

TECHNICAL SPECIFICATION



Marine energy – Wave, tidal and other water current converters – Part 101: Wave energy resource assessment and characterization





THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2015 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

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

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

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

More than 60 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.



TECHNICAL SPECIFICATION



Marine energy – Wave, tidal and other water current converters – Part 101: Wave energy resource assessment and characterization

IEC/TS 62600-101 Ed. 1.0 - Preview only Copy via ILNAS e-Shop

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.140

ISBN 978-2-8322-2724-4

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references.....	8
3 Terms and definitions	8
4 Symbols and units	10
5 Classes of resource assessment.....	11
5.1 Introductory remarks	11
5.2 Resource assessment and characterization flow chart.....	11
6 Study planning and data collection	14
6.1 Introductory remarks	14
6.2 Study area	14
6.3 Bathymetry	14
6.4 Existing wave data	14
6.5 Wave measurement	15
6.5.1 Purpose	15
6.5.2 Selection of measuring instrument and analysis methodology	15
6.5.3 Instrument calibration.....	16
6.5.4 Instrument deployment.....	16
6.5.5 Redundancy.....	17
6.5.6 Analysis of measurements.....	17
6.6 Wind data	17
6.7 Tide data	18
6.8 Current data.....	18
6.9 Ice coverage and/or exceptional environmental conditions	18
6.10 Water density.....	18
6.11 Gravitational acceleration.....	18
7 Numerical modelling	19
7.1 Introductory remarks	19
7.2 Suitable numerical models.....	19
7.3 Definition of boundary conditions.....	21
7.4 Modelling the nearshore resource.....	22
7.5 Effect of WEC array on wave energy resource	23
7.6 Validation of numerical models	23
7.6.1 Introductory remarks	23
7.6.2 Validation data specification.....	23
7.6.3 Procedure.....	24
7.6.4 Extent of validation	27
7.7 Model tuning and calibration.....	28
8 Measure–Correlate–Predict (MCP)	29
8.1 Introductory remarks	29
8.2 Procedures	29
9 Data analysis.....	30
9.1 Introductory remarks	30
9.2 Characterization using two-dimensional wave spectra	31
9.2.1 Overview	31

9.2.2	Omni-directional wave power.....	31
9.2.3	Characteristic wave height	31
9.2.4	Characteristic wave period	32
9.2.5	Spectral width	32
9.2.6	Directionally resolved wave power.....	32
9.2.7	Wave system partitioning	33
9.3	Estimation of wave power using parameterized sea states	33
9.4	Aggregation and statistics of results	34
9.4.1	General	34
9.4.2	Mean	34
9.4.3	Standard deviation	34
9.4.4	Percentiles.....	34
9.4.5	Monthly variability	34
9.5	Uncertainty of the resource assessment	35
10	Reporting of results	35
10.1	Introductory remarks	35
10.2	Selection of study points	36
10.3	Technical report	36
10.4	Digital database	36
10.5	Presentation of regional information	37
10.6	Presentation of information at study points	38
Annex A (informative)	A method for sensitivity analysis	42
A.1	General.....	42
A.2	Specification of significance	42
A.3	Sample sea states.....	42
A.4	Condition of insensitivity.....	43
Annex B (normative)	Evaluation of measurement uncertainty	44
B.1	General.....	44
B.2	Uncertainty analysis	44
Annex C (informative)	Example calculation of long-term uncertainty.....	45
C.1	General.....	45
C.2	Climatic variability	46
C.3	Anthropogenic climatic variability.....	49
C.4	Conclusion	49
Annex D (informative)	Nearshore resource	50
D.1	General.....	50
D.2	Limiting water depth	50
D.3	Bathymetry	51
D.4	Fluctuating water level	51
D.5	Currents.....	51
D.6	Validation.....	51
D.7	Uncertainty	52
Bibliography	53
Figure 1	– Wave resource assessment and characterization flow chart	13
Figure 2	– Validation flow chart	27
Figure 3	– Example map of mean annual wave power.....	38

