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TECHNICAL SPECIFICATION

Marine energy – Wave, tidal and other water current converters –
Part 301: River energy resource assessment

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FOREWORD

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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 TS 62600-301, 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
114/285/DTS	114/301/RVDTS

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document 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- withdrawn,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.

INTRODUCTION

The extraction of energy from flowing water in rivers and canals is gaining acceptance around the world as a means of generating electricity without the use of conventional hydropower dams. The purpose of this document is to provide a uniform methodology that will ensure consistency and accuracy in the estimation, measurement, characterisation, and analysis of the river-velocity resource at sites that could be suitable for the installation of an individual or array of River Energy Converters (RECs), together with defining a standardised methodology with which this resource can be described and reported. Application of the estimation, measurement, and analysis techniques recommended in this document will ensure that resource assessment is undertaken in a consistent and equitable manner. This document presents techniques that are expected to provide fair and suitably accurate results that can be replicated by others. This document is intended to be updated as understanding of the resource and its response to power extraction improves.

The overall goal of the methodology is to enable calculation of the Annual Energy Production (AEP) for the proposed individual or array of river energy converters either as part of a feasibility study (generic river energy converter) or a full study. For the full study, this methodology is employed in conjunction with IEC TS 62600-300 applied at each river energy converter location. Consistency is also maintained with IEC TS 62600-201 wherever possible.

In this document, the river energy resource (undisturbed or disturbed by power extraction) is defined by the velocity duration curve. This document describes only the aspects of the resource required to calculate the velocity duration curve and it does not describe aspects of the resource required to evaluate design loads or to satisfy environmental regulations. Furthermore, this document is not intended to cover every eventuality that may be relevant for a particular project. Therefore, this document assumes that the user has access to, and reviews, other relevant IEC documentation before undertaking work (e.g., surveys and modelling), which could also satisfy other requirements.

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

Part 301: River energy resource assessment

1 Scope

This part of IEC 62600 provides:

- Methodologies that ensure consistency and accuracy in the determination of the theoretical river energy resource at sites that may be suitable for the installation of River Energy Converters (RECs);
- Methodologies for producing a standard current speed distribution based on measured, historical, or numerical data, or a combination thereof, to be used in conjunction with an appropriate river energy power performance assessment;
- Allowable data collection methods and/or modelling techniques; and
- A framework for reporting results.

The document explicitly excludes:

- Technical or practical resource assessments;
- Resource characterisation;
- Power performance assessment of river energy converters; and
- Environmental impact studies, assessments, or similar.

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

IEC TS 62600-201, *Marine energy – Wave, tidal and other water current converters – Part 201: Tidal energy resource assessment and characterization*

IEC TS 62600-300, *Marine energy – Wave, tidal and other water current converters – Part 300: Electricity producing river energy converters – Power performance assessment*

ISO 1100-2:2010, *Hydrometry – Measurement of liquid flow in open channels – Part 2: Determination of the stage-discharge relationship*

ISO 9825:2005, *Hydrometry – Field measurement of discharge in large rivers and rivers in flood*

ISO 15769:2010, *Hydrometry – Guidelines for the application of acoustic velocity meters using the Doppler and echo correlation methods*

ISO 18365:2013, *Hydrometry – Selection, establishment and operation of a gauging station*

ISO TS 19130-2:2014, *Geographic information – Imagery sensor models for geopositioning – Part 2: SAR, InSAR, lidar and sonar*

ISO TR 24578:2012 *Hydrometry – Acoustic Doppler profiler – Method and application for measurement of flow in open channels*

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

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

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

ICES, 2006, *Guidelines for Multibeam Echosounder Data*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 62600-1 and the following apply.

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

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

3.1
equivalent diameter
<of a river energy converter> diameter of a circle with area equal to the device **projected capture area**

3.2
power-weighted speed
<of a river energy converter> mean current speed derived with the weighted function of the cube of the speed across the **projected capture area**

3.3
principal flow direction
<of a river current> primary orientation or heading of the **river current**

3.4
project blockage ratio
<of a river energy converter> ratio of the sum total of the flow-facing area of the moving and non-moving parts of all **river energy converters** divided by the average channel cross-sectional area

Note 1 to entry: The average cross-sectional area is calculated by dividing the volume of the fluid in the river energy converter site, determined from bathymetry subject to the lowest operational flow, by the length of the project site along the direction of flow.

