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TECHNICAL SPECIFICATION

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

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colour inside

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INTERNATIONAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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MARINE ENERGY –
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FOREWORD

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- 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- withdrawn,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.

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

Part 101: Wave energy resource assessment and characterization

1 Scope

This part of IEC 62600, which is a Technical Specification, establishes a system for estimating, analysing and reporting the wave energy resource at sites potentially suitable for the installation of Wave Energy Converters (WECs). This Technical Specification is to be applied at all stages of site assessment (from initial investigations to detailed project design) and in conjunction with the IEC Technical Specification on WEC performance (IEC TS 62600-100) enables an estimate of the annual energy production of a WEC or WEC array to be calculated. This Technical Specification is not intended for estimation of extreme wave conditions.

The wave energy resource is primarily defined using hydrodynamic models that are successfully validated against measurements. The framework and methodologies prescribed in this Technical Specification are intended to ensure that only adequate models are used, and that they are applied in an appropriate manner to ensure confidence and consistency in the reported results. Moreover, the document prescribes methods for analysing metocean data (including the data generated by modelling) in order to properly quantify and characterize the temporal and spatial attributes of the wave energy resource, and for reporting the results of a resource assessment in a comprehensive and consistent manner.

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 TS 61600-100, *Marine energy – Wave, tidal and other water current converters – Part 100: Electricity producing wave energy converters – Power performance assessment*

ISO/IEC Guide 98-3:2008, *Guide to the expression of uncertainty of measurement*

ASME 20-2009, *Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer*

IHO (International Hydrographic Organisation), 2008, *Standards for Hydrographic Surveys*, Special Publication No. 44, 5th Edition

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
class of resource assessment

3.1.1
class 1: Reconnaissance
resource assessment class requiring relatively low effort, and resulting in a resource characterization with relatively high uncertainty

Note 1 to entry: Reconnaissance (Class 1) resource assessment is one of three distinct classes of resource assessment. The remaining two classes are Feasibility (Class 2) and Design (Class 3). A Reconnaissance resource assessment is most suitable for application over large areas of seascape and would typically be the first resource assessment conducted in an area.

3.1.2
class 2: Feasibility
resource assessment class requiring relatively moderate effort, and resulting in a resource characterization with relatively moderate uncertainty

Note 1 to entry: Feasibility (Class 2) resource assessment is one of three distinct classes of resource assessment. The remaining two classes are Reconnaissance (Class 1) and Design (Class 3). A Feasibility resource assessment is most suitable for refinement of a Reconnaissance resource assessment prior to undertaking a Design resource assessment.

3.1.3
class 3: Design
resource assessment class requiring relatively high effort, and resulting in a resource characterization with relatively low uncertainty

Note 1 to entry: Design (Class 3) resource assessment is one of three distinct classes of resource assessment. The remaining two classes are Reconnaissance (Class 1) and Feasibility (Class 2). A Design resource assessment is most suitable for application over small areas of seascape and is typically the final and most detailed assessment conducted for a particular project.

3.2
wave energy resource
amount of energy that is available for extraction from surface gravity waves

Note 1 to entry: This may be characterised using the directional spectrum or by spectral parameters.

3.3
wave propagation model

3.3.1
parametric wave model
wave model using aggregate sea state parameters such as significant wave height and peak period to calculate the propagation and transformation of waves

3.3.2
2nd generation spectral wave model
wave model using a phase-averaged spectral representation of the sea-state and simplified parametric representations of non-linear interactions to calculate the propagation and transformation of waves

3.3.3
3rd generation spectral wave model
wave model using a phase-averaged spectral representation of the sea-state and explicit representation of the physical processes to calculate the propagation and transformation of waves

3.3.4
mild-slope wave model / parabolic wave model / elliptical wave model
wave model using the associated phase-resolving equation (e.g. mild-slope equation) to calculate the propagation and transformation of waves

4 Symbols and units

The results of the resource assessment shall be presented in accordance with the SI system of units. Results may also be presented in terms of an alternative system of units if desired.