Figure 4 – Example of a scatter table summarizing a long-term wave climate in terms of H_{m0} and T_e 40

Figure 5 – Example of a wave power rose40

Figure 6 – Example plot showing the distribution of wave power for different months.....41

Figure C.1 – Annual wave power variability in the UK. Eleven sites in North East, North West and South West Regions [4].....45

Figure C.2 – Comparison between mean annual power from the E04 model dataset and the North Atlantic Oscillation index from 1988 to 2006 [5].....46

Figure C.3 – Recorded North Atlantic Oscillation index from 1825 to 2010 (red bars), with a five year moving average (black line) [5].....47

Figure C.4 – Annual, 5-year, 10-year and 20-year moving averages of available wave power at the a site [7]48

Figure C.5 – Annual mean power and running 5, 10 and 20 year mean values, 150 km North of Scotland [6]48

Table 1 – Classes of resource assessment.....11

Table 2 – Resolution of bathymetric data.....14

Table 3 – Minimum requirements for wave measuring instruments and associated analysis.....16

Table 4 – Resolution of wind data17

Table 5 – Elements of suitable numerical models.....19

Table 6 – Minimum validation requirements25

Table 7 – Uncertainty categories35

Table 8 – Summary of wave energy resource parameters to be archived and mapped.....37

Table A.1 – Recommended sensitivity thresholds42

Table A.2 – Recommended condition of insensitivity.....43

Table B.1 – List of uncertainty components44

Table C.1 – Comparison of Mean Average Error (MAE) and Maximum error (Max error) between the 3, 5 and 10 year averages of the data at the combined UK sites and the E04 Dataset (WaveHub)46

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**MARINE ENERGY –
WAVE, TIDAL AND OTHER WATER CURRENT CONVERTERS –****Part 101: Wave energy resource
assessment and characterization**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- 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 TS 62600-101, 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
114/145/DTS	114/154A/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.

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

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.

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 Technical Specification provides a uniform methodology that will ensure consistency and accuracy in the estimation, measurement, and analysis of the wave energy resource at sites that could be suitable for the installation of Wave Energy Converters (WECs), together with defining a standardised methodology with which this resource can be described. The wave energy resource is primarily defined using hydrodynamic models that are successfully validated against measured data. This Technical Specification deals directly with the theoretical resource and the main focus of the defined methodology is to generate the resource information required to estimate energy production. Practical energy production can then be estimated in conjunction with other Technical Specifications in this series (IEC TS 62600), and by considering available technology and external constraints.

This Technical Specification provides guidance relating to the measurement, modelling, analysis and reporting of the wave energy resource, and the linkages between these activities. A framework for estimating the uncertainty of the wave energy resource estimates is also provided. Application by all parties of the methodologies recommended in this document will ensure that continuing resource assessment of potential development sites is undertaken in a consistent and accurate manner. This Technical Specification presents techniques that are expected to provide fair and suitably accurate results that can be replicated by others.

The development of the wave power industry is at an early stage and the significance of particular wave energy resource characteristics is poorly understood. Because of this, the present document is designated as a Technical Specification and will be subject to change as more data is collected and experience with Wave Energy Converters develops.

This Technical Specification, when used in conjunction with other Technical Specifications in this series (IEC TS 62600), is intended for several types of users, including but not limited to the following:

- Project developers – income, return on investment
- Device developers – performance of device
- Utilities/investors – reliability/predictability of supply, return on investment,
- Policy-makers/Planners – usage of seascape, optimisation of resource, power supply issues
- Consultants to produce resource data/due diligence – compatible/readable data format

The report required by this Technical Specification is highly technical and may be difficult to understand for some intended users. It is recommended that a short (2 to 4 pages) summary of the key findings of the resource assessment is also produced, converting some of the more technical language into information that could be readily understood by a non-technical user.