TIGER TIDAL STREAM INDUSTRY ENERGISER

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Test Procedure Report 1

IEC/TS 62600:200 Gap Analysis and Feedback

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Document History

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Disclaimer

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Executive Summary

This report is part of the deliverable T1.7.3 – Accredited turbine performance test procedures - under the Interreg TIGER project.

The purpose of this first deliverable is to provide feedback on the IEC/TS 62600-200: Electricity producing tidal energy converters – Power performance assessment technical specification. The current specification is assessed by conducting a gap analysis on the technical specification's relevance for the present-day tidal sector, and where it is likely to be in the future. Areas which need further requirements or guidance are highlighted based on EMEC's experience in using the technical specification in real world testing.

The key outputs are adaptions to provide clearer guidance and requirements for floating Tidal Energy Converters.

Abbreviations

Acronym	Meaning
AEP	Annual Energy Production
ADV	Acoustic Doppler Velocimetry
ADCP	Acoustic Doppler Current Profiler
AHRS	Attitude and Heading Reference System
BSI	British Standards Institute
EMEC	European Marine Energy Centre
ERDF	European Regional Development Fund
FCE	France (Channel Manche) England
GPS	Global Positioning System
HAT	Highest Astronomical Tide
IEC	International Electrotechnical Commission
ISO	International Organisation of Standardisation
JS	Joint Secretariat
LAT	Lowest Astronomical Tide
MHW	Mean High Water
MLW	Mean Low Water
PPA	Power Performance Assessment
PSG	Project Steering Group
SAG	Stakeholder Steering Group
TIGER	Tidal Stream Industry Energiser
TEC	Tidal Energy Converter
TC	Technical Committee
TS	Technical Specification
TSE	Tidal stream energy
USBL	Ultra-short Baseline
UKAS	United Kingdom Accreditation Service

1 Introduction

The purpose of this deliverable is to assess any potential areas in the IEC/TS 62600-200: Electricity producing tidal energy converters – Power performance assessment technical specification which could be improve. By conducting a gap analysis on the specification, recommendations can be drawn as to which areas need to be improved, where further research may be required and how the specification can be changed to be more appropriate for where the tidal sector is now and the future.

The aim is that this will then act as feedback to the IEC TS 62600-200 maintenance team so that the comments can be considered as a second edition is developed. It will be informative in how EMEC approaches and reports on future performance tests.

This activity falls under the scope of the Interreg Channel Manche – Tidal Stream Industry Energiser Project (TIGER), intended to develop a go-to pan European energy supply chain resource in the channel region.

2 Gap Analysis

The current technical specification (IEC/TS 62600-200: Electricity producing tidal energy converters – Power performance assessment technical specification) has well defined requirements for carrying out a power performance assessment. Last published in 2013, the sector has diversified in the 9 years since in terms of the variety of device concepts that are being developed. As already mentioned, previous work has been conducted by EMEC feeding back on the - 200 Technical Specification to the IEC, which was published 4 years ago under the Met-certified Interreg project (EMEC, 2018). This report will reassess the Met-certified feedback and update it with additions based on EMECs testing experience since its publication so that the latest and most up-to date recommendations and feedback can be provided.

To avoid unnecessary repetition, this report will only highlight points made in the Met-certified feedback report (EMEC, 2018) if there is further to add or they are relevant to other suggestions.

2.1 Summary of the current state of the tidal industry and likely direction over coming years

Initially, the tidal industry was dominated by the horizontal-axis seabed mounted turbine concept and this is clearly evident in the methodologies defined in the TS. In the last decade the development of the sector has advanced a long way and many other concept types have emerged. Even within the horizontal axis concept, there is a fair degree of divergence.

This increase in diversity of concepts has been observed at EMEC's own test sites, with an increase in floating devices which are typically using horizontal axis turbines.

Currently, OMP’s O2 TEC and Magallanes’ ATIR TEC are both examples of floating devices which are due to test this year at the Fall of Warness, Orkney.

Table 1 shows a brief overview of the current spread in concept types within the Tiger project.

Table 1 - Device types of developers in the Tiger project

Developer	TEC type
HydroQuest	Seabed mounted, vertical axis
Orbital Marine Power	Floating, horizontal axis
Minesto	Tidal kite
QED Naval	Seabed horizontal axis

There are of course a broad range of other devices, such Minesto’s Kite, and HydroQuest’s seabed-mounted vertical-axis turbine.

