IEC TS 62600-300

Edition 1.0 2019-09

TECHNICAL SPECIFICATION

colour inside

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

IEC TS 62600-300:2019-09(en)

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

Part 300: Electricity producing river energy converters – Power performance assessment

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

IEC TS 62600-300, 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:

Draft TS	Report on voting
114/284/DTS	114/300/RVDTS 114/300A/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- withdrawn,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.

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

Part 300: Electricity producing river energy converters – Power performance assessment

1 Scope

This part of IEC 62600 provides:

- A systematic methodology for evaluating the power performance of river current energy converters (RECs) that produce electricity for utility scale and localized grids;
- A definition of river energy converter rated capacity and rated water speed;
- A methodology for the production of power curves for the river energy converters in consideration; and
- A framework for the reporting of results.

Exclusions from the scope of this document are as follows:

- RECs that provide forms of energy other than electrical energy unless the other form is an intermediary step that is converted into electricity by the river energy converter;
- Resource assessment, that will be addressed separately in the River Energy Resource Assessment Technical Specification;
- Scaling of any measured or derived results;
- Power quality issues;
- Any type of performance other than power and energy performance; and
- The combined effect of multiple river energy converter arrays.

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 60041, *Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines*

IEC 60688:2012, *Electrical measuring transducers for converting A.C. and D.C. electrical quantities to analogue or digital signals*

IEC 61400-12-1:2005, *Wind turbines – Part 12-1: Power performance measurements of electricity–producing wind turbines*

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 62600-1:2011, *Marine Energy – Wave, tidal and other water current converters – Part 1: Terminology*

IEC TS 62600-100:2012, *Marine Energy – Wave, tidal and other water current converters – Part 100: Electricity producing wave energy converters – Power performance assessment*

IEC TS 62600-200:2013, *Marine Energy – Wave, tidal and other water current converters – Part 200: Electricity producing tidal energy converters – Power performance assessment*

IEC TS 62600-301:2019, *Marine Energy – Wave, tidal and other water current converters – Part 301: River energy resource assessment*

ISO IEC 17025:2017, *General requirements for the competence of testing and calibration laboratories*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 62600-1 as well as 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
blockage ratio
<of a river energy converter> ratio of the flow-facing area of the moving and non-moving parts, to the river cross-sectional area at the test site

3.2
demonstrated performance
<of a river energy converter> portion of device operation for performance assessment that occurs in a river that is representative of sites where the device will be deployed commercially

Note 1 to entry: Refer to Clause 7 for additional information.

Note 2 to entry: This contrasts with the term tested performance.

3.3
energy extraction plane
<of a river energy converter> the plane that is perpendicular to the principal axis of energy capture where device rotation or energy conversion nominally occurs

3.4
equivalent diameter
<of a river energy converter> diameter of a circle with area equal to the device **projected capture area**

3.5
principal axis of energy capture
<of a river energy converter> axis parallel to the design orientation or heading of a River Energy Converter passing through the centroid of the **projected capture area**

3.6
principal flow direction
<of a river current> primary orientation or heading of the **river current**

3.7
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**

3.8
projected capture area
<of a river energy converter> frontal area perpendicular to the **principal flow direction** of the **current energy converter** components hydrodynamically utilized in energy conversion

3.9
rated water speed
<of a river energy converter> lowest mean flow speed at which the river energy converter rated capacity is delivered to its output terminals

3.10
tested performance
<of a river energy converter> portion of device testing that is for the purpose of extending the power curve beyond the range of velocities that is measured in the **demonstrated performance** portion of the test

4 Symbols, units and abbreviated terms

4.1 Symbols and units

Symbol	Description	Unit
A	Projected capture area of the REC	[m^2]
$A_{Channel}$	Channel cross-sectional area at the test site at a particular volumetric flow rate	[m^2]
A_{duct}	Projected capture area of a ducted structure	[m^2]
AEP	Annual energy production	
A_k	Area of kth current profiler bin across the projected capture area	[m^2]
A_{Total}	Cross-sectional area including all support structures	[m^2]
B	Total number of speed bins in the horizontal direction across the projected capture area normal to the principal axis of energy capture	[-]
D_E	Equivalent diameter	[m]
h	Height of the capture area	[m]
i	Index number of the current speed bin	[-]
$i_1, i_2, \ldots i_N$	The set of data point indices, t, in speed bin i	[-]
j	Index number of the time instant when the measurement is performed	[-]
k	Index number of the current profiler bin across the projected capture area	[-]
L_U	Number of current speed data samples in the defined averaging period that produces data point t	[-]
L_P	Number of power data samples in the defined averaging period that produces data point t	[-]
M		
N_i	Number of data points in speed bin i	[-]

Symbol	Description	Unit
$\overline{P}_i$	Mean recorded REC active power in speed bin i	[W]
P_j	Magnitude of the total instantaneous active electrical power from the REC	[W]
$\breve{P}_i$	Mean REC active power after combining demonstrated data with scaled test data	[W]
$\tilde{P}_t$	Mean recorded REC active power output of the t^{th} data point	[W]
$\overline{Q}_i$	Mean recorded REC reactive power in speed bin i	[var]
Q_j	Magnitude of the total instantaneous reactive electrical power from the REC	[var]
$\tilde{Q}_t$	Mean recorded REC reactive power output of the t^{th} data point	[var]
R	Radius of circular capture area	[m]
S	Total number of current profiler bins normal to the principal axis of energy capture across the projected capture area	[-]
t	Index number of a data point	[-]
T	Number of hours variation from UTC time	[h]
U_i	Current speed of speed bin i	[m/s]
$\overline{U}_i$	Mean current speed in speed bin i	[m/s]
$\hat{U}_j$	The power-weighted current speed in m/s averaged across the projected capture area	[m/s]
$U_{j,k}$	Current speed flowing through current profiler bin k of the projected capture area, at time instant j	[m/s]
$\tilde{U}_t$	Power-weighted mean current speed of the t^{th} data point	[m/s]
$\tilde{U}_{t,k}$	Current speed data point in current profiler bin k over a given averaging period at a specific speed increment	[m/s]
$Ua_{j,k}$	Current speed flowing through the k^{th} current profiler bin of current profiler *a,*	[m/s]
$Ub_{j,k}$	Current speed flowing through the k^{th} current profiler bin of current profiler *b*	[m/s]
$\widetilde{Umean}_{t,k}$	Mean current speed flowing through current profiler bin k at the centroid of the projected capture area	[m/s]
$\overline{Urms}_{i,k}$	RMS fluctuating current speed in current profiler bin k at the centroid of the projected capture area at speed bin i	[m/s]
$\widetilde{Urms}_{t,k}$	RMS fluctuating current speed in current profiler bin k over the specified averaging period	[m/s]
$\overline{Ushear}_{i,k}$	Mean current speed in speed bin i at current profiler bin k	[m/s]
w	Width of the capture area	[m]
$\eta_{system,i}$	REC overall efficiency in current speed bin i	[-]
ΔU	speed bin increment	[m/s]
γ	The test-data power scale factor	[-]
$\theta_{j,k}$	The river current direction of the hub height current profiler bin k	[°]
$\tilde{\theta}_{t,k}$	Mean river current direction of the hub height current profiler bin k over the defined averaging period	[°]
ρ	Fluid density	[kg m^{-3}]

4.2 Abbreviated terms

Abbreviation	Description
AC	Alternating Current
DC	Direct Current
GPS	Global Positioning System
IEC	International Electrotechnical Commission
IHO	International Hydrographic Organisation
ISO	International Organisation for Standardization
REC	River Energy Converter
RMS	Root Mean Square
UTC	Coordinated Universal Time

5 Overview

The primary objective of this document is to quantify the power output of a River Energy Converter (REC) as a function of the current speed inflow in which it is designed to operate, i.e. to quantify the device's "power curve". The accepted approach for accomplishing this is to deploy a device at a representative deployment site, and simultaneously measure the inflow speed to the device and the power output from it over a range of inflow speeds. This approach works well for tidal energy converters and wind turbines (IEC 62600-200, IEC 61400-12), because the inflow speed at representative deployment sites typically varies on a daily basis. Sampling for several days, therefore, provides the range and repetition of inflow speeds that is needed to populate an accurate power curve.

Testing devices in rivers, however, presents a challenge because river flow speed typically varies on timescales of weeks to months. A device test, therefore, may need to last several months before enough data is captured to populate an accurate power curve over the range of speeds that the device is meant to operate. A test of this length may be untenable for many REC device manufacturers, and may be unnecessary for the purpose of sufficiently quantifying the power curve of many RECs.

To minimize the length and cost of REC power performance tests, this document combines the approach of testing a device at a representative site – hereinafter termed "demonstrated performance" – with the option to perform tested performance tests in a controlled scenario, such as a "push" or "pull" test, in a flume, in a tow-tank, or in a tidal-influenced environment. Demonstrated performance assessment is a requirement of this specification. Tested performance assessment is optional for the REC manufacturer for the purpose of providing additional power curve information beyond what is encountered during the demonstrated performance portion of the test. Scaled models may not be used in either the tested performance or demonstrated performance portion of the tests.

Extrapolating results beyond the range measured during either demonstrated or tested performance is not permitted. Data from the tested performance and demonstrated performance portions of the test may not be averaged together. A method for extending the demonstrated power curve using tested performance data—only for the purpose of estimating Annual Energy Production (AEP as described in IEC 62600-301)—is described in Annex B. For all other purposes, results based on data from the demonstrated performance portion shall be presented separately from results based on data from the tested performance portion. For example, figures shall clearly identify and use distinct colours for the two data sets. Discussion and conclusions regarding the REC performance should treat the demonstrated performance data as the higher quality and more reliable dataset.

6 River current energy converter (REC) description

6.1 General

A general description and diagram of the REC is required. Specifically, a description of the system, including components, subsystems and a method of operation for the REC, as well as a description of the expected operating envelope are required. Procedures for satisfying the reporting requirements specified in 10.2 are described in 6.2.

6.2 Operational parameters

As well as a detailed description of the device system and operation method, given in 10.2, the following parameters should be reported:

- REC rated capacity;
- Rated water speed;
- Equivalent diameter (D_E);
- Device width;
- Device height;
- Cut-in water current speed to begin power production;
- Low cut-out water current speed to end power production (if different from the cut-in water current speed);
- Cut-out water current speed (maximum water current speed for REC operation);
- Rotational speed range or period for an oscillating device.

7 Demonstrated performance

7.1 General

This clause describes the methods for measuring REC performance on site or in a river that is similar to the anticipated deployment locations. This demonstrated performance data should be considered more representative of performance in other locations than the "tested performance" data collected per Clause 8, and should be clearly emphasized in all reports as such. 7.5 details methods for measuring REC performance in a tidal influenced river site such as tidal channel or estuary.

7.2 Site and test conditions

7.2.1 General

The REC test site should be characterized in detail and reported prior to any assessment of power performance. Specifically, the bathymetry and flow conditions should be clearly identified. Guidance for satisfying the reporting requirements in 10.3 are described in this section.

A test site should be a region where bathymetric changes (e.g. water depth and riverbank) are small compared to the dimensions of the device. A test site should be on a straight section of a river; locations that are up- or down-stream of large sandbars, sharp bends, or other significant obstructions that alter the flow from a steady and uniform distribution should be avoided. Whenever possible, the path of the thalweg should not change by more than 30° for at least 3 river widths upstream of the test site. A test site should be a location where river bathymetry and riverbank do not change significantly during the test. Bathymetric features that do exist should be clearly documented.