3.5
project site
<of a river energy converter> portion of the river within which **river energy converters** and their entire supporting infrastructure are located

3.6
projected capture area
<of a river energy converter> frontal area perpendicular to the **principal flow direction** of **river energy converter** components hydrodynamically utilised in energy conversion

4 Symbols, units and abbreviated terms

4.1 Symbols and units

a, b Linear fit coefficients for index rating (–)

A Projected capture area of the REC (m^2)

$A_{i,k}$ Area of current speed bin i,k (m^2)

$A(h)$ Cross-sectional area of the river as a function of water level, h (m^2)

B Number of current speed bins (–)

B_i Width of the i^{th} bin for the VDC (–)

d River depth (m)

D_E Equivalent diameter (m)

EP Energy production (kW)

F Exceedance probability (%)

Fr Froude number (–)

h River water level (stage) (m)

i Rank (–)

I Turbulence intensity (–)

k Index number across the vertical dimension of current speed bins (–)

n Number of discharge (or velocity) measurements (–)

N_B Number of velocity bins for the VDC (–)

N_h Number of hours in the month or year of interest (–)

$P_i(U_i)$ Power according to the REC power curve (kW)

Q Discharge (m^3/s)

S Total number of current speed bins (–)

U_i Speed of the i^{th} bin from the VDC (m/s)

$\hat{V}$ REC power-weighted speed

V_{avg} Average velocity for a river cross section (m/s)

V_i Index velocity (m/s)

$V_{i,k}$ Speed of the river velocity at current speed bin i,k (m/s)

4.2 Abbreviated terms

ADV Acoustic Doppler velocimeter

AEP Annual energy production

CP Current profiler

EP Energy production

FDC Flow duration curve

GPS Global positioning system

IEC International Electrotechnical Commission

IHO International Hydrographic Organization

ISO International Organization for Standardization

MEP Monthly energy production

MV Moving vessel

NTP Network time protocol

PST Phase space thresholding

REC River energy converter

RTK Real time kinetic

TS Technical specification

VDC Velocity duration curve

5 Methodology overview

5.1 Study classification

Two types of studies are covered in this document: a full study and a feasibility study. The distinction between the two is based on the amount of information available for the RECs to be employed (i.e., whether it is a generic REC or has been extensively characterised with regard to its performance). To complete the analysis, the following details of the REC shall be available:

- REC dimensions including position in the water column and swept area;
- REC power curve with specified freestream measurement location;
- REC operational range; and
- REC thrust coefficient (for projects that include modelling energy extraction by the REC).

For the full study, REC data are supplied by the manufacturer following IEC TS 62600-300. For the feasibility study, a generic REC is chosen and all supporting device data shall be presented with justification in the report. The power and thrust coefficient shall be defined as a range and therefore the feasibility study will result in an AEP range.

5.2 Project location identification

There is no required methodology for identifying particular project locations. This document assumes that a project location has already been identified; however, some or all of the methods outlined herein may be used to assist with project-location identification.

In this document, projects are considered small when the project blockage ratio is less than 5 %. Projects with blockage ratios greater than 5 % are considered large.

5.3 Resource definition

This document describes the methodology for the resource assessment, which consists of the determination of the VDCs required for computing the AEP for individual or arrays of RECs.

5.4 Methodology

5.4.1 General

The resource assessment requirements are defined depending on the scale of the project relative to the scale of the resource at the project location as well as the availability of measurement data of sufficient quality and duration relative to the annual hydraulic cycle. The resource assessment may be undertaken based upon exclusive use of site data or upon numerical-model simulations used in conjunction with direct measurements for model calibration and validation. A combination of measurements and numerical models may be used to generate the required data for different parts of the resource assessment.

The following assumptions are made:

- The turbines are operating, therefore excluding impact of maintenance or technical issues on the resource assessment;
- The turbines are operating in steady flow. Transient flow conditions due to flooding or due to human impact such as filling or draining of a reservoir are excluded; and
- The turbines are operating in subcritical flow, i.e. with a Froude number smaller than 1:

$$Fr = \frac{V_{\text{avg}}}{\sqrt{gd}} < 1 \tag{1}$$

where

V_{avg} is the average velocity,

g is the gravitational acceleration, and

d is the water depth.