2.2 Feedback on power performance assessment

In this section we have reviewed each section of the IEC/TS 62600-200 Edition to provide feedback based on the following areas:

- Review if the document reflects latest best practise
- Technical review of the methods and terms in the document
- If additional information has become available since the last edition of the TS was published

TS Section	Text in TS	Comment	Recommendation
3.10	Equivalent diameter		Suggest this is reviewed and expanded to incorporate guidance for other devices i.e. tidal kite. Also, it should include guidance on exceptions such as when there are 2 horizontal rotors orientated upstream/downstream of one another so that they share the same capture area – is the equivalent diameter based on both rotors or just one in this instance?
3.17	Tidal ellipse	For floating TEC, it is unclear if it would be best for this be done for a fixed position (bin) or mean hub height of the TEC? Clarity is required for floating devices (EMEC, 2018).	Suggest it is reviewed. See test procedure 2 (EMEC, 2022) for recommendations on alternative test methodologies for floating TEC's.
4.1	Area of current profiler bin k across the projected capture area	In the case of a floating TEC and a seabed mounted ADCP, this definition may not be a fixed value. The ADCP bins will be 'geostationary' whilst the capture area will move relative to them changing sea level due to tidal variation etc. Therefore the area of the top and bottom bin will vary as the projected capture area moves within the column.	Suggest Ak,j is used so that it reflects the area at a given point in time. Alternatively Ak could be used for a specified point in time defined in the specification.
4.1	"k" "*Index number of the current profiler bin across the projected capture Area*"	In the case of a floating TEC and a seabed mounted ADCP, this definition may not be a fixed value. The capture area will move with the changing sea level whilst the ADCP bins are 'geostationary' and so the bins within the capture area may vary.	Suggest that rewording is considered: *"Index number of the current profiler bin"* alone or *"Index number of the current profiler bin at time j"* may be more robust definitions.
5.3	*"the compass calibration should take place in the deployment frame away from all magnetic influence"*	Due to the rotation and angular positioning during calibration it is not generally practical or feasible to calibrate in the frame (EMEC, 2018). If opting for a TEC-mounted instrument as described in Section 8.9.1, calibrating a compass away from magnetic influence, whilst mounted representative of the deployed position on the device will not be possible.	It is suggested that the phrase stating *"should take place in the frame"* is removed. It is suggested that a caveat, or alternative guidance for TEC-mounted on floating TEC's should be provided. Suggest specified beam or local-reference frame coordinates. Option for external compass linking with ADCP.

7.2	*"measure with sampling levels, at a minimum, the entire height of the TEC projected capture area;"*	Seabed ADCPs may not capture the whole water column due to side lobe contamination and blanking distances. Depending on the beam angle this could be approximately 6-10 % at the top of the water column (EMEC, 2018). For floating or near surface devices this may mean complete coverage of the capture area is not feasible using this method so an option to repeat a value or extrapolate is necessary.	See test procedure 2 (EMEC, 2022) for recommendations on alternative test methodologies for floating TEC's. Suggest further guidance on incident resource measurement is added for floating TEC's. Suggest some criteria
7.2	*"measure a vertical profile with a maximum vertical distance between sampling levels of 1m across the TEC projected capture area;"*	Suggest that the sampling requirement be at the discretion of the test team depending on the shear velocity profile at the site rather than an arbitrary minimum bin size stated. A value of 1 meter could still be suggested as a guide. For some sites where there is limited vertical variation in the flow incident on the TEC developing an equivalent to "IEC61400-12-2: Power performance of electricity-producing wind turbines based on nacelle anemometry" would mean a significantly longer test period would be possible with a horizontally mounted ADCP. (EMEC, 2018) EMEC typically aims for bin sizes of 0.5m where possible.	See test procedure 2 (EMEC, 2022) for recommendations on alternative test methodologies for floating TEC's. Suggest further guidance on incident resource measurement is added for floating TEC's. Suggest option for TEC below certain equivalent diameter or rated power can use single point velocity meter where the vertical variation is negligible, to make the test more financially viable accessible for smaller TEC developers.
7.2	*"record data with a minimum number of 10 vertical sampling levels across the TEC projected capture area;"*	10 appears arbitrary in this requirement and may be overly onerous for devices with a small vertical height of capture area.	See test procedure 2 (EMEC, 2022) for recommendations on alternative test methodologies for floating TEC's. Suggest altering the requirement definition from a fixed number of sampling levels to a requirement of number of sample bins = factor of Capture bin height. Therefore the maximum bin size will be controlled to 1m maximum but this prevents small TEC's from having to do smaller than 1 if less than 10m capture bin height. If the shear velocity profile of the site is available and does not indicate significant variation alternative sampling strategies may be justifiable. Suggest providing values on TEC size, beneath which this is justifiable with the added exception that single point velocity metres are allowable in such cases.
7.2	*"the geographic position during deployment should be measured using a system with accuracy equal to or better than a differential GPS 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*	This requirement is not practical.	It is recommended that only GPS rather than differential GPS is specified, as recommended when using a TEC-mounted ADCP, the TEC position, excursion and an offset of the ADCP position relative to the GPS receiver should be clearly documented. If the ADCP is deployed from a vessel, it is suggested that the GPS position of the vessel and an estimate of the ADCP position relative to the GPS receiver is provided with a tolerance to the accuracy of that estimate. An acoustic positioning system, such as an ultra-short baseline (USBL) responder, providing slant range to a