7.2.2 Bathymetry

The bathymetry of the REC test site should be surveyed to ensure that it is free from obstacles and topography that could affect the performance of the REC or the local quality of the flow. It is recommended that the REC test site be surveyed 10 D_E upstream and downstream of, and 5 D_E on either side of, the REC location according to IHO Order 1a hydrographic survey standard. A depth transect through the test site and across the entire river should also be obtained to quantify the cross-sectional area of the river at the test site. The riverbed and riverbank material (sand, clay, gravel, vegetation, etc.) should be documented.

Any significant variation in the local bathymetry should be clearly identified and characterized in detail. There should be no local bathymetric disturbances present that could lead to a serious local variation in the quality and reliability of the incident resource, and thus, a misrepresentation of the REC power performance.

Any known seasonal and inter-annual variability in bathymetry should be noted, and locations where significant bathymetric changes occur should be avoided. For sites that are prone to sedimentation or deposition (shifting bathymetry), the bathymetry survey should be completed less than 30 days prior to the test. It is recommended that cross-stream bathymetry transects through the test site be completed several (>3) times throughout the test period to confirm that bathymetric changes during the test – relative to the full-sweep detailed bathymetric survey – are minimal.

7.2.3 Flow conditions

7.2.3.1 General

It is necessary to characterize the general flow conditions of the REC test site to provide context for the power performance assessment. Guidance is provided here for the assessment of the following flow conditions: principal flow direction, lateral shear (the variation of the mean stream-wise current speed in the cross-stream direction), and vertical shear (the variation of the mean stream-wise current speed in the vertical direction).

It is important to take baseline measurements of the lateral and vertical shear at a test site because significant shear can affect power performance measurements. The presence of the river bottom creates vertical shear. Sites with large lateral shear should be avoided if possible because meandering of this lateral shear across the energy-extraction plane during testing will dramatically reduce the accuracy of device performance estimates. It is important to measure principal flow direction because this indicates where the current profiler should be placed relative to the REC during testing.

The flow conditions should be assessed as a set of at least 5 vertical profiles of current speed. The vertical profile locations should be determined according to the following guidelines:

- they should be evenly spaced in a line across the river that either:
- passes through the anticipated REC test site, or
- if the REC is deployed at the test site, is 2 to 5 D_E upstream of the REC location;
- they should span a distance of twice the REC width, or the entire channel width, whichever is smaller;
- the spacing between profiles should be no more than twice the water depth;
- one of the profiles should be centred on the REC principal axis;
- at least one profile should be available on either side of the REC projected capture area.

The principal flow direction at the centroid of the projected capture area of the anticipated REC deployment location should be calculated and provided. The lateral and vertical shear should be presented as cross-stream contour plots of the current speed profiles, line-plots of those profiles, or as tabulated data of those profiles.

In order to resolve the mean-current speed (non-turbulent) estimates of these variables it is important to average at least 10 min of current speed measurement data at each profile location. The vertical profiles can be obtained from one of the following methods:

- from models corroborated by measurements;
- from current profiler transects.

7.2.3.2 Estimating flow conditions from models

Models corroborated by measurements may be used to estimate the flow conditions. For example, a model from a resource assessment (IEC TS 62600-301) may be used to assess and report flow conditions. The flow conditions should be taken from the model when the model flow state is representative of the conditions expected during the test period (i.e. when the river flow of the model is similar to the test period). If the model uses a time step of less than 10 min several time steps should be averaged together to obtain a 10 min average. The estimate of principal flow direction and lateral or vertical shear should be corroborated by current profiler measurements taken during resource assessment, or during the test period.

7.2.3.3 Estimating flow conditions from current profiler transects

The flow conditions (5 vertical profiles of downstream current speed) may be measured using a boat-mounted, downward-looking current profiler. These measurements should be made when the flow rate of the river is similar to what is expected during the test period. The locations of the profiles should be determined prior to performing transects according to the guidelines in 7.2.3. The spacing between sampling levels should follow the same guidelines as in 7.3.2. These profiles can be obtained by either:

- performing repeated transects across the river, and performing spatial binning until each bin contains the required 10 min of data;
- holding station over each profile location for at least 10 min.

Spatial binning involves breaking transects into sections that are each nearest to the profile location, and averaging together data from all transects that fall within a section. A current profiler measurement may be included in a profile only if it is within a distance less than twice the water depth of the profile location.

7.2.4 REC test site constraints

REC performance assessment may be affected by a variety of external influences that need to be mitigated. The REC test site, therefore, should be representative of the final deployment environment and bathymetry, with the following constraints:

- The REC test site should be free from any performance enhancing features (i.e. objects or terrain that deflect flow to create local increases in the incident resource) located between the flow measurement devices and the capture area;
- If the blockage ratio is high (e.g., >5 %), then the flow may not divert naturally around the REC as would occur in free-stream conditions. This could result in performance measurements that misrepresent the true REC performance when free from external influences (commonly referred to as blockage effects). The REC test site cross-sectional area should therefore be representative of a typical deployment site. A diagram illustrating the proportion of channel cross-sectional area occupied by the projected area of the REC and supporting structure (including foundations) onto the plane perpendicular to the principal flow direction should be provided (example provided in Figure 9). Information should be provided for both the low- and high-discharge conditions observed during the test. Dimensions should be provided for the distance of the centroid of the projected capture area above the riverbed and below the free surface, and the proximity to any fixed boundaries should be reported.

7.2.5 External constraints

Any external constraints that effect either data measurement or recording should be listed in the report. Continuous operation of a REC during the test period is strongly preferred and any external constraints that may prevent REC operation should be identified during test planning and reported clearly. It is also necessary to identify the external constraints that may limit the ability to satisfy the data collection requirements, as given in 7.4.3. Additional constraints should be addressed and summarized as appropriate given the individual REC test site. In any event only data that meets the requirements of 7.4.3 should be allowed when evaluating the performance. Potential constraints may include, but are not limited to:

- Regulatory limitations;
- Electric grid conditions;
- Permitting limitations;
- Abnormal weather related events.

7.3 Test equipment

7.3.1 Electric power measurement

The net electric power of the REC should be measured using a power measurement device such as a power analyser capable of measurements in presence of harmonics and should be based upon measurements of amperage and voltage on all three phases for an AC REC (measurement of amperage on only 2 phases is permitted where it is demonstrated that there can be no neutral current), and the measurement of the voltage and amperage for a DC REC.

Electrical transducers and the data recording device used in the electrical measurements should be accuracy class 0,5 or better, should be calibrated (where relevant) to recognized and traceable standards and should meet the requirements of the following standards:

Power transducers: IEC 60688

Instrument transformers used in the measurement of electrical power should meet the following standards:

- Current transformers: IEC 61869-2
- Voltage transformers: IEC 61869-3

The operating range of the power transducer should be sufficient to include all positive peaks corresponding to net generation and all negative peaks corresponding to net imported power. As a guide the full-scale working range of the power measurement device and transducers should be at least:

- Export: 5 % to 150 % of REC rated capacity
- Import: –5 % to –50 % of REC rated capacity

If the working range of the transducers and the recording device allow for class 0.5 measurements within the power range less than ±5 % of the device’s rated capacity, the values within the working range should be recorded at their measured values. All measured values less than the lower working range of the transducers and the recording device should be recorded as zero.

In the case of an AC REC, the method of calculation of the active and reactive power from the voltage and amperage should be clearly documented.

Local power consumption during periods of non-power production should be measured by a separate measurement system where they are too small to be accurately measured using the main export power measurement setup. The measurement setup should be specified to measure the house load with a minimum of class 0,5 accuracy.

NOTE It is important that current transformers are specified correctly because they become non-linear for low currents; roughly ≤5 % of the specified range. To improve accuracy at low current, class 0.5S current transformers can be used with a known accuracy down to 1 % of rated current.

7.3.2 River current measurement

The inflow river current to the REC should be measured with a current profiler during the assessment of power performance. The profiler should be capable of measuring the current speed in the location where it is deployed (e.g. in shallow rivers). The following list describes the minimum data collection requirements for a current profiler. As such, any instrument chosen for data collection should be able to:

- record a continuous time series of river current speed and direction;
- measure with sampling levels or horizontal bins, at a minimum, the entire height or width of the REC projected capture area;
- measure a vertical (relevant dimension: height) or horizontal (relevant dimension: width) profile across the device's projected capture area with a bin spacing according to one of the following:
  – For devices where the relevant dimension is smaller than 2 m, the maximum bin-spacing should be 0,2 m;
  – For devices larger than 2 m, the maximum bin-spacing should be the smaller of one-tenth the relevant device dimension, or 0,5 m;
- record data with a minimum sampling frequency of 1 Hz;
- record time-stamped data;
- record a continuous time series of pitch and roll of the current profiler.

Any measurements collected should adhere to the following:

- the recording current speed range should be capable of measuring current speeds 50 % greater than the maximum anticipated current speed at the site with a resolution better than ±0,05 m/s;
- the geographic position during deployment should be measured using a system with accuracy equal to or better than +/- 1,0 m to identify the final current profiler placement location accurately. If the current profiler is deployed from a vessel, the measurement system should be positioned directly above the davit arm or block and the wire angle should be monitored during deployment. The final current profiler placement should adhere to the placement requirements described in 7.4.9.2.

Additionally, any available information on the following should be summarised and reported:

- the inherent (e.g. Doppler) noise for the current profiler data collection scheme(s) utilized;
- the estimated and/or measured time stamp drift over the entire test period;
- details on current profiler pre-deployment calibration;
- current profiler blanking distance;
- the number of beams and beam spreading angle.

Great care should be taken when measuring flow direction from bottom mounted current profilers using internal flux gate compasses as the heading input. The following precautions should be taken during calibration and deployment:

- it is advisable to use non-ferrous mounting frames and fittings;
- the compass calibration should take place in the deployment frame away from all magnetic influence;
- the calibration of the compass should include a cross-check of the heading of the current profiler against a known magnetic north;

NOTE None of these precautions guard against additional magnetic influences at the deployed location, the use of a calibrated gyroscope input avoids these magnetic effects.

7.3.3 Data acquisition

A data acquisition system should be used to gather measurements and to store pre-processed data. End-to-end checking of any installed data acquisition system should be performed for each signal and/or channel. The uncertainty introduced by the data acquisition system should be demonstrated as being at least one order of magnitude lower than that of the sensors.

7.4 Measurement procedures

7.4.1 General

The objective of the measurement procedure is to collect data that meet the requirements of 7.4.3. This ensures that the data is of sufficient quantity and quality to accurately determine the power performance characteristics of the REC.

The specific test conditions related to the power performance measurement of the REC should be well defined and documented in the test report, as detailed in Clause 10. The test report should be sufficient to allow every procedural step to be reviewed, and if necessary, repeated.

The accuracy of the measurements should be expressed in terms of measurement uncertainty. Categories of error are provided in Annex A, and an example uncertainty calculation may be found in Annex E of IEC 61400-12-1:2005.

The time used for data acquisition and all other test reporting should be UTC ± T hours. T should not alter for the test period and the time used should be clearly stated in the test report.

7.4.2 Operational status

During the measurement period, the REC should be in normal operation as prescribed in the REC operations manual. The machine configuration should not be changed during the test period. The control algorithm should not be changed during the test, and key parameters that control the performance of the machine should be those that are planned for normal operation, rather than for the test period alone.

At least one parameter indicating the operational status of the REC should be monitored so that the test availability during the test period can be calculated. The test availability is the ratio of the total number of hours during the demonstrated performance test period where all test conditions are met, to the total number of hours of the demonstrated performance test period.

A test log should be kept during the test period that details:

- times when the machine became unavailable or partially unavailable and the cause;
- the periods of data collection;
- any recordings of measured quantities that are not logged on the data-acquisition devices, i.e. time drift, river depth;
- any other noteworthy observations or unusual circumstances.