NOTE While installation in supercritical flow, such as at rapids may be feasible, this type of installation would most likely be small scale due to the nature (shallow, highly localised, high-velocity flow) of such flow systems. Further, a turbine-triggered hydraulic jump is likely, however, capturing this effect in a model is challenging, and could lead to significant error in the resource assessment.

The flowchart in Figure 1 outlines the methodology for performing the resource assessment. The flowchart maps the multiple viable pathways through the methodology (centre of flowchart) and includes all requirements (left and right sides of the flowchart). The rectangles represent the required goals of the resource assessment, the ovals represent the different paths to achieve these goals, and the rounded rectangles represent the measurements required to support each step of the process. Table 1 outlines the various measurements, their purpose, the minimum quantity, and the standardised collection method.

5.4.2 Flow duration curves

A flow duration curve (FDC) quantifies the percentage of time that the discharge in a river exceeds a particular magnitude typically compiled on a monthly or annual basis. To produce the FDC, at least 10 out of the previous 15 years of discharge and water-level field data for the project site shall be used. If the specified minimum duration of field data is not available, regional hydrological modelling shall be performed to develop at least 10 years of data, validated with at least one year of discharge measurements. This document describes the acceptable methodology for collecting the necessary field data, performing the model simulations, and creating the FDC based on measured (6.2) or modelled (6.3) data.

5.4.3 Velocity duration curves

5.4.3.1 General

A VDC quantifies the percentage of time that REC power-weighted speed at a REC location exceeds a particular value. The relationship between the river discharge and the corresponding speed at each REC location needs to be ascertained to develop the VDC. For small projects (project blockage ratio less than 5 %) where each REC has at least 10 D_{E} downstream spacing, and where no flow modification for enhancing the power is incorporated, the VDC may be estimated from direct hydrodynamic measurements as described in 7.2.

For all other projects, the VDC shall be assessed by hydrodynamic modelling including the effect of energy extraction with appropriate verification by measurements. Of course, even small projects may implement the hydrodynamic modelling required for larger projects. If the resource assessment reveals that RECs should be deployed in different locations where field data have not been collected, then a combined data-collection and modelling effort focused on the new REC locations shall be implemented.

