Advancing IEC standardization and certification for tidal energy converters

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Abstract— **Conformity assessment can mitigate technical and financial risks of technologies, which in turn attracts finance and encourages international trade. As marine energy is an emerging industry, international standards are yet to be consistently adopted and a conformity assessment system is currently under development.**

MET-CERTIFIED (Marine Energy Technologies – Certified) is an Interreg 2 Seas funded project [1] which aims to accelerate the development of standards and certification schemes for marine energy technologies under the umbrella of the International Electrotechnical Committee [2]. The project enables the application of IEC technical specifications 62600 for marine energy convertors to pilot projects within tank testing and open sea testing to provide feedback to the committees that develop and maintain the specifications. This paper will discuss the scale experimental campaigns of three pilot projects that have been assessed against these technical specifications. These include design requirements, moorings, electrical power quality, acoustics, tidal power performance assessment, tidal resource assessment and scale tidal testing. In addition, progress on drafting new specifications for mechanical loads and technology qualification are discussed.

This paper introduces the MET-CERTIFIED project, explains the conformity assessment system under development, summaries the key feedback on the technical specifications to date and the overall impact of the project. The lasting benefit of the project will be the inclusion of the feedback into future editions of the technical specifications and assistance in establishing a conformity assessment system that will mitigate technical and commercial risk.

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I. Introduction

THE implementation of international standards and certification schemes de-risks the technology providing a good level of confidence to insurers, investors and licensing authorities. This is one of the main recommendations from the Ocean Energy Forum Strategic Roadmap [3]. MET-CERTIFIED (Marine Energy Technologies – Certified) is an Interreg 2 Seas funded project [1]. The project aim is to accelerate the development of standards and certification schemes for marine energy technologies under the umbrella of the International Electrotechnical Commission (IEC[4]). The project enables the application of IEC technical specifications from the 62600 series for marine energy convertors to pilot projects within tank testing and open sea testing which will aid the progression of technical specification to an international standard or at least contribute valuable input and lessons learnt for a future edition.

This paper outlines the MET-CERTIFIED project scope, intent and progress to date. Providing an overview of the concept of conformity assessment and the system under development for marine energy, followed by key developments in technical specifications for tidal energy converters and recommendations on improvements to the specifications based on application of the technical specifications of pilot projects. The paper concludes with the impact the project has had to date.

II. MET-CERTIFIED Project

The MET-CERTIFIED project enables the application of International Electrotechnical Commission technical specifications in the 62600 series for marine energy convertors to pilot tidal energy projects and tank testing. The IEC 62600 series of Technical Specifications for Marine Energy which are currently under development are shown in figure 1. Technical Specifications are published as Marine Energy is still under development so there is insufficient consensus for approval of an

International Standard is available so the TSs act as a precursor.

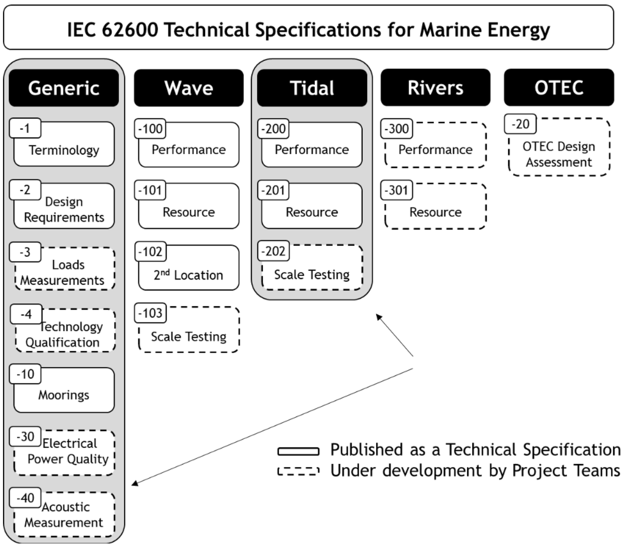

Fig. 1. IEC 62600 Technical Specifications for Marine Energy.

To date, four scale experimental campaigns and three pilot projects have been completed. The four scale experimental campaigns have been carried out in the wave and current flume tank of IFREMER on a variety of marine energy technologies: a generic tri-bladed turbine subjected two flows, one steady and one turbulent; a floating platform developed by Tocardo and an undulating membrane developed by Eel Energy, Fig. 2.