Normal maintenance of the turbine may be carried out throughout the test period, but such work should be noted in the test log. In particular any special maintenance actions, which may ensure good performance during the test, such as blade washing, should be noted.

7.4.3 Data collection

The test should take place over a minimum of 15 consecutive days, and the test availability should exceed 80 % during the test period. These requirements provide a minimal demonstration of the reliability of the device performance.

River current inflow, and device power output measurements should be collected at a sampling rate of 1 Hz or higher. The data acquisition systems should store raw sampled data. This includes the current profiler data acquisition system where the data from each ping should be recorded.

No filtering, other than anti-aliasing filtering, may be used prior to data acquisition.

7.4.4 Instrument calibration

Instruments should be calibrated when required by an organisation complying with the requirements of ISO/IEC 17025:2017.

For power measurement transducers (current transformers, voltage transformers and power transducers) it is acceptable to rely on the certificate of conformity to the relevant standard as proof of its accuracy. Where there is no certificate of conformity, i.e. for a power meter, then a calibration should be performed.

Where the current profiling sensors on current profiler devices can be calibrated, a valid calibration certificate should be provided. Otherwise a certificate of conformity is required and there should be evidence that the current profiler is in a serviceable state (an auditable self-test). The internal compass should be calibrated before deployment using the procedure given by the manufacturer, taking care to avoid the effects of external magnetism. A final check against the known magnetic north should be carried out. Any pressure gauge should have a current calibration certificate.

7.4.5 Data processing

Demonstrated performance should be derived using data obtained during normal operation of the REC device as prescribed in the REC operations manual. The exclusion of data sets should be allowed under the following circumstances to ensure that data during abnormal operations or corrupt data is not included in the derivations:

- the REC is manually shut down or in test or maintenance mode;
- the REC is unable to operate due to a failure condition;
- external conditions other than current speed are out of the operating range of the REC;
- there is a failure or degradation of the test equipment or any downstream electrical equipment that would affect the measured results;
- the REC is operating in a limiting mode due to an external factor, i.e. network limitations.

Any exclusion criteria, including those listed above, should be fully reported and substantiated. Individual outliers should not be removed unless they meet one of the general exclusion criteria.

Filtering the data during the data processing operation is not permitted.

7.4.6 Averaging

Selected data points and resulting data sets should be based on 10 min averaging periods derived from continuous measured data samples, and this averaging period should remain constant for the entirety of the test period.

An optional additional data set may be processed and reported at an averaging period less than 10 min but greater than or equal to 2 min. A suitable integer divisor of 10 min, or 600 s, should be used.

A data set should be discarded if less than 90 % of the data points are valid due to measurements falling outside of data acquisition limits. Criteria for excluding data sets are discussed in 9.3.2 and detailed in 7.4.5.

Where separate data acquisition systems are used, a method of associating the same averaging periods should be devised. A method for monitoring the drift of all acquisition devices' time stamp relative to UTC ± T hours should be devised and the data repair technique reported.

7.4.7 Test data properties

The test data should be sorted using the method of bins procedure (see 9.4.1). Due to the minimal variability in mean flow that is common in rivers, the demonstrated performance data may only contain current speed measurements in a limited number of current speed bins (e.g. <20 % of REC device's operational range). The data from the demonstrated performance data should be distinctly identified in contrast to "tested performance data" in the final report, as detailed in 10.9.

The demonstrated performance data set is considered complete when it has met the following criteria:

- at least three current speed bins (bin size = 0,10 m/s) contain a minimum of 30 min of sampled data;
- the data set includes a minimum of 288 h (80 % of 15 days) of sampled data.

Interpolation across current speed bins is not permitted in the demonstrated performance data set.

7.4.8 Electric power measurement

7.4.8.1 Power measurements

The net electrical power output is the active power flowing from the device at the output terminals (i.e. reduced by auxiliary power requirements) excluding any power generated by on-board ancillary generators or imported via separate cables. For AC RECs, the reactive power at this point should also be recorded. The power (or voltage and amperage) measurements should be digitized at a minimum of 1 Hz.

7.4.8.2 Output terminals of the REC

In the case of an AC REC, its output terminals should be at the point where the output power is in the form of AC at the network frequency. Where the AC REC is not grid connected this point should be where the frequency is stable and at a commonly used network frequency of 50 Hz or 60 Hz.

In the case of a DC REC, its output terminals should be at the point where the power is in suitable DC form for battery charging or connecting directly to the DC load.

In both AC and DC cases, the output terminals should be located at the point of the net electrical power output of the REC (see 7.4.8.4).

Results obtained for DC applications are not valid for AC applications. In the event of a DC REC being adapted for AC use it should be separately tested. The same should apply when adapting a REC from AC to DC use.

7.4.8.3 The power measurement location

The power measurement location should be at the output terminals of the REC. Where this is impracticable or infeasible, power loss due to cables and other components between the measurement point and the REC's output terminals should be calculated and the power output should be adjusted accordingly. Annex B of IEC TS 62600-100:2012 contains a suitable method for calculating such power losses. The methodology for these corrections should be fully detailed, explained and accompanied with supporting documentation as necessary.

The power measurement location should be stated with justifications when it is not the output terminals. The measured output should be adjusted as specified above and stated for the output terminals of the REC.

7.4.8.4 Remote REC sub-systems

Some REC technologies have remote sub-systems that are external to the primary energy extraction equipment itself, such as power converters that are located ashore, but should be considered as a part of the complete system for the purposes of performance assessment. In these situations, the REC power should be measured at the output terminals of the REC (i.e. at the output of the onshore power converter). Losses due to cables and other components between the main REC system and the remote sub-systems that are site specific should be calculated and the power output should be adjusted accordingly. The methodology for these corrections should be fully detailed and explained and accompanied by supporting documentation as necessary.

7.4.9 Incident resource measurement

7.4.9.1 General

The measurement instruments should be capable of recording the temporal variation in river flow current speed in three orthogonal components across the projected capture area of the REC energy extraction plane. For bottom mounted current profilers, the distance from the riverbed at the current profiler deployment location to the centre of each current profiler bin should be reported.

Vertical shear and horizontal shear can alter the amount of power that a device produces. In rivers, water depth is the relevant length scale for changes in mean current speed (i.e. shear), and it is therefore compared to the device dimensions to determine the need for measuring shear:

- Vertical shear shall be measured if either:
  - the device height is greater than 25 % of the water depth, or
  - the device is positioned such that its capture area overlaps with the bottom 25 % of the water column.
- Horizontal shear shall be measured if the device width is greater than the water depth.

The measurement of the current profiler's position should include an estimate of the location accuracy, if possible (e.g., GPS horizontal dilution of precision).

7.4.9.2 Current profiler placement relative to REC

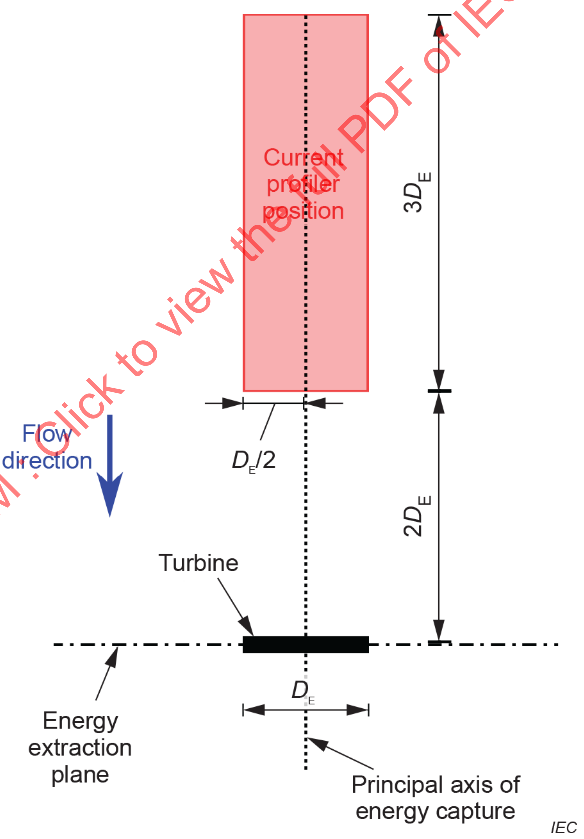
Measuring instruments should be installed at appropriate positions close to the REC location to provide an accurate measurement of river current (magnitude and direction) inflow to the turbine during operation.

The difference in total water depth between the sampling location and the REC location should be less than 10 % based on the best available bathymetry data. The current profiler should be positioned so that the distance from the nearest external surface of the measuring volume to the REC extraction plane is between 2 and 5 D_E upstream of the REC's projected capture area (Figures 1, 2, 3).

There are three recommended profiler placements depending on the shear measurement requirements:

a) Placement A: a current profiler upstream of the device within 0,5 D_E of the principal axis of capture for the REC (Figure 1 and 2).
b) Placement B: a single horizontal current profiler upstream of the device (Figure 2). The beams of the horizontal profiler should be horizontal and centred on the device's principal axis of energy capture.
c) Placement C: two current profilers upstream of the device. Each profiler should be positioned in line with the edge of the REC and within the bounds shown in Figure 3.

Any of the above placements may be used if neither vertical nor horizontal shear are required to be measured according to 7.4.9. If horizontal shear measurements are required according to 7.4.9, placement B for horizontal profiler, or placement C may be used, or placement A with cross-stream transects as described in 9.5.3. If vertical shear measurements are required according to 7.4.9, placement A or C may be used, with vertical current profilers. If both vertical and horizontal shear measurements are required, placement C shall be used with vertical current profilers, or placement A with cross-stream transects.



The current profiler position box indicates the region where the current profiler should be deployed relative to the REC.

Figure 1 – Current profiler deployment position for placement A (plan view)

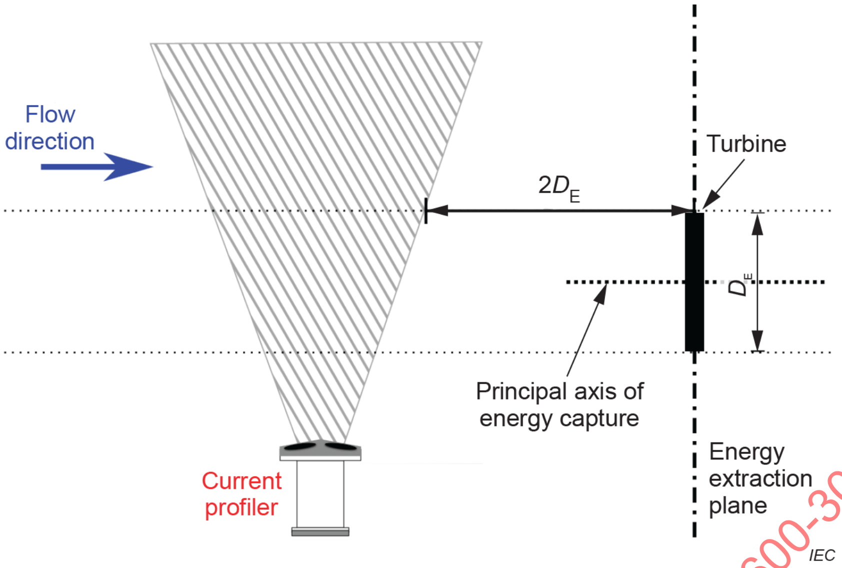
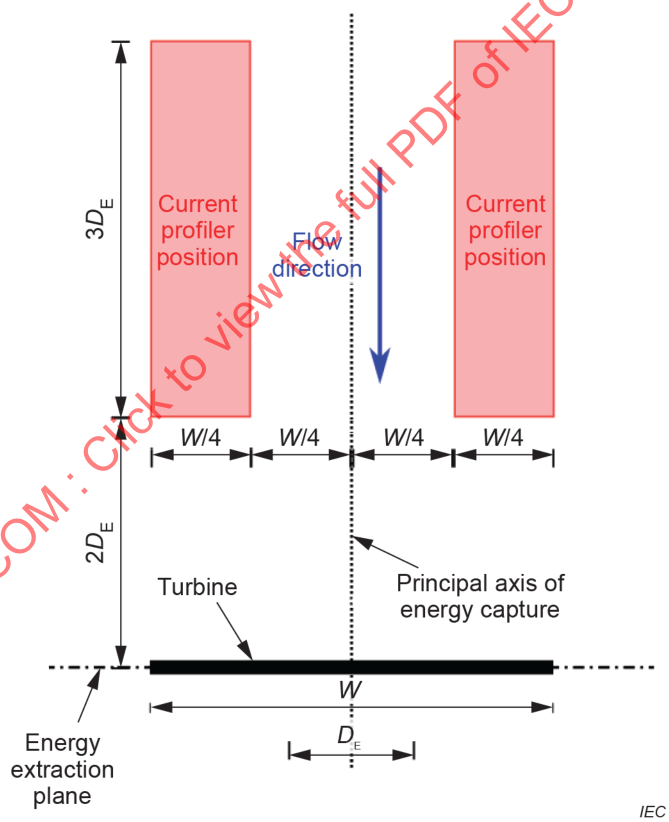


Figure 2 – Current profiler deployment position for placements A and B (placement A: profile view, placement B: plan view)



This wide device has different lengths D_E and W.

