Advancing IEC standardisation and certification for tidal energy convertors

P. Scheijgrond [1], A. Southall [2], C. Bittencourt [3], P. Davies [4], P. Mathys [5], G. Germain [6]

[1] Dutch Marine Energy Centre, DMEC, The Netherlands. peter@dutchmarineenergy.com, [2] European Marine Energy Centre, EMEC, Orkney, UK. anna.southall@emec.org.uk, [3] DNV GL, London, UK, cbf@dnvgl.com,
[4] Lloyds Register, Southampton, UK peter.davies@lr.org, [5] University of Ghent, Belgium, Pieter.Mathys@UGent.be
[6] IFREMER, France, gregory.germain@ifremer.fr

Abstract- This paper discusses the IEC TC 114 technical specifications for marine energy convertors and the IECRE Marine Energy Sector certification scheme and how the MET-CERTIFIED project contributes towards the advancement of the system by verifying various technologies against the system.

Keywords- Marine energy, tidal energy, standards, certification, experimental trial, test protocol, IEC, IECRE.

I. INTRODUCTION

Certification can help reduce actual and perceived risks of the technologies in terms of performance and structural integrity, and thus helps to attract commercial financing and facilitate international trade. At present, a certification scheme for marine energy convertor is under development by the International Electrotechnical Commission (IEC) involving all stakeholders in a consistent way based on international consensus. The implementation of international standards and certification schemes are needed to accelerate marine energy technologies development. This was also one of the main recommendations from the Ocean Energy Forum Strategic Roadmap [1]. In order to create a valuable and robust system, it is important that it is applied in the real world and feedback from experience is given back to the groups developing the specification and certification schemes.
After presenting the MET-CERTIFIED project, we recall the process of standardisation and certification. Then we present the main results obtained during the first years of the project.

II. MET-CERTIFIED PROJECT

In July 2016, the Interreg 2 Seas Monitoring Committee gave the green light to the MET-CERTIFIED project [2], which stands for Marine Energy Technologies Certification. The project aims to contribute towards the development of the specifications and certification schemes under the umbrella of the IEC TC 114 committee and the IECRE ME-OMC [3]. Stakeholders around certification, from banks and insurers to consenting authorities, end-users, test facilities and certification bodies are involved throughout this project.

Four pilot projects will be verified against the IEC TC 114 standards that are currently under development. For example, the tidal power plant in the Eastern Scheldt Storm Surge barrier will be used as a reference case for in order to make recommendations for procedure adaptation.

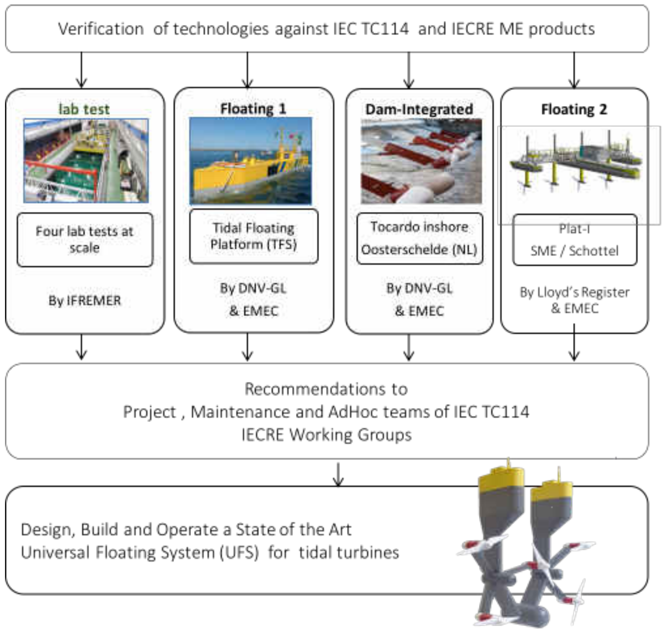

Figure 1 : Diagram showing how the various technologies are reviewed under the MET-CERTIFIED project and feed into recommendations to IEC TC 114 Technical Specifications and IECRE ME certification schemes.

By applying the standards and certification schemes on such real world projects, valuable feedback is collected to improve the IEC products. It is expected that this process will result in a robust and internationally recognised certification scheme for the sector and reduce the actual and perceived risk associated with marine energy projects [4]. This in turn will increase the interest from large investors, enabling the sector to deploy large marine energy projects.

