Project developers – income, return on investment
- Device developers – performance of device
- Utilities and investors – reliability/predictability of supply, return on investment
- Policy-makers and planners – usage of seascape, optimisation of resource, power supply issues
- Consultants to produce resource data/due diligence – compatible/readable data format

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Complete all the required elements within the email pop-up. For the Subject field please include the document title and edition you are providing feedback for (ex: feedback for TS 62600-1 ED2). In the Message field, include text which summarizes your feedback and note if further information can be made available (note attachments are not allowed). The Chair may request added information as needed before forwarding the submission to the remaining TC 114 Officers for review and then to the appropriate Working Group for their consideration.

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

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

1 Scope

Wave Energy Converters (WEC) are designed to operate efficiently at different locations. Systematic methods are used to evaluate the power performance of a WEC at a second location (hereinafter Location 2) based on power performance assessment at a first location (hereinafter Location 1). The degree of similarity of the measured WEC (WEC 1) and the metocean conditions at Location 1 to the secondary WEC (WEC 2) at Location 2 determine the methodology and the applicability of this document.

This document applied in conjunction with the IEC Technical Specification on wave energy resource assessment and characterization (IEC TS 62600-101), provides a method for estimation of the mean annual energy production of a WEC, assessing the electrical power production performance of a single, non-array, wave energy converter, at Location 2 based on the performance at Location 1.

The scope of this document includes:

- a) All wave energy converters that produce electrical power from wave energy.
- b) All sea resource zones (near and offshore, deep and shallow water).
- c) Capture width matrix transposition from one location to another.
- d) Limitation on the changes that are allowed to the WEC and the specification of the location.
- e) Wave data required at Location 2, as a minimum the requirements found in IEC TS 62600-101.
- f) Development of the capture width matrix at Location 2.
- g) Validation of the capture width matrix at Location 2.
- h) Assessment of uncertainties in the derived performance parameters at Location 2.
- i) Requirements for the allowable power performance transfer by geometric, kinematic and dynamic similarity.
- j) Requirements for the allowable incorporation of additional empirical model data.
- k) Requirements for the allowable incorporation of additional numerical model data.
- l) The document applies to commercial scale wave energy converters that are:
 - 1) compliantly moored.
 - 2) tautly moored.
 - 3) bottom mounted.
 - 4) shore mounted.

The scope of this document does not include:

- a) Wave energy converters that produce nonelectrical energy.
- b) Resource assessment.
- c) Scaled devices in test facilities (tank or scaled sea conditions) where any scaling would be carried out to extrapolate results for a full-scale device.
- d) Power quality issues.

- e) Environmental issues.
- f) Operation and maintenance.
- g) Annual energy production (AEP).

This document provides a systematic method which includes:

- measurement of WEC capture width in a range of sea states.
- transposition of capture width from one location to a second location.
- an agreed framework for reporting the results of capture width and wave measurements.
- estimate of the capture width of a modified WEC at Location 2. This work would include the development of parameters for the modified WEC for the second location.

This document provides:

- guidance on the use of observations from Location 1.
- methods for assessing and reporting the validity of numerical and physical models.
- limits on the permissible changes to the WEC between Locations 1 and 2.
- limits on the use of data fitting techniques, and
- requirements for reporting.

The wave power industry is at an early stage of development. There is little practical experience with field-scale WECs deployment. Because of this, the present document will be subject to change as more data is collected and experience with wave energy converters develops.

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 60688, *Electrical measuring transducers for converting AC and DC. electrical quantities to analogue or digital signals*

IEC 61869-1, *Instrument transformers – Part 1: General requirements*

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 62600-3, *Marine energy – Wave, tidal and other water current converters – Part 3: Measurement of mechanical loads*

IEC TS 62600-101:2015, *Marine energy – Wave, tidal and other water current converters – Part 101: Wave energy resource assessment and characterization*

IEC TS 62600-103, *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*

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

ISO/IEC Guide 98-3, *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*

ISO 19901-1, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 1: Metocean design and operating considerations*

3 Terms, definitions, symbols, units, and abbreviated terms

3.1 Terms and definitions

No terms and definitions are listed in this document.