Figure 3 – Current profiler deployment position for placement C (plan view)

A floating REC that is free to move on a compliant mooring or surface-floating structure should use current profiler(s) positioned on the riverbed or on a support structure that comply with the dimensions in Figure 1 through Figure 3. Moored devices and current profilers mounted on floating platforms should be equipped with devices that record their position and orientation, and should be positioned so that the entirety of the measurement volume is 2 to 5

D_E upstream of the energy extraction plane (i.e., an upside-down version of Figure 3). Current profilers should be placed such that the measured current speed is free from interference by mooring system components such as lines, marker buoys, etc.

Redeployment of a current profiler during the test period should be avoided. Where this is impractical the current profiler should be redeployed to the same position (if possible: leave the riverbed frame in place and retrieve/redeploy the current profiler only). A redeployed current profiler should comply with the placements described above.

7.4.9.3 Contribution from turbulence

While there is a potentially significant influence on REC power performance due to turbulence inherent in the current flow, no corrections for the effect of turbulence should be performed in the reported assessment of power performance. Future efforts will be made to quantify this influence; however, this issue is not covered at this stage of the Technical Specification development.

7.4.9.4 Contribution from waves

Any wave activity – from passing ships, weather, or otherwise – should be documented as clearly as possible.

7.5 Demonstrated performance at a tidal influenced river site

Performance data collected during testing at a site with tidal influence may be presented alongside data collected per the procedures in this document in order to demonstrate REC performance over a broad range of velocities. The following criteria shall be satisfied in order to report demonstrated performance data collected at a tidal site alongside the REC performance data collected following the procedures in this technical specification:

- All procedures specified in IEC TS 62600-200 shall be followed when collecting performance data at a tidal site with the following exceptions:
  - Current profiler placement should follow the procedures in 7.4.9.2 in this document.
  - The number of current profiler bins used when evaluating the performance of the marine energy converter may be taken according to the requirements in this document.
- The device tested at a tidal site shall be the same make and model of the REC tested according to this specification;
- Any differences in the controller or operational aspects of the REC compared to those used for the REC test shall be clearly identified, and any potential impacts on device performance should be explained.
- Reporting of all tidal site performance data should follow the procedures in Clause 10.

8 Tested performance

8.1 General

The river current speed may remain relatively constant during REC field testing; therefore, it may only be possible to evaluate REC performance over a limited speed range. In order to characterize REC performance over a broad range of current speeds, tested performance data from the full scale REC may be reported alongside the demonstrated performance data collected at a river location according to the procedures in Clause 8. Tested performance data consists of full scale REC performance data collected during towing tank, flume tank, or push/pull tests, and shall be collected according to the procedures in 8.2, 8.3, or 8.4. Tested performance data is supplemental to the demonstrated performance data collected according to Clause 7; where they overlap demonstrated performance data supersedes tested performance data.

Tested performance data should be carefully compared to demonstrated performance data for points collected at the same speed. Any differences between demonstrated performance data and tested performance data at the same current speeds should be examined in detail and explanations for such differences should be provided. REC tested performance may be significantly affected by blockage effects, which occur when the REC undergoing testing is a significant portion of the cross-sectional area of the flume or towing tank. For example, blockage ratios as low as a few percent may result in unrealistic performance measurements compared to free-stream conditions.

NOTE A number of studies have attempted to quantify blockage effects and correction methods; however, due to the variety of technologies, foundations, and deployment and test locations, it is not possible to recommend a maximum permissible blockage ratio or suitable method to correct blocked performance to free-stream conditions at this time. Users of this document can be alert to the potential impacts of blockage on REC performance. Existing useful references include Bahaj et al. (2007), Chen et al. (2011), Consul et al. (2013), Garret et al. (2007), Houlsby et al. (2008), Kinsey et al. (2015), MacAdam et al. (2013), Shives (2011), Sorensen et al. (2006), Tremblay (2015), and Whelan et al. (2009).

The collection of tested performance data is not a required part of this technical specification. If collected, tested performance data shall satisfy the following criteria:

- The REC used to obtain the tested performance data shall be the same make, model and dimensions of the REC used when collecting demonstrated performance data in the field. Testing of scaled devices is not permissible.
- Any differences in the foundation or mounting mechanism used to deploy the REC during testing (compared to that used when collecting demonstrated performance data) shall be clearly identified, and any potential impacts on device performance should be explained.
- Any differences in the controller or operational aspects of the REC required to facilitate testing (compared to those used when collecting demonstrated performance data) shall be clearly identified, and any potential impacts on device performance should be explained.
- All data points obtained when collecting demonstrated performance data shall be repeated at the same velocities when collecting tested performance data.
- Scaling or modifying tested performance data to correct for blockage effects in the tank is not permitted.

If the power measured during towing tank, push/pull, or flume tank testing is not the same voltage and amperage as that measured at the output terminals when collecting REC demonstrated performance data, then the following information should be reported:

- The type of electrical equipment required to transform the power to match the amperage and voltage at the output terminals when collecting demonstrated performance data;
- The estimated power loss that would occur when transforming the power measured in the towing tank to match the amperage and voltage achieved at the output terminals when collecting demonstrated performance data.

The power used to calculate REC performance from test data should include the predicted losses that would occur when transforming the measured power to match the voltage and amperage achieved at the output terminals during the collection of demonstrated performance data.

Tested performance data should be reported according to the procedures in Clause 10.

8.2 Towing tank tests

8.2.1 General

Towing tank tests typically occur in a large testing facility. The REC is fixed to a carriage and suspended into the water. The carriage travels down the tank at a specified speed, inducing an encountered water current speed relative to the REC.

8.2.2 Test facility description

A description of the test facility and tested setup should be provided including:

- Facility name and location;
- Tank size (length, width and depth);
- Run length (e.g. traversable length of the tank when performing a run down the tank);
- Towing carriage operating capabilities:
  - Minimum and maximum travel speed;
  - Acceleration;
- Any other tank characteristics such as the existence of wave dampeners or a beach.

A diagram clearly indicating the cross-sectional area of the tank and the size and location of the REC within the tank should be provided. The method used to attach the REC to the towing carriage should be clearly illustrated and explained. The blockage ratio should be reported.

8.2.3 Test equipment

A description of the test equipment and instrumentation should be provided including:

- The instrumentation used to measure carriage speed, including the accuracy and resolution that may be achieved;
- The instrumentation used to measure power generated by the REC;
- Any other instrumentation or equipment used to monitor facility conditions or REC performance such as water level measurement, temperature, etc.

8.2.4 Measurement procedures

A minimum of one minute of steady state data (constant carriage speed and corresponding REC rotating/operating speed) should be collected for each operating point at the target speed. One single run down the tank, or multiple shorter runs, may be completed to acquire the full minute of data at a single operating point and carriage speed.

A clear description of the procedure used to complete a run down the tank should be provided. For example, if the REC was set to a specific rotational speed before starting carriage motion, this procedure should be described in detail. For each run, the following should also be reported:

- Target run parameters (carriage speed, REC rotating speed or operating frequency);
- Carriage speed and time at steady state during the corresponding run;
- Generated power measured in accordance with 7.4.8;
- Time between runs to allow for dissipation of turbulence in the tank (calm water).

8.3 Push and pull tests

8.3.1 General

A push or pull test is considered to be a test where the tested device is mounted on a self-propelled floating vessel in such a way that the motion of the vessel relative to the water creates a current through the REC. In the case of a push test the REC is mounted ahead of the bow, in a pull test it is mounted behind the stern.

8.3.2 Test setup and site description

A description of the test site should be provided including:

- Location name, location, and type (lake, river, ocean);
- Location characteristics (significant wave height, salinity, currents, bathymetry);
- Type of vessel, diagram of testing setup and barge or beams for mounting REC, etc.;
- Vessel operating capabilities:
  - Minimum and maximum travel speed;
  - Acceleration;
  - Engine/propeller power;
- Precautions taken for avoiding wake or wash effects from towing;
- The vessel path (if moving in a large circle due to limited space, clearly document how actual speed at the turbine is estimated).

REC tested performance may be significantly affected by local currents, (ir)regular wave patterns and the presence of the carrying vessel (return current, propeller wash, ship wake, ship induced waves, etc.). These effects may result in unrealistic performance measurements compared to free-stream conditions.

A diagram clearly indicating the local water depth of the test site and the size and location of the REC within the water profile should be provided. The method used to attach the REC to the vessel should be clearly illustrated and explained to demonstrate that it has minimal influence on device performance. In particular, the mounting structure shall have no ducting, hydrofoils, or other flow diversion structures that are not included in the device.

8.3.3 Test equipment

A description of the test equipment and instrumentation should be provided including:

- The instrumentation used to measure current speed, including the accuracy and resolution that may be achieved (i.e.: current profiler, pitot tube);
- The instrumentation used to measure power generated by the REC;
- Any other instrumentation or equipment used to monitor facility conditions or REC performance such as water depth, temperature, etc.

8.3.4 Measurement procedures

A minimum of one minute of steady state data (constant vessel speed and corresponding REC rotating/operating speed) should be collected for each operating point at the target speed. Data may be collected in a single continuous run or in multiple shorter runs, as long as the boundary conditions for the test (currents, waves, etc.) are sufficiently similar and well documented.

A clear description of the procedure used to complete a run should be provided. For example, if the REC was set to a specific rotational speed before starting vessel motion, this procedure should be described in detail. For each run, the following should also be reported:

- Target run parameters (vessel speed, REC rotating speed or operating frequency);
- Vessel speed, and time at steady state during the corresponding run;
- Generated power measured in accordance with 7.4.8;
- Local boundary conditions such as wave and current data.

8.4 Flume tests

8.4.1 General

A flume test facility consists of a long tank in which flow conditions can be imposed by letting water flow from one end of the tank to the other while a device is held stationary somewhere along the tank. This means that in flume tests the water moves relative to the device.

Flume tests can be used to supplement the data of in-situ testing where the in-situ situation does not give a sufficient range of flow conditions to fully characterize the power curve.