III. PROCESS OF STANDARDISATION AND CERTIFICATION

Within the IEC, Standards are developed by Technical Committees (TC), TC 114 prepares standards for Marine Energy converters. Conformity assessment is separated from this and is managed by IECRE Marine Energy Operational Management Committee (IECRE ME-OMC).

a. IEC TC 114 Project, Maintenance and Ad Hoc Teams.

Technical Specifications (TS) are developed by a Project Team consisting of experts from at least four different countries and chaired by a convener. Typically, it takes three years for a TS to be developed from scratch. Once a TS is published, they are kept up to date by Ad Hoc Groups or Maintenance Teams. The role of an Ad Hoc group is to deal with specific issues (e.g. alignment between TSs, adding annexes or clarification sheets) and collect feedback from the in situ application of the standards. Maintenance Teams are formed to revise published Technical Specifications based on the feedback received from end-users or from other stakeholders in the sector.

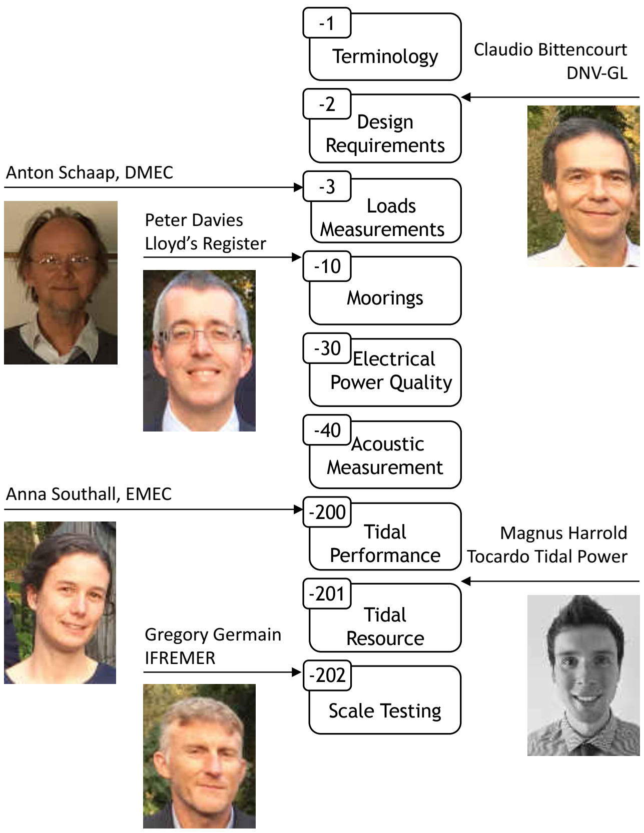

Figure 2: Partners in the MET-Certified project are also experts in Project or Maintenance Teams, thus delivering their recommendations directly into the teams they are part of.

A number of partners in the MET-Certified project are also experts in the various Project Teams, Ad Hoc groups and Maintenance Teams. This puts them in a good position to deliver the recommendations directly back into the teams dealing with revisions of the Technical Specifications. For those teams that the project has no representation, the recommendations are sent to the relevant convener and to the IEC TC 114 Chair. As an example, several Teams met during the IEC TC 114 annual plenary meeting recently held in Seattle, WA USA. Partners from the MET-Certified project prepared recommendation documents for their teams, which were presented and discussed in the various meetings. Also, the recommendations were uploaded to the Collaboration Tools, accessible to all members of relevant teams.

b. IECRE Marine Energy Working Groups

The IECRE ME-OMC develops the certification schemes. Certification takes place against the Technical Specifications developed under IEC TC 114. For each evaluation against a TS either a Test Report or a Conformity Statement is issued. Collectively a number of Test Reports and Conformity Statements can form the following:

- Prototype Certificate
- Component Certificate
- Type Certificate
- Project Certificate

Certification Bodies, like DNV GL, Lloyd's Register and Bureau Veritas and others can issue Conformity Statements. Accredited Test Laboratories can issue Test Reports carrying the IECRE logo. In order to encourage Test Laboratories to join the system, they can go through a system of self-assessment for the first three years while they operate under the system.