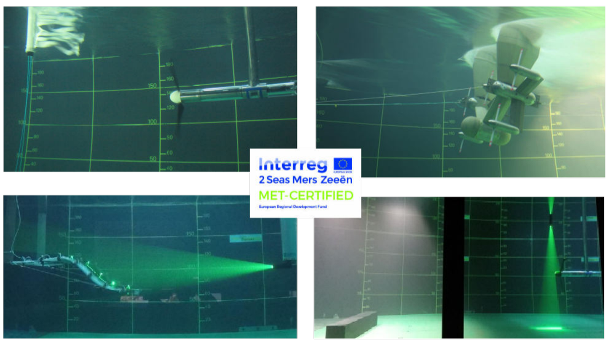

Fig. 2. Technologies tested under MET-CERTIFIED project at IFREMER (from left to right): (1) tri-bladed Ifremer turbine, (2) UFS platform developed by Tocardo, (3) EEL Energy being tested at IFREMER, (4) tidal turbine submitted to vortex structures.

The pilot projects include the Tocardo Eastern Scheldt Tidal Power plant, the Tocardo Tidal Floating System installed at the European Marine Energy Centre (EMEC) and the Sustainable Marine Energy (SME) PLAT-I installed in Connel near Oban, Scotland.

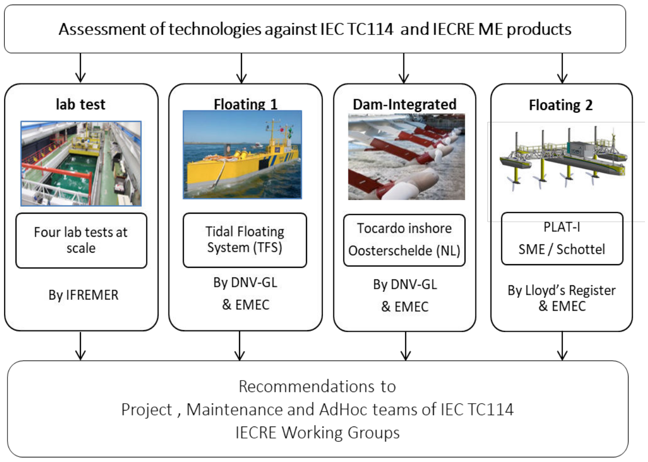

Fig 3. Diagram showing pilot projects and feedback process.

The benefits are twofold. Firstly, the developer's device is assessed to the technical specifications, and secondly feedback on its practicality is provided to the IEC Technical Committee (TC) 114 to aid progression for International Standards. TC 114 is the technical committee for marine energy converters which aims to prepare standards. Drawing from expertise from the membership of 27 countries, the committee oversees the project teams which develop standards; the maintenance team works on revising editions; and the ad-hoc groups collate feedback in between editions.

III. CONFORMITY ASSESSMENT

The project partners of MET-CERTIFIED are active in the development IEC Renewable Energy (RE) certification scheme to enable third party Conformity Assessment (CA). The system aims to facilitate international trade in marine, solar photovoltaic and wind energy by verifying the safety, performance and reliability of equipment and services. IECRE members use the principle of reciprocal acceptance of test results and the resultant certifications to obtain certification or approval at national level, enhancing access to markets. Accredited test laboratories and certification bodies produce test reports and conformity statements have demonstrated the following:

- Assurance of technical competence
- Approved methods and procedures aligned to international best practices
- Processes in place to ensure impartiality.

The IEC define Conformity Assessment (CA) as "demonstration that specified requirements relating to a product, process, system, person or body are fulfilled" [5]. The requirements mentioned in this definition could be a published technical specification (TS) or a standard. Conformity assessment works by assessing technical risk, such as structural integrity, or addressing financial risk by reducing uncertainty around projected income by measuring power performance.

Thus, for marine energy conformity assessment, the primary requirements used are the IEC 62600 series of TSs.

Figure 4 shows the process being developed for type certification. The client will discuss the scope of certification with the certification body and test laboratory at the certification planning stage, so that it meets the client's requirements and clarifies whether optional steps will be included. However, for some aspects of the design and testing the existing IEC 62600 series of TS may not be suitable. For example, due to the configuration of the marine energy device. To assist in this a new TS is being written for Technology Qualification, this will be IEC 62600-4 which is outlined in section IV C.

MET-CERTIFED has coordinated a series of workshops aiming to engage both marine energy developers and the finance and insurance sectors to communicate the potential for conformity assessment to mitigating technical and financial risk. The workshops were an opportunity for the standardisation and CA community to collate feedback on the barriers and needs perceived by marine energy developers and the investors and insurers for standards and CA. The project has also commissioned a series of informative interviews with an investment advisor and the project partners to discuss the benefits of certification [1].