8.4.2 Test facility description

A description of the test facility and tested setup should be provided including:

- Facility name and location;
- Flume size (length, width and depth);
- Current speed operating capabilities:
  - Minimum and maximum current speed;
  - Acceleration;
- Any other tank characteristics such as the existence of wave dampeners or flow dividers.

A diagram clearly indicating the cross-sectional area of the flume and the size and location of the REC within the tank should be provided. The method used to fix the REC in place in the flume should be clearly illustrated and explained. The blockage ratio should be reported.

8.4.3 Test equipment

8.4.3.1 General

A description of the test equipment and instrumentation should be provided including:

- The instrumentation used to measure current velocity, including the accuracy and resolution that may be achieved (i.e.: current profiler, pitot tube);
- The instrumentation used to measure power generated by the REC;
- Any other instrumentation or equipment used to monitor facility conditions or REC performance such as water depth, temperature, etc.

The equipment used for testing RECs in a flume test should consist of at least the following:

- Flume with a width of at least the D_E and a length of 9 D_E of the REC;
- Fluid pumps capable of cumulatively producing the required discharge range for testing the REC;
- Current profilers for current velocity measurements in accordance with 7.3.2;
- Hydrostatic pressure sensors for water level measurements;
- Thermometer for air and water temperature measurements;
- Power transducers capable of measuring the power output range of the tested REC in accordance with 7.3.1.

8.4.3.2 Placement

The distance from the point of inflow of the water to the installation point of the REC should be at least 7 D_E. There should be at least 2 D_E between the REC and the outflow.

The test equipment placement should be similar to what is illustrated in Figure 4. The inflow velocity and water level should be registered by a current profiler, located between 2 and 5 D_E from the REC.

The measurement equipment should be able to register the variations in flow velocities in the three orthogonal directions through the projected hydraulic profile of the channel to the REC.

The flow through the measuring field should not be disturbed by the REC.

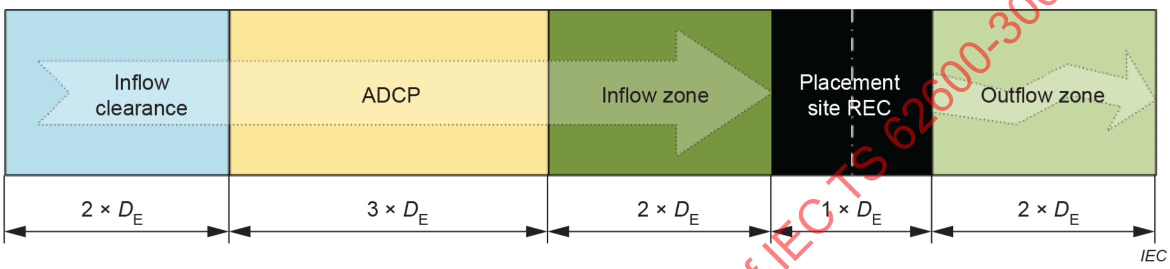


Figure 4 – Flume test equipment location

8.4.4 Measurement procedures

8.4.4.1 General

All testing should be done in accordance with 7.4. This section discusses specifics for flume testing that are additional to what has been prescribed there.

8.4.4.2 Level measurement

The water level on both sides of the REC should be measured and documented. These measurements ought to be taken in a manner that eliminates velocity induced irregularities as much as possible. Furthermore, a level indicator should be placed on both sides of the REC at the location of the ADCP for direct reading of the water level. IEC 60041 should be followed where applicable for the testing set-up.

8.4.4.3 Velocity measurement

The incident current velocity needs to be measured using current profilers located between 2 and 5 D_E upstream of the REC's placement site. Inflow speed should be calculated using the method of bins as described in 9.4.2.

8.4.4.4 Test duration

Sufficient data should be collected to supplement the REC's power curve as required. Each data point requires a minimum steady state testing period of 1 min. It is advisable to test for a longer period than this minimum to reduce uncertainty. The availability of the REC and test equipment should be at least 80 % during testing. If the flume is subject to a tidal forcing period, tests need to include at least one representative cycle of that respective period.

8.4.4.5 Description of necessary measurements/observations

During the power performance test(s) a detailed log of the activities/actions should be kept. The following measurements/observations should be recorded:

- flow speed in accordance with 7.3.2;
- generated power in accordance with 7.4.8;
- water level difference over the test site;
- water level at the REC in- and outflow;
- water density;
- REC rotating speed or operating frequency;
- timestamp at measurement point/moment;
- any events out of the ordinary that could be of influence to test data.

9 Derived results

9.1 General

The performance of the REC should be described by a representative power curve that has been derived according to the methods described in this document. In order to demonstrate REC performance over a range of velocities, both demonstrated and tested performance data may be presented; however, results from these individual tests shall be clearly distinguished and identified as described in 10.9 when reporting the power curve.

The effects of flow misalignment on REC performance are not addressed in this document. The user of this information should be aware that river sites with large flow misalignment may result in significant performance variation.

9.2 Water density

The water density should be determined at the test location and used for all calculations. Alternatively, written documentation may be provided to assume a given value (such as ρ = 1 000 kg/m^3) if it can be shown that the density is locally unaffected by potential influences such as salt water and sediment.

9.3 Data processing

9.3.1 Filtering

Filtering data is not permitted as per 7.4.3.

9.3.2 Exclusion

The power curve should be derived using data obtained according to procedures specified in this document. Data sets may be excluded under the circumstances defined in 7.4.5, and shall be excluded under these two conditions:

- if less than 90 % of the data points are valid;
- if the current profiler is not able to resolve the flow over 80 % of the current profiler bins in the projected capture area.

All data series should be traceable and any reasons for excluding or invalidating data should be fully reported and substantiated.

9.3.3 Correction

All data corrections required during the derivation of results should be fully reported and substantiated.

9.4 Calculation of the power curve

9.4.1 General description of the method of bins

The power curve constitutes a plot of the power production (*y*-axis) against the incident river current resource (*x*-axis). This curve is derived using the method of bins approach to calculate the mean values of the power output and the river current speed values for each bin. The method of bins is summarized in the following steps:

1) Record the instantaneous current speed in each current profiler bin, and the corresponding instantaneous power measurement.
2) Calculate the instantaneous power-weighted speed from each current profiler bin averaged across the projected capture area, Formula (2);
3) Calculate the temporally-averaged (10 min) power-weighted speed, Formula (3), and the corresponding (same time interval) averages of active and reactive power, Formulas (4) and (5);
4) Bin the current speed and power data points according to their corresponding current speed bin values;
5) Calculate an average of power data points using all of the data samples in each speed bin. Plot these average active and reactive power data points, Formulas (9) and (10), against the corresponding mean current speed values, Formula (8), for each speed bin.

Figure 5 summarizes the method of bins. Formula details are provided in 9.4.2.

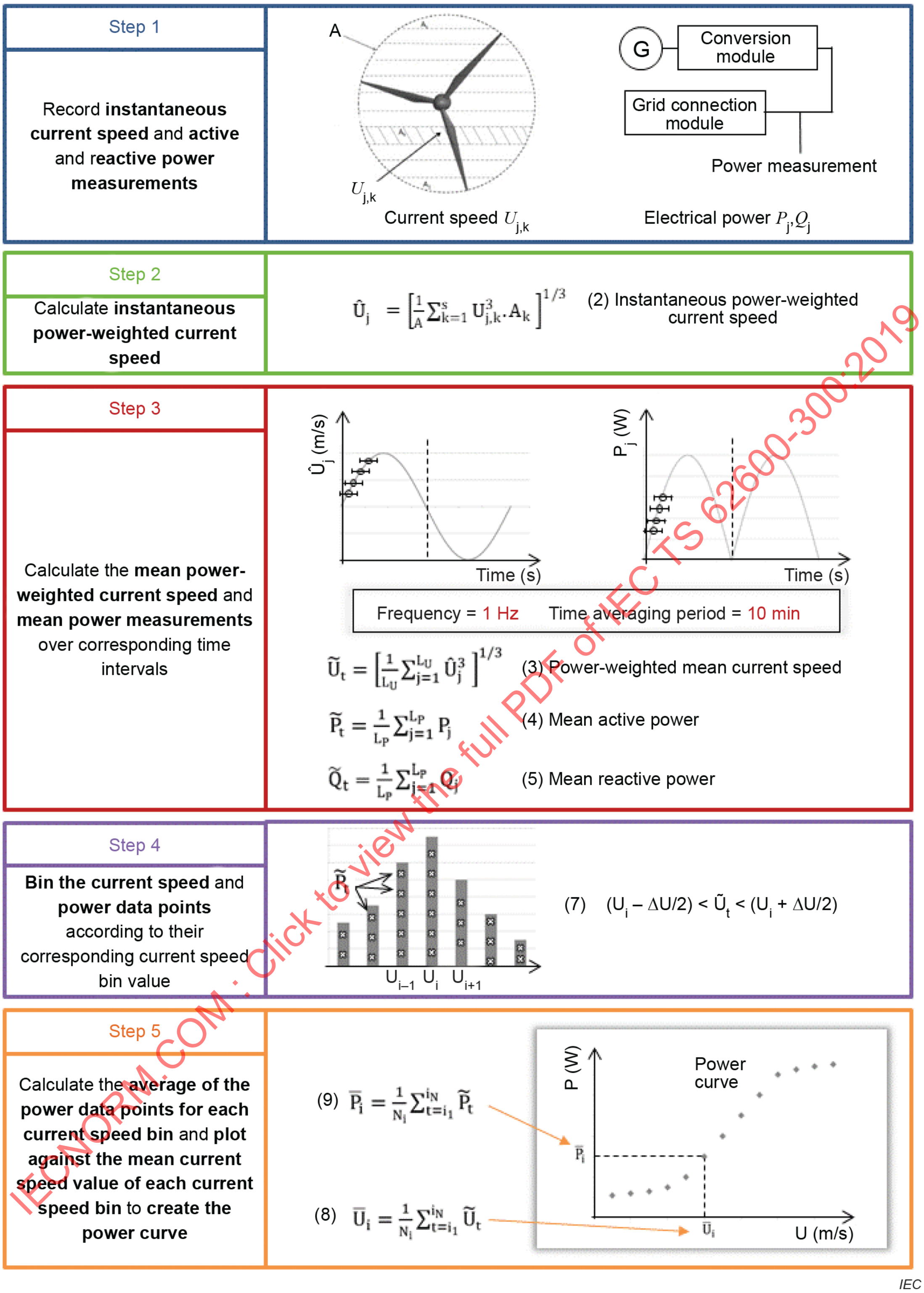


Figure 5 – Summary of the power curve calculation using the method of bins

9.4.2 Detailed description of method of bins

9.4.2.1 General

The definition of the current profiler bins is dependent on whether the REC width or aspect ratio results in the need to measure horizontal shear in the flow, as described in 7.4.9.

9.4.2.2 Demonstrated data for RECs not requiring horizontal shear flow measurement

For RECs having dimensions such that horizontal shear flow measurement is not required, it should be assumed that the current speed data sample at any elevation is representative of the river current speed across the entire width of the projected capture area at that elevation. The vertical variation of the river current speed at each sampling time interval (data sample $U_{j,k}$) should be integrated across the projected capture area to provide a power-weighted current speed, $\hat{U}_j$, based upon Formulas (1) and (2) and illustrated in Figure 6:

$$A = \sum_{k=1}^{S} A_k \tag{1}$$

$$\hat{U}_j = \left[\frac{1}{A}\sum_{k=1}^{S} U_{j,k}^3 \cdot A_k\right]^{1/3} \tag{2}$$

where

A	is the projected capture area of the REC [m²];
A_k	is the area of current profiler bin k of the projected capture area [m²];
S	is the total number of current profiler bins normal to the principal axis of energy capture across the projected capture area;
j	is the index number of the time instant when the measurement is performed [-];
k	is the index number of the current profiler bin across the projected capture area [-];
$\hat{U}_j$	is the power-weighted current speed averaged across the projected capture area [m/s];
$U_{j,k}$	is the current speed flowing through current profiler bin k of the projected capture area, at time instant j [m/s].