	davit arm or block and the wire angle should be monitored during deployment. The final current profiler placement should adhere to the geographic tolerances described in 8.9.1."		transponder could also be used to estimate the relative position of the ADCP to the vessel once deployed to a high degree of accuracy. Acoustic positioning systems are often part of an acoustic release mechanism; however, it should be noted that in EMEC's experience, acoustic releases are not a reliable method for deployment and recovery (EMEC, 2018).
7.2	*"Additionally: the number of beams and beam spreading angle"*	As beam spreading is a potential issue in certain circumstances in terms of incident resource measurement placement (See 8.9.1 and Test procedure 2 (EMEC, 2022))	Suggest making beam spread angle a requirement to report. Suggest requirement side and plan view figures in final test report illustrating beam spread relative to extraction plane and measurement zones.
7.2	*"Additionally, any available information on the following should be summarised and reported:"*		Consider adding additional bullet points along these lines. So long as the following has been considered: • Consider configuring the ADCP for surface tracking to record depth if it does not adversely affect the fidelity of the velocity measurements. It is strongly recommended that depth is recorded for floating devices (Test procedure 2 (EMEC, 2022)). • Consider configuring the ADCP for wave measurements. See Annex D for details.
7 or 8	Addition		Consider including a concise list of all the parameters to be measured in either section 7 or 8 so that a simple check list is available showing the mandatory and recommended measurands and calculated parameters. A suggested list of mandatory and recommended requirements could be provided. As the monitoring requirement may be different for floating or seabed mounted devices the recommended list could indicate what is applicable to the different types. (EMEC, 2018).
8.7	*"If there is an incomplete velocity bin preventing completion of the test then that velocity bin value can be estimated by linear interpolation from two directly adjacent complete bins."*	For floating TEC's with capture areas near to the surface, some, if not all, of the capture area may be lost due to side lobe contamination. In such a case there will not be two adjacent bins of sufficient data quality to interpolate between.	Review if there is a preference for extrapolation, repeating data points or alternatives that could reduce the amount of data lost (EMEC, 2018). See test procedure 2 (EMEC, 2022) for recommendations on alternative test methodologies for floating TEC's. Suggest highlighting this risk within the specification.

8.9.1		In EMEC's experience, this is not practical for floating devices. Floating devices have an excursion radius and mooring lines so care needs to be taken in deployment and when considering beam interference with the mooring lines or cables. Beam spread of ADCP is much larger at depth, or near surface, where a floating TEC capture area is likely to be. It is common for typical TEC's to have ADCP beam footprints at the surface which are larger than the orientation B drop specifications, or the width of orientation A. This is discussed in more detail in the second deliverable report specifically on floating TEC performance assessments (EMEC, 2022).	See test procedure 2 (EMEC, 2022) for recommendations on alternative test methodologies for floating TEC's. Recommendation to include guidance on alternative positioning methods for floating TEC with exceptions listed when TEC-mounted ADCPS, which may not fit other requirements, or TEC mounted single point velocity meters are allowable (perhaps for TEC's below a certain power rating or capture area size). Suggest amending the orientation A and B specifications to allow exceptions for when the beam footprint is larger than measuring zones at floating TEC hub height. Suggest wording in-line with : "*If the beam spread means that the measurement volume diameter is greater than 1DE, then the minimum distance should still be 1DE and the maximum distance be 2DE + [beam spread-1DE] + deployment accuracy*."
8.9.1	*"vertically throughout the water column across the projected capture area of the TEC energy extraction plane."*	This may not always be feasible for a near surface device due to side lobe contamination. This is discussed in more detail in the second deliverable report specifically on floating TEC performance assessments (EMEC, 2022).	Suggest that additional guidance is made for profiling for PPA of a floating TEC with TEC-mounted ADCPs. Horizontally mounted ADCPs are also permitted for locations with low velocity shear across the projected capture area (EMEC, 2018).
8.9.1	In reference to floating TEC's: *" If none of these deployment orientations are achievable, an array of bottom mounted current profilers may be used, a correction methodology developed and justified, such that the ambient current behaviour without medication due to the proximity of the TEC is measured. One method of justifying a methodology would be to perform site calibration."*	No guidance on how to perform a site calibration in the case of a tidal site suitable for a floating TEC.	Suggest that guidance is developed and appended in the TS. See test procedure 2 (EMEC, 2022) for recommendations on alternative test methodologies for floating TEC's. Suggest introducing single velocity meters for smaller TEC's, and a size or power limit above which current profilers are a requirement. Suggest allowing numerical modelling of the TEC local flow field to be acceptable for justifying measurement locations for TEC-mounted ADCPs, horizontal or downward facing, as well as ADV if appropriate.
8.9.1	Addition	For floating TEC-mounted current profilers, provide some set-up requirements to ensure good quality data.	Suggest providing some set-up requirements to ensure good quality data (i.e. TEC hull mounted profiler must protrude from hull adequately to avoid the hull boundary layer and any hull associated turbulence creating interference to the beam measurement.