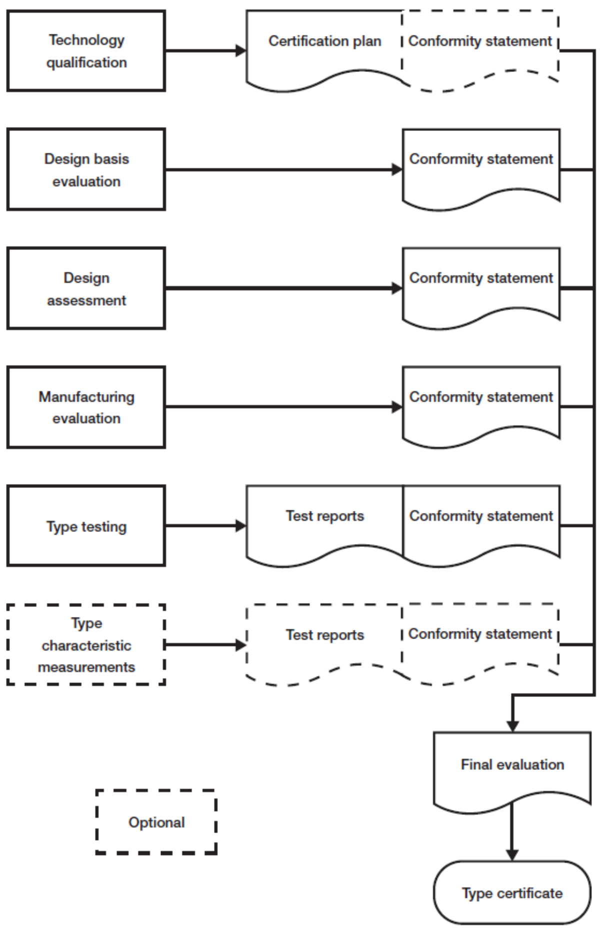

Fig. 4. Diagram showing Marine Energy Certification Process.

IV. Recommendations per Technical Specification

The following subsections address either development activities supported by the project or specific technical feedback that has been compiled during the project relating to the draft and published IEC 62600 series of technical specifications. Focusing on 62600 parts that are applicable to tidal energy and pilots completed to date in the project. A point not discussed below but has been identified across the 62600 series is inconsistency of terminology, this is something TC114 are already aware of and are aiming to improve.

A. Design

The current text of IEC TS 62600-2: 2016 Design requirements for marine energy systems [6] relates mostly to structural design. The pilot project which was reviewed was a floating platform which was being deployed for a short test period. IEC TS 62600-2: 2016 outlines the design load cases that need to be considered. For a project which has only a short deployment it is unclear if all return periods, design categories and limit states are applicable. It was recommended to the maintenance team for IEC TS 62600-2 that they should consider if all load cases in section 7 are necessary for short deployments (for example, less than 4 months). This could be covered in an annex.

Additionally, it was noted that section 10 which deals with mechanical and electrical aspects was too brief to be of any use to designers. It was also noted that this section did not refer to any other standards or other relevant references where more information on mechanical and electrical aspects could be found. This could be rectified either by making clear in the introduction of IEC TS 62600-2 that the TS only deals with structural design or that the detail within section 10 needs to be extended.

The version of IEC TS 62600-2 which is currently being drafted aims to include Technology Qualification as part of the design process, however, at the time of writing the current draft does not address the issues raised above.

B. Mechanical Loads

The IEC TS 62600-3 [7] (under development) describes the measurement of mechanical loads on full scale marine energy converters such as wave, tidal and other water current converters (including river current converters). As the TS is not published this has not been applied to the pilot projects, instead the MET-CERTIFIED project partners are contributing to the drafting of the TS. The load measurements standard is a generic standard applicable for different marine energy technologies. It is aimed at the development stages technology readiness level (TRL) 7 to 9, i.e. full-scale prototype up to production device. This new standard can play an important role in the type certification of marine energy converters (MECs) (structural design).

A committee draft (CD 62600-3) was published in November 2018. All IEC member countries have had the opportunity to comment on the CD and these comments have been reviewed. The project team is now developing a draft technical specification (DTS) with an aim to publish the first edition of the technical specification in the first half of 2020.

The CD that is already available outlines the intent of the TS under development. However, it is certain that changes will be made during 2019, to accommodate for the comments that were collected during the international review of the CD. For a more detailed description of the development of IEC TS 62600-3 see Schaap et al [8].

C. *Technology Qualification*

The IEC TS 62600-4 (under development) describes the process of Technology Qualification (TQ). As the TS is not published this has not been applied to the pilot projects, instead the MET-CERTIFIED project partners are contributing to the drafting of the TS. TQ is a process for identifying and creating the evidence that the technology will function reliably within a defined operating envelope and duration, and within an acceptable level of confidence. CA normally qualifies technology against existing standards to confirm compliance. TQ differs in that it allows systems to be qualified that do not conform to an existing standard (or may partially conform to an existing standard).