Within the IECRE ME-OMC, there are Working Groups that develop the Operational Documents (OD) that describe the various aspects of certification. A number of partners in the MET-Certified project are also members of these Working Groups. E.g. DMEC and Lloyd's Register are convening the WG360 on Scope of Certification. As such the partners are able to bring in their learnings from the project, directly in Working Groups as has been the case in the drafting of Operational Document for Performance testing of Tidal Energy Converters which is about to be published.

IV. RESULTS & FINDINGS

Intermediary results are discussed in this section. IFREMER conducted three experimental campaigns in the wave and current flume tank. The results are discussed in section (A). EMEC, DNV GL and Lloyd's Register performed reviews of three pilot projects: being (B) the Texel Floating Platform installed initially at DMEC in 2015 and then moved to EMEC in 2017, (C) the Eastern Scheldt Tidal Power plant, and (D) the SME Plat-I installed in Connel on the west coast of Scotland. Later in the project a full scale semi-submersible system, The Universal Floating System (UFS) will also undergo the process of certification. The UFS is being developed by Tocardo Tidal Power.

Figure 3: Some of the technologies reviewed under the MET-CERTIFIED project (from left to right): (1), the Eastern Scheldt Tidal power plant of Tocardo, (2) SME's Plat-I submerged platform for tidal turbines and scale models of (3) EEL Energy and (4) Tocardo UFS tested at IFREMER.

The Technical Specifications applied and recommendation for changes will be discussed, covering the IEC TC 114 62600 -2 for Design Requirements [5], -10 for Moorings [6], -30 for electrical power quality (draft) [7], -40 for acoustics (draft) [8], -200 for tidal power performance assessment [9], -201 for tidal resource assessment [10] and -202 for scale testing (draft) [11]. As shown in
Figure *4*.

A. Scale testing at IFREMER

Under the Met-Certified project, three experimental campaigns have been carried out aiming to provide feedback to -202 for scale testing [11] on the experimental protocol, instrumentation used and applicability to different aspect and types of Tidal Energy converters.

Firstly, a three-bladed horizontal axis turbine is tested, a well-known generic turbine [12] has been used to investigate the sensitivity to measurement position, choice of instrumentation and turbulence characteristics. The second set of tests were on a floating platform for multi-turbines deployment developed by Tocardo. The aim was to validate numerical models and demonstrate the behaviour of the full concept, from the mooring lines system to the platform behaviour under wave and current loads. The most recent

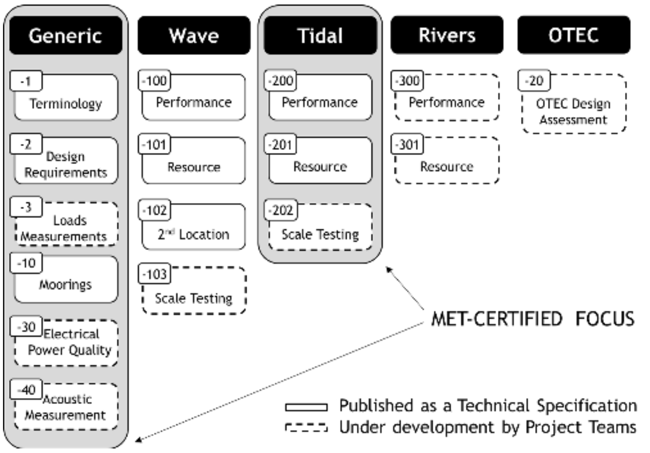

Figure 4 : Technical Specifications under development under IEC TC 114 standards for Marine Energy Convertors. MET-CERTIFIED focusses on specifications relevant for Tidal Energy Convertors in the grey areas.

tests on an undulating membrane developed by EEL Energy. This has been considered in order to evaluate the applicability of the classical protocols for other kind of technologies. These three devices have been tested in the wave and current circulating basin of IFREMER [13].