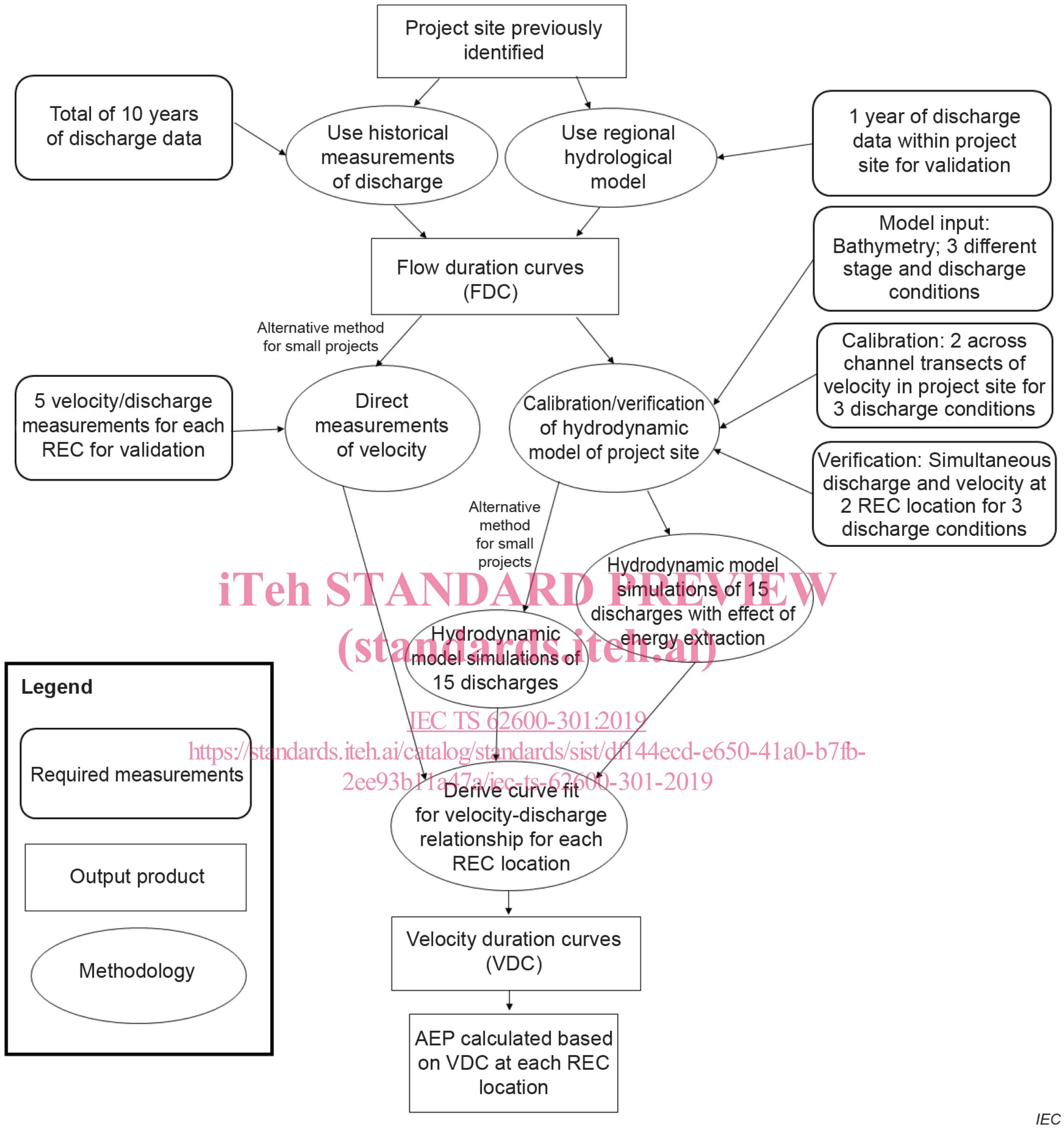

Figure 1 – Flowchart outlining the methodology for a resource assessment

Table 1 – Outline of measurements

Types of measurements	Purpose	Number of measurements	Method	Clause
Discharge	Measurement FDC	10 years of daily field data	ISO 1100-2, ISO 18365	A.3
	Hydrology model FDC	1 year of daily field data for validation		
	Boundary conditions for hydrodynamic model validation	3 different discharges for each calibration (i.e., high-flow, median-flow, and low-flow calibrations)		
*Water level	Boundary condition and calibration of the hydrodynamic model	Upstream and downstream boundaries and within the project site during discharge measurements	ISO 18365: 2013	A.2
Bathymetry	Cross-sectional data Field data for the hydrodynamic model	At least 1 set (more if river morphology is seasonal and multiple model grids are used)	IHO, S-44: 2008	A.1
*Cross-section velocity contour *Cross-channel transects of flow velocity	Calibration of the hydrodynamic model	4 transects for each river cross-section, for each discharge used in the calibration	Vessel or in situ, ISO 15769	A.4.2
Vertical distribution of velocity at REC location	*Validation of hydrodynamic model	2 REC locations for each of the 3 discharge conditions	Vessel or *in situ*	A.4.1
	Computation of VDC from measurements	5 velocity/discharge measurements from each REC location		
*Turbulence	Optional for the hydrodynamic model	Each discharge	Vessel or *in situ*	A.5
*Only needed for projects using hydrodynamic models to compute the VDC as defined in 7.3.				

5.4.3.2 Direct measurement method

This document describes the acceptable methodology for collecting velocity and water-level data in 7.2. Velocity data shall be collected at each REC location, but the water-level data (stage) may be obtained anywhere within the project site. Total-discharge data shall be collected simultaneously with the water-level and velocity field data to determine the relationship between the current speed, water level, and discharge, which is then used to develop the VDC.

5.4.3.3 Numerical modelling method

This document describes the acceptable methodology for determining the current speed/discharge relationship based on numerical-model simulations in 7.3. First, the required hydrodynamic model features are described, then the model inputs and required field data are stipulated. The model shall have sufficient grid resolution to resolve individual REC locations. Calibration field data consist of water-level measurements within the project region and cross-channel transect measurements of current velocities. The model may have separate calibration parameters (e.g., horizontal and vertical momentum diffusivities, eddy viscosities, etc.) for different flow conditions; however, the model shall be validated for each set of calibrated parameters with independent direct measurements of the vertical profile of velocity at an individual REC location for three different discharges. Verification field data consists of