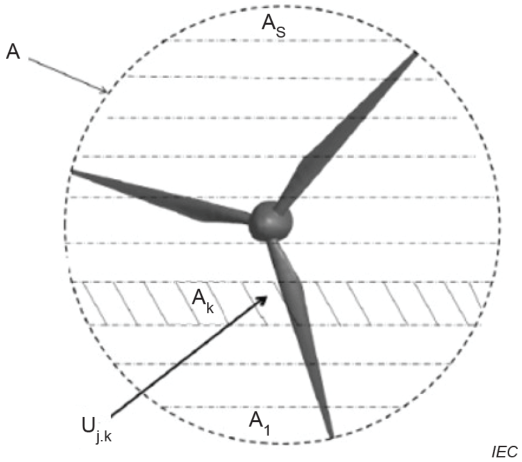


Figure 6 – Vertical variation of river current speed across the projected capture area

Whether the REC is fixed, having no yaw capability, or capable of orientating to the dominant river current direction, the recorded speed should be used for data sample $U_{j,k}$.

The instantaneous power-weighted current speed calculated in Formula (2) should be averaged over the period defined in 7.4.6 (typically 10 min). This temporal averaging of current speed data samples, Formula (3) will produce a mean power-weighted current speed that will form a data point in the data set of a specific current speed bin, i. A corresponding averaged active power and reactive power (for AC machines) output for that specific speed bin should also be calculated over the period defined in 7.4.6 as given by Formulas (4) and (5).

$$\tilde{U}_t = \left[\frac{1}{L_U}\sum_{j=1}^{L_U}\hat{U}_j^3\right]^{1/3} \text{ for t = 1, 2, 3,} \tag{3}$$

$$\tilde{P}_t = \frac{1}{L_P}\sum_{j=1}^{L_P}P_j \text{ for t = 1, 2, 3, …} \tag{4}$$

$$\tilde{Q}_t = \frac{1}{L_P}\sum_{j=1}^{L_P}Q_j \text{ for t = 1, 2, 3, …} \tag{5}$$

where

j is the index number of the time instant when the measurement is performed;

L_U is the number of current speed data samples in the defined averaging period that produces data point t [-];

L_P is the number of power data samples in the defined averaging period that produces data point t [-];

t is the index number of the data point [-];

$\tilde{P}_t$ is the mean recorded REC active power output of the t^{th} data point [W];

P_j is the magnitude of the total instantaneous active electrical power from the REC [W];

$\tilde{Q}_t$ is the mean recorded REC reactive power of the t^{th} data point [var];

Q_j is the magnitude of the total instantaneous reactive electrical power of the REC [var];

$\tilde{U}_t$ is the power-weighted mean current speed of the t^{th} data point [m/s].

$\hat{U}_j$ is the power-weighted current speed flowing through the projected capture area [m/s];

The summations in Formulas (3), (4) and (5) are repeated for each valid segment of data in the dataset, thus generating the index "t". Ideally, a data acquisition system collects both the power and velocity data and stores it on a common time step; in this case, $L_U = L_P$. If the velocity and power measurements are made using independent data acquisition systems L_U and L_P may be different and care shall be taken to ensure that the time stamps of the two systems are accurately aligned (i.e., clock-drift of the two data acquisition systems can lead to measurements that have the same time-stamp, but were not in fact made at the same instant in time).

The measured active power curve is to be calculated by binning the current speed data points ($\tilde{U}_t$), and their corresponding active and reactive power mean recorded values ($\tilde{P}_t$ and $\tilde{Q}_t$), into speed bins using a maximum bin increment of ΔU=0,10 m/s. If a bin increment smaller than 0,10 m/s is chosen, it should be an increment that is an integer divisor of 0,10 m/s. Once a bin increment is selected, the bins are defined according to Formula (6). Data points, $\tilde{U}_t$, with corresponding values of $\tilde{P}_t$ and $\tilde{Q}_t$, are organized into bins such that they obey Formula (7).

$$U_i = (i - \tfrac{1}{2})\Delta U \text{ for } i = 1, 2, 3, \dots M \tag{6}$$

$$i_1, i_2, i_3, \dots i_N = \{t \mid (U_i - \Delta U/2) < \tilde{U}_t < (U_i + \Delta U/2)\} \tag{7}$$

where

i is the index number of the speed bin;

$i_1, i_2, \dots i_N$ is the set of data point indices, t, in speed bin i (see Formula (7));

M is the number of speed bins for which the user wants to compute the power curve;

t is the index number of the data point;

ΔU is the speed bin increment [m/s];

U_i is the current speed of speed bin i [m/s];

$\tilde{U}_t$ is the power-weighted mean current speed of the t^{th} data point [m/s].

Note that Formula (7) uses "set builder notation"; this says that the set of indices "$i_1, i_2, \dots i_N$" are the indices of the speed time-series, $\tilde{U}_t$, that are within $\Delta U/2$ of U_i (i.e., the indices, t, that fall in speed bin i).

The power curve is calculated as shown in Formulas (8) and (9):

$$\bar{U}_i = \frac{1}{N_i}\sum_{t=i_1}^{i_N} \tilde{U}_t \tag{8}$$

$$\bar{P}_i = \frac{1}{N_i}\sum_{t=i_1}^{i_N} \tilde{P}_t \tag{9}$$

where

i is the index number of the current speed bin;

$i_1, i_2, \dots i_N$ is the set of data point indices, t, in speed bin i (see Formula (7));

N_i is the number of data points in speed bin i;

$\bar{P}_i$ is the mean recorded REC active power in speed bin i [W];

$\tilde{P}_t$ is the mean recorded REC active power for data point t [W];

t is the index number of the data point;

$\tilde{U}_t$ is the power-weighted mean current speed of the t^{th} data point [m/s]

$\bar{U}_i$ is the mean current speed in speed bin i [m/s].

The active power curve should be presented in graphical and in tabular format as defined in 10.9.

For RECs that produce AC power, the reactive power should also be measured in a similar manner as described for active power in Formula (9), as shown by Formula (10):

$$\bar{Q}_i = \frac{1}{N_i}\sum_{t=i_1}^{i_N} \tilde{Q}_t \tag{10}$$

where

i is the index number of the speed bin;

$i_1, i_2, \dots i_N$ is the set of data point indices, t, in speed bin i (see Formula (7));

N_i is the number of data points in speed bin i;

$\bar{Q}_i$ is the mean recorded REC reactive power in speed bin i [var];

$\tilde{Q}_t$	is the mean recorded REC reactive power for data point t [var];
t	is the index number of the data point.

The reactive power should be presented in tabular format as defined in 10.9.

9.4.2.3 Demonstrated data for RECs requiring horizontal shear flow measurement

For REC deployments using two vertical current profilers located as described in 7.4.9.2, the power-weighted current speed should be calculated as follows:

- Each current profiler should measure the same number of vertical current profiler bins, with the maximum vertical distance between sampling levels being 0,5 m across the height of the projected capture area.
- The flow speed is assumed to vary linearly between corresponding vertical sampling levels of each current profiler. The power-weighted current speed for each time sampling interval (data sample $U_{j,k}$) is then calculated by integrating across the projected capture area using Formula (11):

$$U_{j,k} = \left[\frac{1}{4} \cdot \frac{{Ub_{j,k}}^4 - {Ua_{j,k}}^4}{(Ub_{j,k} - Ua_{j,k})}\right]^{1/3} \tag{11}$$

where

j	is the index number of the time instant at which the measurement is performed;
k	is the index number of the current profiler bin across the projected capture area;
$Ua_{j,k}$	is the current speed flowing through the k^{th} current profiler bin of current profiler *a*, where current profiler *a* measures the slowest current speed of the two current profilers placed in-line with the outer edges of the REC projected capture area [m/s]
$Ub_{j,k}$	is the current speed flowing through the k^{th} current profiler bin of current profiler b, where current profiler b measures the fastest current speed of the two current profilers placed in-line with the outer edges of the REC projected capture area [m/s]
$U_{j,k}$	is the river current speed flowing through current profiler bin k of the projected capture area, at time instant j [m/s].

The resulting value of $U_{j,k}$ may be used to calculate $\hat{U}_j$ in Formula (2) in 9.4.2.2. The REC power curve is then calculated according to the remainder of 9.4.2.2. Formula (11) may encounter difficulties when the two current profilers are not perfectly synchronized, or when time-drift occurs. Processing may be required to ensure instantaneous samples from each current profiler are matched as closely as possible when calculating $U_{j,k}$. Any such corrections to the data should be fully reported per 9.3.3. When a data sample from one ADCP shall be excluded due to less than 80 % of the current profiler bins being resolved, the corresponding data sample from the second ADCP should also be excluded.

For REC deployments using a horizontally oriented current profiler as described in 7.4.9.2, the current profiler bins are distributed horizontally across the width of the REC (see Figure 7). Each current profiler bin should have a maximum bin size of 0,5 m or, in instances where the REC has a width greater than 5 m, the maximum width should be one-tenth of the REC width. The current speed measured in a current profiler bin is assumed to represent the river current speed across the entire height of the projected capture area in that current profiler bin.

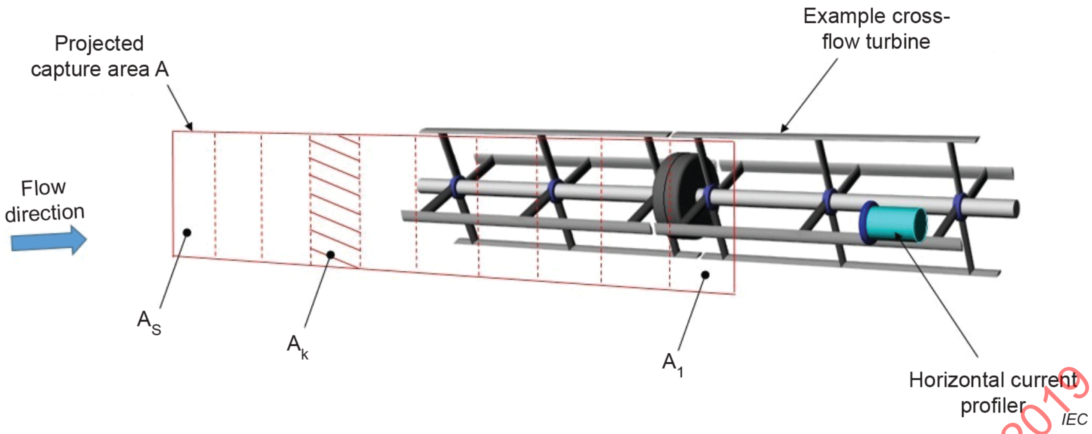


Figure 7 – Horizontal variation of river current speed across the projected capture area

Formulas (1) to (5) should be used to calculate the time-bin averaged data points $\widetilde{U}_t$, the only difference in applying those equations is that the current profiler bins $k=1$ through S are oriented horizontally (as shown in Figure 7), rather than vertically. The REC power curve is then calculated according to the remainder of 9.4.2.2.

9.4.2.4 Tested data for towing tank, push/pull, or flume tank tests

When collecting REC tested performance data according to Clause 8, the method of calculating the current speed will vary depending on the type of testing being conducted (i.e., tow tank, push/pull test, flume).