TQ is performed at the beginning of the CA process to identify the uncertainties, novelties, and modes of failure, mechanisms of failure, risks and risk control measures. In addition, TQ will identify the standards that are applicable, to what extent and what adaptation is required to address the risks. The Technology Qualification Plan is the deliverable from this process and will provide all necessary actions to achieve certification.

D. *Moorings*

The text of IEC TS 62600-10:2015 assessment of mooring system for marine energy converters [9] was reviewed against the design of the floating platform mentioned in section A. It was noted that there was room for clarification within the text of IEC TS 62600-10. For example, it was not clear if the load cases in section 9 aligned with the load cases in IEC TS 62600-2. In addition, it was unclear if the risk assessment in IEC TS 62600-10 aligned with the risk assessment in IEC TS 62600-2 or any other risk assessment that might be carried out, for example, as part of a technology qualification exercise. Lastly it was noted that the section on anchors in IEC TS 62600-10 does not deal with anchors drilled into rock (as is proposed in some designs).

E. *Power Quality*

The IEC TS 62600-30:2018 Electrical power quality requirements [10] was only released after current tests had been completed, therefore the full process outlined in the TS has not been implemented. Overall this specification details a step change in the rigour and cost compared to current practice in the marine industry. The approach outlined in this specification may not be proportionate for the prototypes operated in the marine sector at present, but it is vital that developers understand these requirements early to avoid fundamental design changes once at commercialisation and that test facilities have time to invest in the infrastructure and equipment required. Components of the power quality tests would also assist with demonstrating compliance with some of the requirements in EU Network Code Requirement for Generators [11].

F. *Acoustics*

IEC TS 62600- 40 Committee Draft (CD) Acoustic characterisation of marine energy converters [12] was only released after the pilots were completed, so the acoustic data collected did not follow this process. As a result, a desktop review has been completed instead, using the planning of tests around a floating device for context. The recommendations to date include:

- Consider adding a collection of baseline data at the site prior to the deployment of the marine energy converter (MEC) so that ambient/background noise can be characterised and differentiated from the MEC. This should be collected for a range of resource conditions.
- Sampling zones- Due to the risk of entanglement it may be difficult to collect drifting measurement upstream of floating tidal device. For highly energetic tidal areas repeated targeting a 25m zone may prove impractical. It is recommended the actual distance achieved is reported explicitly, it would also be beneficial to show spatial variation captured.
- Consider increasing the maximum frequency from 100kHz to 150-160kHz. This would ensure no noise which may affect the echolocation of cetaceans is missed by setting the standard upper frequency limit to 100 kHz. If no discernible noise from the MEC is detected above 100kHz this could be reduced for later tests.

G. *Tidal Performance assessment*

The IEC TS 62600- 200:2013 Electricity producing tidal energy converters – Power performance [13] has been utilised for each of the pilot projects. Recommendations for procedure adaption to date include:

- Further clarification is required for floating devices that do not have a fixed hub height and/or devices that have multiple rotors at differing heights.
- Inconsistent use of vector and scalar quantities.
- Incomplete coverage of the swept area can occur due to side lobe contamination and there is potential for mooring lines intersecting Acoustic Doppler Current Profiler (ADCP) beams, at the moment the specification does not outline what to do where this data has had to be discarded or is incomplete. Both would affect data quality.

- For floating devices that have an excursion radius the ADCP placement criteria needs to be clarified.
- It is recommended that developing an additional method using device mounted ADCP measurement is considered, this could help address the previous two points.

H. Tidal Resource

IEC TS 62600-201:2015 Tidal energy resource assessment and characterisation [14] has been applied to each of the pilot projects. The recommendations to date include:

- This specification offers different levels of feasibility, but clarity is needed in the methodology section and significantly more detail how to report results so that the appropriate and proportionate approach is selected.
- At present this reads like a modelling guide. Consider adding additional focus on how to report; model validation, analysis of model output, presentation of results and an estimate of uncertainty.
- Clarity is required on how depth averaging should be handled. Depth averaging is common for hydrodynamic models. The shear velocity profile could be site specific and different styles of device may sit at different heights in the water column, with different swept areas. Depending on the objective of the resource assessment different approaches may be required. For instance, swept area or hub height velocity would be device specific and could be combined with a power curve to estimate annual energy production, whereas it is unlikely to be appropriate to use a depth averaged velocity straight from a 2D model for that purpose.