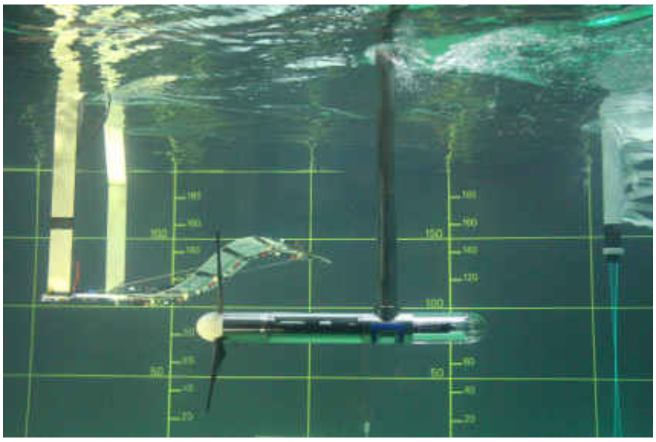

Figure 5 : Tests carried out for comparison between a generic 3-bladed horizontal axis turbine and the Eel Energy undulating membrane.

Scale testing provides valuable insights in the form of recommendations to the IECRE or TC 114:

It is recommended that the upstream velocity is used to calculate the power coefficient and that it is measured simultaneously with the turbine parameters. However, the further the measurement point is from the turbine the lower the coherence [14]. A particular study focus on the time and space correlation between velocity measurement and turbine parameters will be presented by Gaurier & al [15].

The turbulence characteristics in term of iso or anisotropy, energy level and spatial repartition, effect on turbine performances and fatigue must be also addressed. As highlighted by Ikhennicheu & al [16], low frequency structures, with a diameter up to the diameter of the turbine, affect the efficiency of the turbine so turbine performance, in term of the classical power and thrust coefficients, should be processed.

The blades bending moment coefficients should be analysed as well, in a temporal and spectral point of view. Particle Image Velocimetry (PIV) measurements for upstream flow characterization can be preferred as presented by Gaurier & al [17], rather than Laser Doppler Velocimetry (LDV).

A 1/18th scale UFS was tested in a range of conditions with a staged approach. During the test the position and orientation were monitored and how the surge and pitch motions and shape resistance varied with conditions. Conditions included current only, regular and irregular wave conditions, both with and without current. While regular waves will not occur in reality at sea, these tests provide useful datasets that are easier to compare with numerically simulations and identify where an empirical correction may be required to accurately model the full-scale behaviour. In this instance an empirical correction was recommended for the development of a bow wave at the UFS columns in high flow velocities, adding considerable shape resistance to the platform. The obtained datasets not only provide information on the stability of the platform in a range of wave conditions, but also the induced cyclical variations in mooring line tensions required to estimate fatigue life.

PIV measurements have been performed in the wake of an undulating tidal energy converter developed by EEL Energy [18]. Three configurations of the converter have been tested: one un-damped case (without PTO), a low damping case and a high damping case with shorter cables. A motion tracking system has been synchronized with the PIV measurement. It enables to phase the different planes of a same wake. For this technology the confinement effects represent at scale in-situ conditions, they don't allow easy comparison with numerical simulations. Due to the duration of the experiments, the adjustment of PTO varied. The PTO adjustment has been measured before and after each experiment in order to minimize the uncertainty and errors. This variation causes difficulty in the power estimation and in the junction of the planes.

In conclusion even for classical turbine the PTO system, some specific developments are still needed if one can reproduce the good behaviour of the energy converter, from the energy caption to its transformation. As underlined by the experimental results obtained from these three test cases, the existing experimental infrastructures don't allow all the parameters to be taken into account (operating conditions and device characteristics).

B. Review of Tidal Floating System by DNV GL and EMEC

Undertaking a performance test on the Tidal Floating System (TFS) has enabled the comparison of sea bed mounted velocity measurement as recommended in the IEC TS 62600-200 [9] to device mounted measurements. Both measurements were undertaken with Acoustic Doppler Current Profiler (ADCP) equipment, but the different configurations give differing coverage and strengths.

Seabed mounted ADCPs enable the capture of the vertical velocity profile and wave orbitals. Due to side lobe contamination near the surface it was not possible to capture the entire swept vertical profile. In this instance there was negligible shear across the turbine swept area, so depending on the site and the device position in the water column, capturing the vertical velocity profile may not be essential to producing a performance curve. Developing a transfer function approach based only on a hub height measurement as used in the Wind standard IEC 61400-12-2 [19] may be applicable for some applications.