For towing tank or push/pull testing, the current speed may be obtained from either the speed of the towing carriage, or from the speed-over-water of the REC during the pushing or pulling operation. Each instantaneous speed measurement corresponds to a value of $\hat{U}_j$ which is then used in Formula (3) of 9.4.2.2. The instantaneous active power, P_j, and instantaneous reactive power, Q_j, are the corresponding power measurements over the same period, after accounting for the estimated losses to transform to the correct voltage and amperage as described in Clause 8. These values of P_j and Q_j may be used in Formula (4) and Formula (5) respectively, and the active power curve should be calculated according to the remainder of 9.4.2.2.

For flume tank testing, a current profiler should be used to measure the flow between 2 and 5 D_E upstream of the REC. Typically a vertically oriented current profiler will be used to measure incident speed; however, in some instances it may be possible that a horizontal current profiler will be used if the horizontal shear flow profile has the potential to impact the performance measurement (using Formula (1)). The power curve is then calculated according to the remainder of 9.4.2.2, where the instantaneous active power, P_j, and instantaneous reactive power, Q_j, correspond to the power values after accounting for the estimated losses to transform to the correct voltage and amperage values as described in Clause 8.

9.4.3 Interpolation

Interpolation of data points is permitted between two complete speed bins. Interpolation is permissible only if adjacent speed bins are complete.

9.4.4 Extrapolation

Extrapolation of data is not permitted.

9.4.5 Uncertainty calculation

The graphical representation of the power curve should display the mean recorded REC active power as a function of the mean power weighted river current speed. The value of power for each speed bin is a mean, or expected value, based upon an average of the collected data points in that bin. Consequently, there should be a distribution of data points scattered randomly around the mean value, with a standard deviation attached to that distribution. The standard deviation on each bin in the power curve should provide one of the levels of uncertainty associated with the behaviour of the device at the site. The derivation of overall system performance uncertainty should also account for the contributions made by the bias of the measuring instruments and other sources of uncertainty (i.e. current profiler position). Categories of error are provided in Annex A, and an example uncertainty calculation may be found in Annex E of IEC 61400-12-1:2005.

9.5 Mean river current speed shear profile

9.5.1 General

Both vertical and horizontal river current speed shear profile should be reported as required in 9.5.2 and 9.5.3 to document the flow conditions at the test site.

9.5.2 Current speed vertical shear profile

When vertical shear measurement is required per 7.4.9, the vertical shear profile measured by each current profiler should be reported.

The calculation should be performed for a typical speed measured at the centroid of the projected capture area during the testing period. When the mean current speed at the centroid of the projected capture area varies by more than 0,5 m/s, the speed vertical shear profile should be reported for this second speed. This should be repeated such that the speed measured at the centroid of the projected capture area is always within 0,5 m/s of a reported speed vertical shear profile.

When the mean current speed in the current profiler bin at the centroid of the projected capture area is within 0,05 m/s of a value requiring vertical shear profile measurement, the average current speed corresponding to each current profiler bin should be calculated using the data samples measured during the defined averaging period. These average current speed values will produce a vertical shear profile for a given reference current speed. If two vertically oriented current profilers are used for the performance assessment, then the vertical shear profile should be reported separately for each current profiler at the times when the calculated speed at the centroid of the projected capture area is at the value requiring a vertical shear profile measurement.

The river current data points are binned according to their corresponding current profiler bin, k, for this procedure. The average current speed at each current profiler bin for each data point should be calculated as shown in Formula (12):

$$\widetilde{U}_{t,k} = \frac{1}{L_U} \sum_{j=1}^{L_U} U_{j,k} \qquad (12)$$

where

k is the index number corresponding to the current profiler bin;

L_U is the number of current speed data samples in the defined averaging period that produces data point t [-];

t is the index number of the data point;

$U_{j,k}$ is the instantaneous current speed flowing through current profiler bin k, as defined in Formula (2) [m/s];

$\widetilde{U}_{t,k}$ is the average current speed in current profiler bin k, at time t [m/s].

The current profiler bin containing the centroid of the REC projected capture area identifies the data points used to calculate the shear profile. If the centroid of the projected capture area is situated on the boundary of two current profiler bins, the use of either current profiler bin adjacent to the centroid of the projected capture is acceptable. If two current profilers are used, the shear flow measurement should be recorded when the average power-weighted speed of the two current profiler bins at the centroid of the projected capture area is at the appropriate 0,5 m/s increment requiring a shear flow measurement. Formula (10) describes how to calculate the average power-weighted speed when two current profilers are used.

Formula (12) is repeated for all values of k from 1 to S to calculate the average current speed in each current profiler bin (S is the total number of current profiler bins normal to the principal axis of energy capture across the projected capture area).

All of the data points in each current profiler bin k are then averaged for a given speed bin i using Formula (13):

$$\overline{\mathrm{Ushear}}_{i,k} = \frac{1}{N_i}\sum_{t=i_1}^{i_N} \widetilde{U}_{t,k} \quad (13)$$

where

i is the index number of the speed bin, at the specified 0,5 m/s increment;

$i_1, i_2, \ldots i_N$ is the set of data points for which the current profiler bin at the centroid of the projected capture area has a current speed falling in speed bin i;

k is the index number corresponding to the current profiler bin;

N_i is the number of data points in speed bin i;

t is the index number of the data point

$\overline{\mathrm{Ushear}}_{i,k}$ is the mean current speed in speed bin i at current profiler bin k;

$\widetilde{U}_{t,k}$ is the average current speed in current profiler bin k, at time t [m/s].

For REC deployments where the vertical shear profile shall be measured, but when a horizontally mounted current profiler is used when measuring performance data, the vertical shear profile shall be measured and reported using a vertically oriented current profiler. The vertical shear profile should be calculated according to Formulas (12) and (13), and should be calculated for a typical speed at the centroid of the projected capture area, and for each 0,5 m/s variation in river current speed. These may be short-term measurements, but are required to document the typical variation in the flow. The vertically oriented current profiler should be located either:

- 2-5 D_E upstream of the vertical centreline of the REC projected capture area during the testing period; or,
- Within 0-5 D_E upstream of the REC deployment location during the resource assessment phase.

The average vertical shear profile, $\overline{\mathrm{Ushear}}_{i,k}$, should be presented in graphical and in tabular format as defined in 10.8.

9.5.3 Current speed horizontal shear profile

When horizontal shear measurement is required per 7.4.9, the horizontal shear flow profile should be measured for all of the flow conditions at the test site. The horizontal shear measurements should be made using either:

- A horizontal current profiler as described in 7.4.9.2 method B.
- Two velocity meters positioned as described in 7.4.9.2 method C.

- Cross-stream transects that resolve the shear profile for all flow conditions. That is, when the mean current speed at the hub height varies by more than 0,5 m/s, measurements of the speed horizontal shear profile should be repeated as necessary so that the measured speed at the centroid of the projected capture area is always within 0,5 m/s of a reported speed horizontal shear profile. Where transects are performed, speed data should be obtained for the bins corresponding to the height of the centroid of the projected capture area over the entire width of the REC. These transects should be obtained by either:
  – Performing transects 2 to 5 D_E upstream of the REC during testing; or,
  – Performing transects 0 to 5 D_E upstream of the REC deployment location during the resource assessment phase (prior to deploying the REC).

For REC tests requiring horizontal shear flow measurement, the horizontal shear flow profile should be calculated as follows:

- For tests using two vertically oriented current profilers, the speed in the current profiler bin at the centroid of the projected capture area for each current profiler should be reported at the measurement speed values of interest using the general procedure described in Formulas (12) and (13).
- For tests using a single horizontally mounted current profiler, the speed should be reported for each current profiler bin k across the width of the projected capture area using the general procedure described by Formulas (12) and (13).
- For tests using cross-stream transects, the speed in the current profiler bin at the centroid of the projected capture area should be reported a minimum of every 2,0 m, or 1/5 of the device width, whichever is smaller. To reduce measurement noise, data can be averaged spatially or between multiple individual transects so long as the speed at the centroid of the projected capture area is in a 0,5 m/s bin for each transect.

The measured horizontal shear profiles should be presented as defined in 10.8.

9.6 RMS fluctuating river current speed

The RMS fluctuating speed and corresponding standard deviation in the current profiler bin at the centroid of the projected capture area should be calculated for a typical speed observed during the testing period. When the mean current speed at the centroid of the projected capture area varies by more than 0,5 m/s, the RMS fluctuating speed should be reported for this second speed value. This should be repeated such that the speed measured at the centroid of the projected capture area is always within 0,5 m/s of a reported RMS fluctuating speed.

For tests using two vertically oriented current profilers, the RMS fluctuating speed and standard deviation in the current profiler bin at the height of the centroid of the projected capture area should be calculated for each individual current profiler. For tests using a horizontally oriented current profiler, the RMS fluctuating speed and standard deviation should be reported for the current profiler bin at the vertical centreline of the projected capture area.

At each period when the average speed of the current profiler bin containing the centroid of the projected capture area corresponds to the targeted speed bin increment, the RMS fluctuating current speed should be calculated as shown by Formula (14):

$$\widetilde{Urms}_{t,k} = \sqrt{\frac{1}{L_U}\sum_{j=1}^{L_U}\left(U_{j,k} - \widetilde{U}_{t,k}\right)^2} \quad (14)$$

where

j is the index number of the time instant at which the measurement is performed;

k is the index number corresponding to the current profiler bin at the centroid of the projected capture area for this calculation;

L_U is the number of current speed data samples in the defined averaging period that produces data point t [-];

t is the index number of the data point;

$U_{j,k}$ is the current speed flowing through current profiler bin k at the centroid of the projected capture area, at time instant j [m/s];

$\widetilde{Urms}_{t,k}$ is the RMS fluctuating current speed in current profiler bin k over the specified averaging period [m/s];

$\tilde{U}_{t,k}$ is the mean current speed data point in current profiler bin k at the centroid of the projected capture [m/s].

All of the data points for the current profiler bin containing the centroid of the projected capture area are then averaged using Formula (15) for each specified speed increment of 0,5 m/s, i.

$$\overline{Urms}_{i,k} = \frac{1}{N_i}\sum_{t=i_1}^{i_N} \widetilde{Urms}_{t,k} \quad (15)$$

where

i is the index number of the speed bin, at the specified 0,5 m/s increment;

$i_1, i_2, \ldots i_N$ is the set of data points for which the current profiler bin at the centroid of the project capture area has a speed falling in speed bin i;

k is the index number corresponding to the current profiler bin;

t is the index number defining an individual data point in current profiler bin k;

N_i is the number of data points in speed bin i;

$\overline{Urms}_{i,k}$ is the RMS fluctuating current speed in current profiler bin k at the centroid of the projected capture area at speed bin i [m/s];

$\widetilde{Urms}_{t,k}$ is the RMS fluctuating current speed in current profiler bin k at the centroid of the projected capture area, for data point t falling in speed bin i [m/s];

The RMS fluctuating current speed, $\overline{Urms}_{i,k}$, should be presented in tabular format as defined in 10.8.

9.7 Current direction at centroid of projected capture area

The current speed and direction in the current profiler bin corresponding to the centroid of the projected capture area should be calculated for a typical speed observed during the testing period. When the mean current speed at the centroid of the projected capture area varies by more than 0,5 m/s, the current direction should be reported for this second speed. This should be repeated such that the measured speed at the centroid of the projected capture area is always within 0,5 m/s of a reported current direction.

For tests using two vertically oriented current profilers, the current direction at the current profiler bin corresponding to the centroid of the projected capture area should be calculated for each current profiler. For tests using a horizontally oriented current profiler, the current direction should be reported for the current profiler bin at the vertical centreline of the projected capture area.