I. Tidal Scale Testing

The IEC TS 62600-202 (DTS) Scale testing of tidal stream energy systems [15] is currently under development. Tank testing is undertaken to establish the behaviour of a tidal energy converter at model scale and to identify the impact of different test configurations on device performance. The availability of a controlled environment where each set of experiments can be repeated is highly valuable. Due to the fact that marine renewable testing centres are not uniformly configured or constructed, standardisation in test practices is an important aspect for industrial development. In order to improve the work already done and to propose protocol adaptations and enhancement, four experimental trials have been undertaken on different tidal energy devices: fixed and floating horizontal axis turbine as well as undulating membrane, as previously presented in [16], [17] and [18].

The tested technologies include the tri-bladed IFREMER turbine, Tocardo's UFS platform, an undulating membrane developed by EEL Energy and a tidal turbine submitted to vortex structures. During these tests, specific attention has been paid take into account and measure the incoming flow and its velocity fluctuations (due to a high mean turbulence intensity level or the presence of vortices in the water column) when characterising turbine performance. The results show that this flow measurement has to be performed simultaneously and synchronously with the turbine parameters. The distance between the flow measurement and the turbine can increase the loss of information between the upstream velocity signal and the turbine parameters. On the other hand, the momentum theory shows that the flow speed should reduce from free-stream conditions far upstream from the turbine to the velocity incident at the rotor plane. In order to better understand this last point, additional measurements have to be performed to take into account the competing requirements between a far upstream undisturbed flow speed and a measurement that is correlated with the flow incident on the turbine.

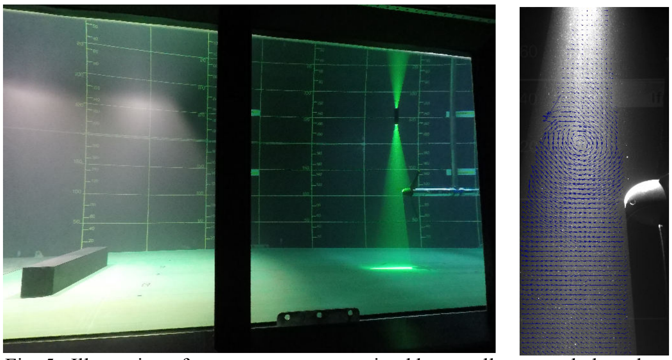

Fig. 5. Illustration of a vortex structure emitted by a wall-mounted obstacle impacting a turbine

From all the results obtained during the last years, we propose the following hierarchy to take into account the flow characteristics and the overall functionality in order to be able to estimate the prototype efficiency. Regardless the Technology Readiness Level but taking into account a good PTO system, the priority order could be:

- captive tests under 1/ steady and 2/ turbulent flow (with or without a uniform vertical velocity profile)
- captive tests under 3/ regular and 4/ irregular waves
- captive tests under combined 5/ wave and current interactions
- forced motion tests a/ without and b/ with current for floating devices
- free tests under c/ current, d/ turbulent current and e/ wave & current for floating devices

We consider here that for marine current converters, the impact of turbulence plays a greater part than the impact of waves. The more the prototype is representative of the real system, the more relevant the extrapolation of the results. The specifics of turbine farm development with turbine interaction effects are not taking into account at this stage.

V. Current impact on advancing Technical specifications

The application to real pilot projects and dissemination around this at conferences and workshops has raised industry awareness of both what technical specifications are available and the conformity assessment system being developed. The workshops have encouraged interaction between certification bodies and test laboratories that provide the services and the technology developers, finance and insurance industries that are looking to mitigate risk.

In addition to the application of the technical specifications to pilot projects, MET-CERTIFIED has increased the participation of the partners in IEC maintenance teams and working groups. To date, the benefits include increased participation in the teams developing standards for the marine energy sector and increased usage of the technical specifications. Both of which have accelerated their development and assist in establishing a conformity assessment system.

The recommendations from each pilot have been fed back to the appropriate team for each specification with the aim that it is considered for the next edition and there is frequent communication between the project and TC 114 and IEC RE working groups.

Specifically, the development of the IEC TS 62600-3 on mechanical load measurements has been enhanced by the MET-CERTIFIED sponsored work from Dutch Marine Energy Centre (DMEC) (convener) and Lloyd's Register in this project team. Similarly, the IEC TS 62600-4 on technology qualification was a new work item proposal by a project member and 6 members of the project team also working for MET-CERTIFIED partners and observers.

The support of these specifications and the recommendations that will be incorporated into future editions has both accelerated progress and the ensured longevity of benefit to the sector.

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