Meeting the positioning constraints outlined in the specification without compromising data quality was difficult for a floating device due to device movement, mooring line scope and ADCP beam spread. While the optimal location was identified there were still periods where the ADCP beams were suspected to have been intersected by the mooring lines and the data point had to be discarded based on quality criteria. The deployment of seabed mounted ADCPs also incurs significant costs for a relatively short data set. In this instance the plan duration was 45 days, constrained by both battery and memory. Another disadvantage of the configuration is that premature failure is only detected retrospectively, and technical faults did occur resulting in data sets shorter than the planned period. This shows that full coverage is not always possible with the methods outlined in the TS [9].

For comparison the second set of ADCPs were mounted horizontally facing, one each facing the flood and the ebb to capture relative velocities. There was good correlation between vertical and horizontal ADCPs except a slight deviation at the peak velocity, into which investigations are ongoing. This ADCP captured real time data for the entire deployment resulting in a far larger data set, did not require costly marine operations. Also, uncertainties from time synchronisation and drift were minimised. Limitations of this method include not capturing wave data and outputting relative as opposed to absolute velocity measurements. Magnetic compass bearing, pitch and role measurement on the ADCP were viewed tentatively meaning only relative flow speeds aligned with the device were extracted with confidence. Supplementary equipment to monitor device motion would be recommended so that absolute velocities could be calculated. This method is in need of further improvement prior to offering this as an option in the TS. By the time of the writing of this paper, this activity is still progressing.

C. Review of Dam-Integrated tidal turbines by DNV GL and EMEC

The recommendations for the IEC TC 114 Technical Specifications and IECRE Operating Directives were based on the activities performed under the existing DNV GL's certification process for Tocardo's T2si turbines and the third-party verification, carried out by DNV GL, of the support structures used for the T2 turbines in Oosterschelde. It is important to highlight that the certification process for the T2si turbines is based on the DNVGL-SE-0163 Certification of Tidal Turbines and Arrays [20] considering the technical requirements specified in DNVGL-ST-0164 Tidal Turbines [21].

The third-party verification of the support structure at Oosterschelde was performed considering the scope defined by Dutch Authorities and it was based on EN 1993-1 [22], EN 1993-2 2006 [23]and DNVGL-RP-C203 Fatigue design of offshore structures [24].

Main observations and recommendations to IECRE and TC 114 were derived based on the TSs and ODs available at the time of the completion of the review (June 2017). The following recommendations are made to TC 114:

- TS 62600-2 [5] should be either renamed to reflect the scope focused on structural design requirements or include significant content to cover all systems that are part of a marine energy converter.
- There is a general inconsistency and lack of detail in the resistance / capacity model of the TS 62600-2 (Section 9) [5]. The existing text should be replaced by recommendations on the applicability (and where needed, adaptation) of the standards as well as partial safety factors in 62600-2 are derived / calibrated / adjusted considering the resistance / capacity models for the different nominated standards.
- Section 8 should be re-worded to consider the acceptable materials from the nominated standards for resistance models. In this case, the nominated standards would define specific criteria for structural categorisation and material selections as well as inspection requirements during fabrication.
- Partial safety factors defined in the 62600-2 [5] require calibration in line with the minimum simulation requirements for the different limit states and the resistance criteria from nominated standards for definition of resistance model. The 62600-2 provides some limited consideration regarding simulation for tidal energy converters, but the resistance model is scattered and limited.
- Specific provisions for control of uncertainty on the site characterisation should be provided in 62600-2. Site measurements are normally of short duration and the robustness of statistical robustness, especially for waves, are not sufficient for a reasonably accurate definition of design condition for extreme sea states. The existing TSs are focused on performance rather than extreme conditions.
- Specific provision in 62600-2 [5] should be given to address the uncertainty regarding the analytical models.
- For a risk-based document, there is a need to provide partial safety factors considering the different safety levels.
- There is a need to define if Allowable Stress Design (ASD) is to be accepted and guidance given on how to apply the requirements for the 62600-2 [5] to ASD.
- There is a need to address multiple turbines. Load combinations in 62600-2 should include provision for multiple turbines for ULS, ALS and FLS.
- Geotechnical aspects are to be included.
- There is a need to emphasise in 62600-2, the application of risk assessment and to define the conditions where abnormal and accidental cases are to be considered. Also, it is recommended to connect the safety levels with a risk matrix used in the risk assessment / technology qualification. This correlation between safety levels and risk is to be further defined in 62600-2 with due consideration of contents of IECRE OD on technology qualification.