$c_{g,i}$	group velocity of the i^{th} discrete frequency	[m/s]
d	directionality coefficient	
f_i	i^{th} discrete frequency	[Hz]
f_p	peak frequency	[Hz]
g	acceleration due to gravity	[m/s^2]
h	water depth	[m]
H_{m0}	spectrally estimated significant wave height	[m]
J	omni-directional wave power	[W/m]
J_θ	wave power resolved along the direction θ	[W/m]
$J_{\theta_{Jmax}}$	maximum directionally resolved wave power	[W/m]
k_i	wave number associated with the i^{th} discrete frequency	[m^{-1}]
m_n	spectral moment of n^{th} order	[m^{2}s^{-n}]
$MV(p)$	monthly variability statistic of parameter, p	
p	any parameter used to characterise the resource	
p_{max}	maximum value of the monthly mean values of p	
p_{min}	minimum value of the monthly mean values of p	
n	order of the spectral moment	
s	directional spreading parameter	
S_i	variance density over the i^{th} discrete frequency	[m^2/Hz]
S_{ij}	variance density over the i^{th} discrete frequency and j^{th} discrete direction	[m^2/Hz/rad]
T_{02}	spectrally estimated average zero-crossing wave period.	[s]
T_e	spectrally defined energy period (also written as T_{-10})	[s]
T_p	peak wave period	[s]
T_z	average zero-crossing wave period	[s]
δ	factor insuring that only positive components are summed	
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]
ϵ_0	spectral width	
ρ	reference sea water density	[kg/m^3]
θ	direction of wave propagation	[deg]
θ_{Jmax}	direction of maximum directionally resolved wave power	[deg]
φ	geographical latitude	[rad]

5 Classes of resource assessment

5.1 Introductory remarks

This document is intended to be applied across a range of resource assessment study types, from reconnaissance studies spanning a large region to detailed design studies focused on a specific site. The procedure to be followed when undertaking an assessment of a wave energy resource depends on the stage of the study and the study objectives.

Three distinct types of studies, reconnaissance, feasibility and design, are defined as indicated in Table 1. Class 1 studies are typically conducted at low to medium resolution, span a relatively large area, and produce estimates with considerable uncertainty. Resource assessments conducted to investigate the feasibility of one or more potential sites or to support the design of a specific project normally will focus on smaller areas, will employ greater resolution and should generate more certain estimates of the wave energy resource. The user shall declare the class of study being undertaken and shall follow the appropriate procedures prescribed herein.

Table 1 – Classes of resource assessment

Class	Description	Uncertainty of wave energy resource parameter estimation	Typical long-shore extent
Class 1	Reconnaissance	High	Greater than 300 km
Class 2	Feasibility	Medium	20 km to 500 km
Class 3	Design	Low	Less than 25 km

NOTE Information on typical extent is provided for guidance only. The class of resource assessment depends on the degree of certainty required, not on the extent or size of the study area.

The results and outputs from previous resource assessment studies can be considered for use as boundary conditions in more detailed studies. As the project progresses through a number of development stages, the wave energy propagation model and its application should be refined such that the uncertainty of the resource estimation decreases. The following factors may reduce uncertainty:

- use of more capable models that include more accurate representation of the physical processes, as outlined in Table 5 in 7.2;
- finer discretization in frequency, direction, space and time;
- use of more realistic boundary conditions and system forcing (winds, currents, etc.);
- availability of additional measurements for model validation; and
- modelling longer durations.

5.2 Resource assessment and characterization flow chart

The flowchart in Figure 1 depicts the general methodology outlined in this Technical Specification. Different procedures are to be followed depending on the class of the resource assessment. For class 1 studies, the resource assessment may be based either on:

a) analysis of existing archived sea state parameters, provided they were generated using a methodology consistent with the requirements for Class 1 studies set forth herein, or

b) analysis of directional spectra generated through the application of a numerical wave propagation model in a manner consistent with the requirements for Class 1 studies set forth herein, or

c) application of measure-correlate-predict methods as specified in Clause 8.

For Class 2 and Class 3 studies, the assessment shall be based on either

d) analysis of directional wave spectra generated through the application of a numerical wave propagation model in a manner consistent with the requirements for Class 2 or Class 3 studies set forth herein, or

e) application of measure-correlate-predict methods as specified in Clause 8.