8.9.1	Addition	No guidance for any non-horizontal axis, ‘unconventional’ device (i.e. tidal kite).	Suggest some addition referring to non-horizontal axis, ‘unconventional’ device (i.e. tidal kite). See test procedure 3 for recommendations on alternative test methodologies for floating TEC’s.
8.9.2	*“While there is a potentially significant influence on TEC power performance due to turbulence inherent in the tidal 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.”*		As long as there is no negative impact on the fidelity of the velocity measurement or the test period, consider configuring the ADCP to measure adequately to allow the turbulence to be quantified – no corrections should be made.
9.1.1	Additional recommendation	Additional information could be provided on flow misalignment either here or in an appendix. We do not recommend any correction to TEC performance curve for flow misalignment. If flow misalignment is identified a secondary curve be produced based on the velocity component aligned to the axis of the device to identify the impact, the vertical velocity shear profile should be provided with this to evidence the validity of using the hub height measurement. (EMEC, 2018)	The following could be provided on an informative basis: For horizontal axis turbines considering only kinetic energy and assuming an incompressible flow E= 0.5 mv^2 , it can then be shown that P ≈ 0.5(ρAv).v2 for a control volume. So instances where the flow is horizontally misaligned by angle θ and there is negligible vertical velocity component, P ≈ 0.5(ρAv).(vcosθ)2 so power is proportional to cos2θ for misalignment θ. (EMEC, 2018)
9.2	Data processing		It is suggested that quality control is applied to the ADCP data and the criteria applied is documented. Criteria could include echo intensity, correlation, and error velocity are reviewed to identify potential issues such as side lobe contamination, ringing, excessive tilt and obstruction of the beams (potentially due to mooring lines or blades). (EMEC, 2018) Suggest recommendation to follow QARTOD guidelines https://repository.oceanbestpractices.org/handle/11329/336

9.4	Mean tidal current velocity vertical shear profile	*"This section lacks clarity as to what is the output and is hard to follow. Particularly when trying to apply to a floating device. It is suggested that this could be calculated for the whole water column rather than just the projected area if the data was recorded. Suggest that a fixed reference such as the seabed is used to avoid spatial averaging."* (EMEC, 2018)	Consider revising to the following steps: • Temporal average over the agreed time period (10 minutes) averaging for each bin position, recording min, mean, maximum and standard deviation • Bin profile based on the velocity at the mean hub height (avoid spatial averaging by selecting a fixed bin) • Find the mean for the bin and present full velocity profile results (EMEC, 2018) Tighter requirements are needed for this as the shear profile could be used to help justify alternative resource measurement strategies for floating TEC's.
9.6	Tidal ellipse at hub height		Suggest that a mean hub height is estimated for floating devices so there is no inadvertent spatial averaging. Suggest recommending including tidal ellipse for TEC maximum limit positions at HAT and LAT in the appendix if they are considerably different compared with hub height.
10.10	**Uncertainty Assumptions**		

3 References

EMEC. (2018). *Development of International Standards and Certification chemes for Marine Energy Technologies - Deliverable:1.5.1 Recomendation for Procedure adaption - Feedback on IEC TS 62600-200 Power Performance when applied to a floating platform.* Interreg MET-Certified.

EMEC. (2022). *Test Procedure 2 - IEC/TS62600-200 Floating TEC Reccomendations.* Interreg.

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