The suite of standards developed by TC 114 focuses on wave, tidal and other water current conversion into electrical energy and recommends the use of TC4 [25] specifications for dam or barrage integrated devices. As a trial this dam integrated tidal turbine was reviewed against the -200 [9] and -201 [10] to check applicability. The key finding with reference to the -200 and -201 was that measuring the velocity to calculate kinetic energy for devices in this configuration was sub optimal due to substantial local variation as the flow accelerates through the dam. Measurement based on water depths to estimate gravitational potential energy was preferable for this configuration confirming the need to use the hydraulic rotating machinery TC4 suite and the need to develop specific specifications for other scenarios such as rivers will be covered by standards under development.

D. Review of SME Plat-I by Lloyd's Register and EMEC at Oban

As the IEC technical specifications were not used for the design process (IEC TS 62600-2 [5] and IEC TS 62600-10 [6]). The review was a look at high level principles, rather than listing all the deviations with the IEC technical specification.

It is noted that several different design codes were used. This does risk that they are not compatible with each other. It is suggested that if more than one design code is adopted that the compatibility of approaches / loads etc. is investigated. The approach used for the design of the device may be adequate for very short deployments (as was the case in this instance). However, for deployments of more than 4 months a more rigorous approach was recommended.

Whilst the IEC TS for design (62600-2) and mooring (62600-10) have not been used in this instance it is recommended that they are used for devices with longer deployments. It should be noted that these documents reflect the experience of domain experts across several countries. In addition, the adequacy of the IEC technical specifications was also being tested (based on a review of the design process). These findings were reported to the IEC teams working on these documents. This was quite detailed so will not be reported here.

EMEC are now collecting data on Sustainable Marine Energy (SME)'s Plat-I tidal energy system, which is currently deployed near Oban, at Connel.

Figure 6 : Bow of SME's Plat-I and ADCP retrieval (Credit SME).

EMEC have deployed an Acoustic Doppler Current Profiler (ADCP) at Connel to measure the tidal speed, in which the results can then be compared to other speed measurement instruments SME and their research partners have around their device. This will enable the evaluation of advantages and disadvantages of the different measurement techniques which will inform best practice. As a machine with four rotors this will also enable a review of using the effective swept area component of the -200. By the time of the writing of this paper, this activity is still progressing.

V. CONCLUSION

The MET-Certified project provides a unique opportunity to apply newly developed technical specifications and certification schemes in real world scale and demonstration projects. Undergoing this process has helped to raise the understanding and reduce the risk profile for the technology developers. At the same time, Test Laboratories and Certification Bodies are learning to apply the specifications in real conditions for the first time. Finally, IEC TC 114 project and maintenance teams benefit from input to improve the specifications. The feedback is provided by experts that are both partners in the MET-Certified projects as well as members of relevant project and maintenance team. It is expected that these activities result in wider acceptance and adoption of more robust international technical specifications and certification schemes. Robust certification reduces actual and perceived risks of the technologies in terms of performance and structural integrity, and thus helps to attract commercial financing and facilitate international trade, thus accelerating the adoption of innovative marine energy technologies.

ACKNOWLEDGMENT

MET-CERTIFIED brings together partners from 4 European countries to advance the marine energy sector in the 2SEAS region: Dutch Marine Energy Centre (NL) as project coordinator, the European Marine Energy Centre (UK), Lloyd's Register EMEA (UK), IFREMER (FR), Tocardo Tidal Power (NL), Perpetuus Tidal Energy Centre (UK), NEC (NL), DNV GL (UK), Regional Development Agency West Flanders (BE), Ghent University (BE).
The project is funded by Interreg 2 Seas, the Dutch ministry of Economic Affairs, the Provinces of South Holland, North Holland & West-Flanders.

REFERENCES

[1] O. E. Forum, "Ocean Energy Strategic Roadmap 2016, building ocean energy for Europe," 2016.

[2] "MET-CERTIFIED," [Online]. Available: http://met-certified.eu/. [Accessed 25 April 2018].

[3] L. M. &. al., "The development of a risk-based certification scheme for marine renewable energy converters," in *EWTEC*, 2015.

[4] IEC, "Standards development TC 114 Marine energy - Wave, tidal and other water current converters," [Online]. Available: http://www.iec.ch/dyn/www/f?p=103:7:22471429770128::::FSP_ORG_ID,FSP_LANG_ID:1316,25.