Regardless of assessment class, the numerical model used to generate the directional wave spectra spanning space and time shall be appropriate for the task, configured in an appropriate manner, and successfully validated against measured oceanographic data. The boundary conditions and source terms (i.e. wind fields, current fields) used to force the numerical model shall also be suitable and verified.

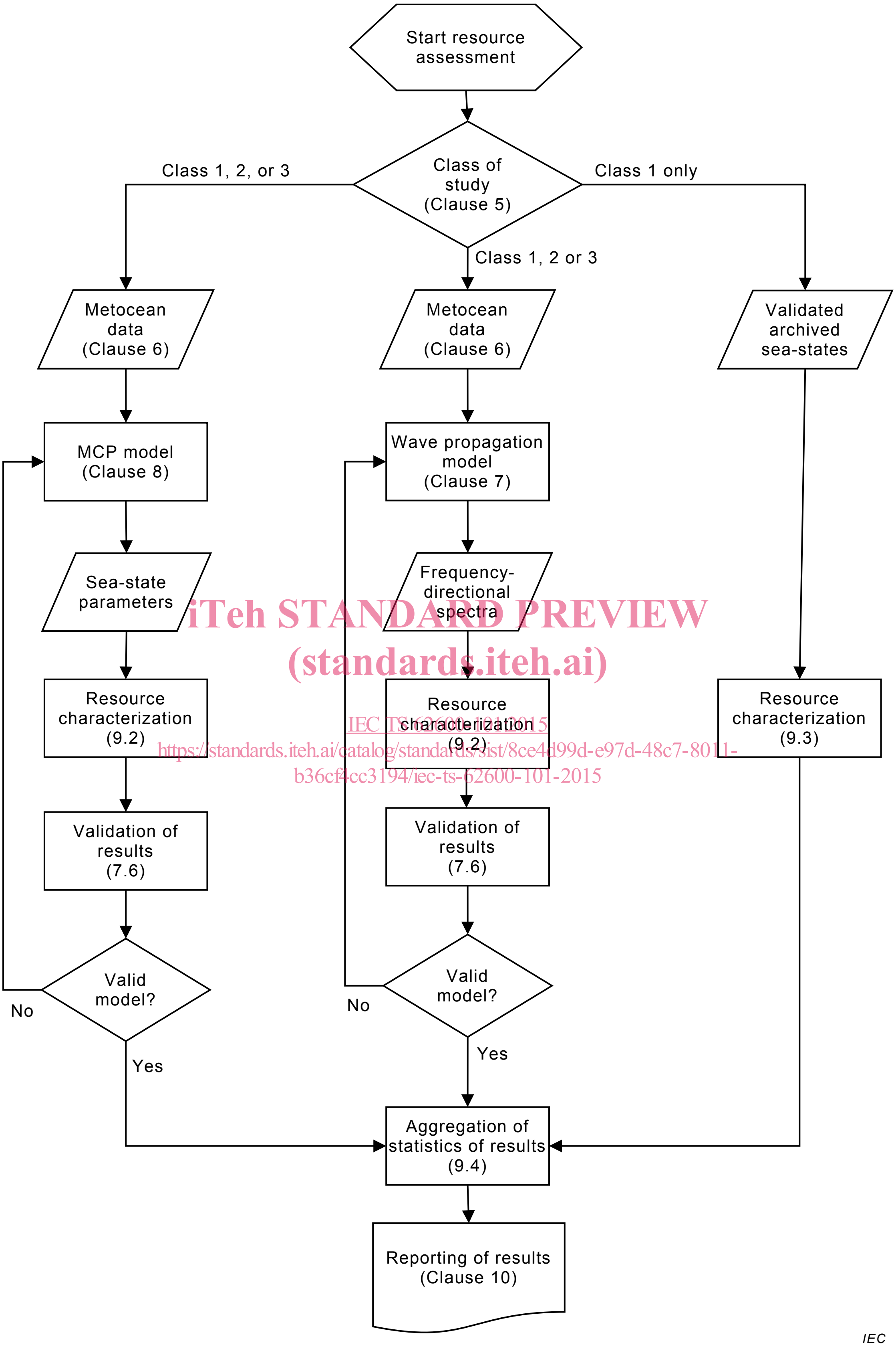

Figure 1 – Wave resource assessment and characterization flow chart