The average river current speed is calculated using Formula (16). This calculation should only be performed for the value of k corresponding to the current profiler bin that is at the centroid of the projected capture area.

$$\widetilde{Umean}_{t,k} = \frac{1}{L_U}\sum_{j=1}^{L_U} U_{j,k} \tag{16}$$

where

j is the index number of the time instant at which the measurement is performed;

k is the index number corresponding to the current profiler bin at the height of the centroid of the projected capture area;

L_U is the number of current speed data samples in the defined averaging period that produces data point t [-];

t is the index number defining an individual data point in current profiler bin k;

$U_{j,k}$ is the river current speed flowing through current profiler bin k at the centroid of the projected capture area, as defined in equation (2) [m/s];

$\widetilde{Umean}_{t,k}$ is the mean current speed flowing through current profiler bin k at the centroid of the projected capture area [m/s].

So long as the river current direction does not vary by more than 90°, and does not cross 360˚/0˚, Formula (17) may be used to calculate the average direction:

$$\tilde{\theta}_{t,k} = \frac{1}{L_U}\sum_{j=1}^{L_U} \theta_{j,k} \tag{17}$$

Otherwise, an alternative means such as a coordinate shift or Formula (18) shall be used to avoid complications when averaging angles in the vicinity of 360˚/0˚:

$$\tilde{\theta}_{t,k} = \operatorname{arctan2}\left(\sum_{j=1}^{L_U} \sin(\theta_{j,k}), \sum_{j=1}^{L_U} \cos(\theta_{j,k})\right) \tag{18}$$

In Formulas (17) and (18):

j is the index number of the time instant at which the measurement is performed;

k is the index number corresponding to the current profiler bin at the height of the

is the centroid of the projected capture area;

L_U is the number of current speed data samples in the defined averaging period that produces data point t [-];

$\theta_{j,k}$ is the river current direction of the hub height current profiler bin k [°];

$\tilde{\theta}_{t,k}$ is the mean river current direction of the hub height current profiler bin k over the defined averaging period [°];

This estimate of the river current direction, and the corresponding river current speed computed using Formula (17) should be displayed on a circular histogram for the value of k corresponding to the centroid of the projected capture area. A line displaying the measured principal flow direction should be plotted using the method of least squares. An example plot is provided in Figure 8.

9.8 Calculation of the REC overall efficiency

The REC overall efficiency at its output terminals should be added to the test results and presented as detailed in 10.10. The REC overall efficiency for each current speed bin "i" should be derived from the measured curve according to Formula (19):

$$\eta_{system,i} = \frac{\overline{P}_i}{\frac{1}{2}\cdot\rho\cdot A\cdot\overline{U}_i^3} \tag{19}$$

where

A	is the projected capture area [m^2];
i	is the index number of the current speed bin;
$\overline{P}_i$	is the mean recorded REC active power output in current speed bin i [W];
$\overline{U}_i$	is the mean current speed in speed bin i [m/s];
$\eta_{system,i}$	is the REC overall efficiency in speed bin i;
ρ	is the fluid density, as defined in 9.1.1 [kg/m^3].

10 Test reporting

10.1 General

Reporting requirements are described below. All work performed should adhere to the requirements in this document, and any deviations should be documented as described in 10.11.

10.2 to 10.6 provide the reporting requirements pertaining to the device, test location, equipment and procedures for the demonstrated performance testing at a river location.

10.7 provides the reporting requirements for performance testing in a towing tank, flume tank, or by conducting push/pull tests to supplement the data collected during the demonstrated performance testing on the river.

10.8 – 10.10 describe how to present the collected data. 10.11 and 10.12 detail how to report measurement uncertainty, and any deviations from the prescribed procedures.

Where requested, demonstrated data from a tidal site may be provided alongside the data collected according to the procedures in this technical specification as long as the tidal performance data meets the requirements provided in 7.5.

10.2 REC report

The REC under evaluation should be described in full. As a minimum, the following parameters should be provided:

- REC make, type, serial number, production year;
- Type of energy capture technology employed and standard dimensions of the REC. This should incorporate the use of a diagram, and include the projected capture area, supporting foundation/platform/mooring system, and either the distance above the riverbed for a bottom mounted device or distance below the surface for a floating device;
- Location of the energy extraction plane;
- Description of the control system (device and software version);
- REC power rating and operational parameters, as described in 6.2, including:
  - REC rated capacity;
  - Rated current speed;
  - Equivalent diameter (D_E);
  - Cut-in speed to begin power production;
  - Low cut-out water speed to end power production (if different from the cut-in water speed);
  - Cut-out water speed (maximum water speed for REC operation);
  - Rotational speed range or period for an oscillating device.

- Description of the power take-off system up to the power measurement location. This should include the rated voltage, current and frequency rating (where applicable) of all components including the generator, converter, and any other equipment used to condition, transfer, or store power. A diagram detailing the power take-off system and location of the power measurement location should also be provided. Where applicable, calculations to account for cable losses as described in 7.4.8.2 and 7.4.8.3 should be provided in detail.

10.3 REC test site report

The REC test site should be well defined in accordance with the details in 7.2. This should include:

- A minimum of one hydrographical/navigational chart of the test area that is of suitable scale to demonstrate the following information:
  - REC location (expressed in World Geodetic System Latitude/Longitude coordinates);
  - Illustration of the REC footprint (fixed device) or anchor location(s) and mooring system (floating device);
  - REC angular orientation relative to True North (where applicable for a fixed device);
  - Electrical cable route and length (if applicable);
  - Shoreline profile;
  - Water depth and typical seasonal range based on historical discharge data;
  - Any nearby hydrographic or environmental monitoring stations;
  - Any other notable features or infrastructure in proximity to the device;
  - Identification of the current measurement locations used during the river resource assessment, if applicable.
- Reporting of the bathymetry in accordance with the survey prescribed in 7.2.2, including clear identification of any unique features;
- Reporting of the general flow characteristics at the site as described in 7.2.3, including the principal flow direction and horizontal and vertical shear profiles as obtained from the cross-stream transects.
- Reporting of the current profiler positions including a figure illustrating that the requirements of 7.4.9 are satisfied;
- Reporting of the vertical dimension and centre position above the riverbed (or from the free-surface if surface mounted) of the energy extraction plane current profiler bins;
- Reporting of the principal flow direction relative to the REC as described in 7.2.3 and 9.7 (see example Figure 8);
- Reporting (with diagram) of the cross-sectional area of the testing location consumed by the REC and foundation as described in 7.2.4 (see example Figure 9);
- Reporting of external constraints affecting or having the potential to affect typical device performance or operational periods as discussed in 7.2.5;
- Reporting of any variation from the representative water density if used for the calculations as discussed in 9.2;
- Reporting of any unusual wave activity as described in 7.4.9.4.

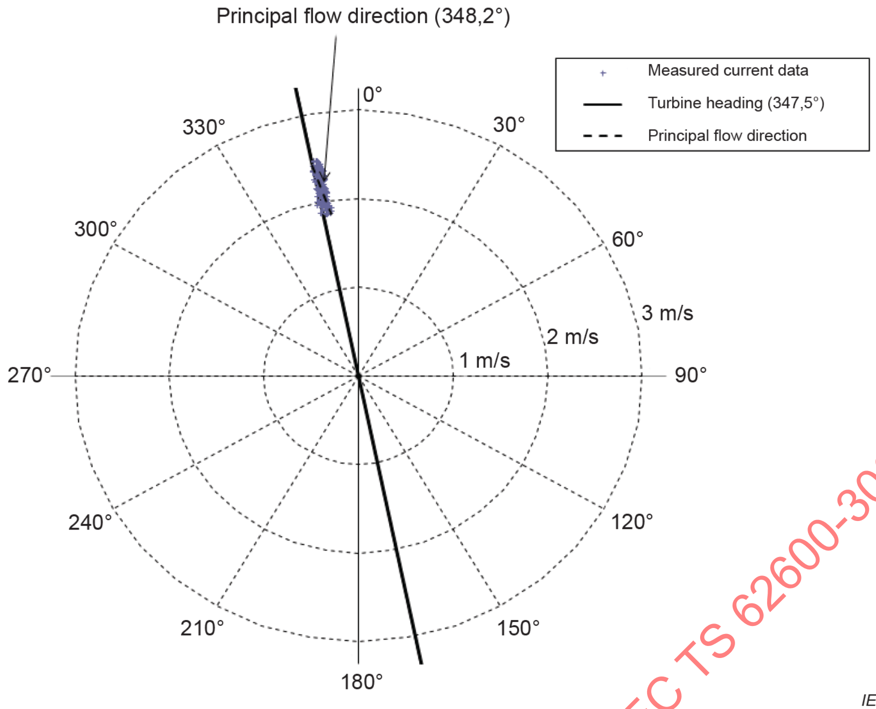


Figure 8 – Example circular histogram of river current direction

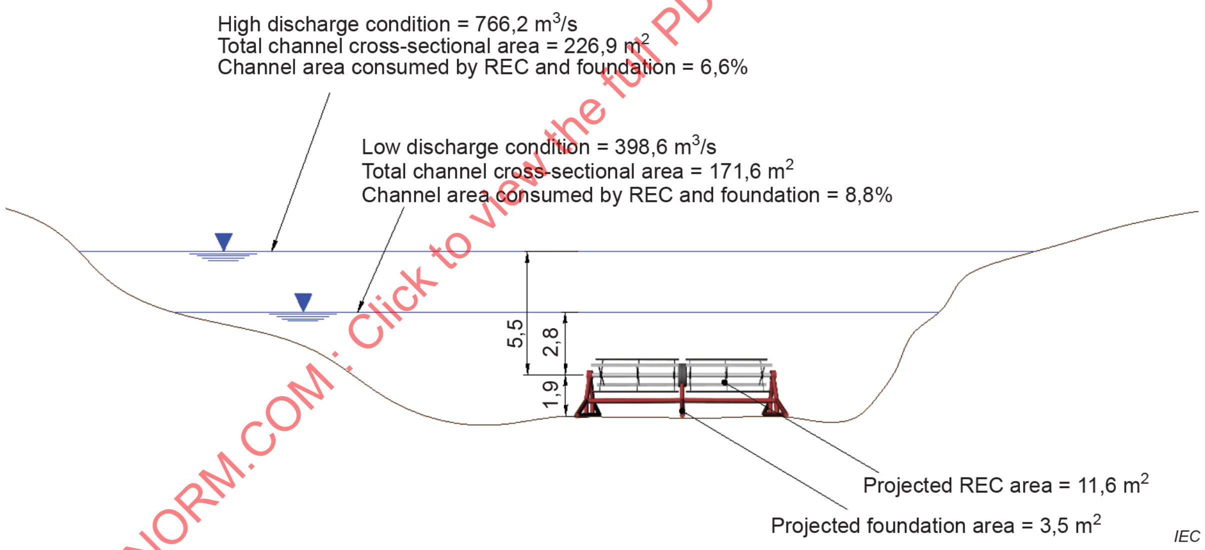


Figure 9 – Example figure showing channel cross-sectional area occupied by the REC on plane perpendicular to the principal flow direction (section view)

10.4 Electrical grid and load report

Grid parameters including voltage, frequency, and permitted tolerances should be provided. Any prevailing grid conditions limiting or having the potential to limit the power output during the testing period should be reported.

For devices not connected to a utility grid (i.e. used to charge battery powered systems) a detailed description of the electrical load, to be representative of the load for which the REC is designed, should be provided. Where applicable this should include specification of the batteries, charge controller, and dump load used to dissipate energy from the system.