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

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

3.2 Symbols, units, and abbreviated terms

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

Table 1 – Symbols, units, and abbreviated terms

Symbol	Definition	Units
C_{cable}	total positive sequence line-to-line capacitance of subsea cable	farad
$c_{g,i}$	group velocity at frequency component i	m/s
c_{pi}	phase velocity at frequency component i	m/s
f	frequency	Hz
f_p	peak frequency	
f_i	frequency at component i	Hz
f_i	frequency spacing	Hz
$G(\theta, f)$	directional spreading function NOTE 1 $\int_{-\pi}^{+\pi} G(\theta, f) \times d\theta = 1$	1/rad
h	water depth	m
H_{m0}	spectral estimate of significant wave	m
H_s	significant wave height	m
I_{meas}	Line RMS current	A
J	Omni-directional wave power per unit width	W/m
$\wedge J$	maximum omni-directional wave power per unit width	W/m
$\vee J$	minimum omni-directional wave power per unit width	W/m
$\bar{J}$	average omni-directional wave power per unit width	W/m
k_i	wave number at frequency component i	1/m

Symbol	Definition	Units
CW	capture width	m
$\wedge CW$	maximum capture width	m
$\vee CW$	minimum capture width	m
$\overline{CW}$	average capture width	m
$CW_{\text{model},i}$	model capture width for i^{th} bin	m
$CW_{\text{measured},i}$	measured capture width for i^{th} bin	m
$CW_{\text{err},i}$	error capture width for i^{th} bin	m
M	number of data sets in a bin	-
m_n	frequency n^{th} order moments of the variance spectrum	Hz ⁿ
n	number of records	-
N	number of bins	-
P_i	measured power output per bin	W
P_h	hydraulic power input	W
P_{abs}	absorbed power	W
P_e	measured real electrical power output	W
P_{pto}	power loss (dissipated) in the PTO	W
PF_{meas}	power factor	-
P_{meas}	real or active power	W
P_{genWEC}	power generated by WEC	W
P_{loss}	cable power loss component	W
PTO	power take off	
Q_{meas}	reactive power	VAR
R_{cable}	total positive sequence resistance of subsea cable	Ω
S	variance density	$\frac{\text{m}^2}{\text{Hz}}$
$S(f)$	variance density as function of frequency	$\frac{\text{m}^2}{\text{Hz}}$
$S(f)_{\text{WEC}}$	spectral density at WEC equals $T(f, t, \theta, h, \dots) \times S(f)_{\text{wmi}}$	$\frac{\text{m}^2}{\text{Hz}}$
$S(f)_{\text{WMI}}$	spectral density at WMI	$\frac{\text{m}^2}{\text{Hz}}$
$S(f, \theta)$	Directional wave energy spectral density $S(f) \times G(\theta, f)$	$\frac{\text{m}^2}{\text{Hz} \cdot \text{rad}}$
$S(f, \theta)_{\text{WEC}}$	Directional wave energy spectral density $S(f) \times G(\theta, f)$ at WEC	$\frac{\text{m}^2}{\text{Hz} \cdot \text{rad}}$
$S(f, \theta)_{\text{WMI}}$	Directional wave energy spectral density $S(f) \times G(\theta, f)$ at WMI	$\frac{\text{m}^2}{\text{Hz} \cdot \text{rad}}$

Symbol	Definition	Units
S_i	variance density over the i^{th} discrete frequency	$\frac{\text{m}^2}{\text{Hz}}$
S_{ij}	variance density of the i^{th} discrete frequency and j^{th} discrete direction	$\text{m}^2/\text{Hz}/\text{rad}$
σ	standard deviation	-
t	time lag or shift between the WMI and the WEC	s
T	operational hours per record	h
$T(f, t, \theta, h, \dots)$	Variance density spatial transfer model, for correction of the spectral density measured at the WMI to the WEC NOTE 2 not all the variables are listed. the transfer model dependencies will be specific to each test site.	-
T_e	energy period (also written as T_{-10})	s
Δf_i	frequency width of the variance density of the i^{th} discrete frequency	Hz
$\Delta \theta_j$	angular width of the variance density of the j^{th} discrete direction	rad
U	line-to-line voltage	V
U_{meas}	line-to-line RMS voltage	V
V_{p1+}, V_{p1-}	WEC side positive sequence voltage	V
V_{p2+}, V_{p2-}	shore side positive voltage	V
WEC	wave energy converter	
WMI	wave measurement instrument	
X_{cable}	total positive sequence reactance of subsea cable	Ω
ρ	fluid density	kg/m^3
θ	wave direction	rad
λ	wavelength	m
φ	phase angle	Degrees°
	voltage phase angle	Degrees°
	current phase angle	Degrees°
η_{pto}	power take off efficiency	-
$CF(X)$	Centre frequency fraction of errors that lie within the limits of $\pm X$ %	%

4 Sequence of work

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