[5] IEC, IEC TS 62600-2:2016 Marine energy - Wave, tidal and other water current converters - Part 2: Design requirements for marine energy systems, 1.0 ed., IEC, 2016.

[6] IEC, IEC TS 62600-10:2015 Marine energy - Wave, tidal and other water current converters - Part 10: Assessment of mooring system for marine energy converters (MECs), 1.0 ed., IEC, 2015.

[7] IEC, IEC TS 62600-30 CD Marine energy - Wave, tidal and other water current converters - Part 30: Electrical power quality requirements for wave, tidal and other water current energy converters.

[8] IEC, IEC TS 62600-40 CD Marine energy - Wave, tidal and other water current converters - Part 40: Acoustic characterization of marine energy converters.

[9] IEC, 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, 2013.

[10] IEC, IEC TS 62600-201:2015 Marine energy - Wave, tidal and other water current converters - Part 201: Tidal energy resource assessment and characterization, IEC, 2015.

[11] IEC, IEC TS 62600-202 DTS Marine energy - Wave, tidal and other water current converters - Part 202: Scale testing of tidal stream energy systems.

[12] P. Mycek, B. Gaurier, G. Germain, G. Pinon and E. Rivoalen, "Experimental study of the turbulence intensity effects on marine current turbines behaviour. Part I: One single turbine," *Renewable Energy,* vol. 66, pp. 729-746, 2014.

[13] B. Gaurier, G. Germain, J. Facq, C. Johnstone, A. Grant, A. Day, E. Nixon, F. de Felice and M. Constanzo, "Tidal energy Round Robin tests comparisons between towing tank and circulating tank results," *International Journal of Marine Energy,* vol. 12, pp. 87-109, 2015.

[14] O. Medina, F. Schmitt, R. Calif, G. Germain and B. Gaurier, "Turbulence analysis and multiscale correlations between synchronized flow velocity and marine turbine power production," *Renewable Energy,* 2017.

[15] B. Gaurier and G. Germain, "How to correctly measure turbulent upstream flow for marine current turbine performances evaluation?," *Renewable Energy,* 2018.

[16] M. Ikhennicheu, P. Druault, B.Gaurier and G. Germain, "An experimental study of bathymetry influence on turbulence at a tidal stream site.," in *EWTEC*, 2017.

[17] B. Gaurier et. al., "Experimental effect of the turbulent wake of a wide wall-mounted obstacle on a marine current turbine, & al., JHYD 2018," *JHYD,* 2018.

[18] M. Träsch, A. Déporte, S. Delacroix, J. Drevet, B. Gaurier and G. Germain, "Power estimates of an undulating membrane tidal energy converter," *Ocean Engineering,* 2018.

[19] IEC, IEC 61400-12-2:2013 Wind turbines - Part 12-2: Power performance of electricity-producing wind turbines based on nacelle anemometry, IEC, 2013.

[20] DNV.GL, DNVGL-SE-0163 SERVICE SPECIFICATION Certification of tidal turbines and arrays, 2015.

[21] DNV.GL, "DNVGL-ST-0164 STANDARD Tidal turbines," 2015.

[22] EUROCODES, "EN 1993-1 Design of steel structures".

[23] EUROCODE, " EN 1993-2 (2006) Eurocode 3: Design of steel structures - Part 2: Steel Bridges," 2006.

[24] DNV.GL, "DNVGL-RP-C203 RECOMMENDED PRACTICE Fatigue design of offshore steel structures," 2016.

[25] "IEC TC 4 Hydraulic turbines," [Online]. Available: http://www.iec.ch/dyn/www/f?p=103:7:0::::FSP_ORG_ID,FSP_LANG_ID:1228,25. [Accessed 25 April 2018].

AUTHORS

Ir Peter Scheijgrond, M.Eng, M.Phil, DMEC, peter@dutchmarineenergy.com

Anna Southall, MEng MSc CEng MIMechE, EMEC anna.southall@emec.org.uk

Grégory Germain, IFREMER, Gregory.Germain@ifremer.fr

ir **Pieter Mathys**, University of Ghent, Pieter.Mathys@UGent.be

Claudio Bittencourt. MSc, DNV-GL UK, cbf@dnvgl.com

Peter Davies, MSc, Lloyd's Register, peter.davies@lr.org