ecoENERGY Innovation Initiative

Research and Development Component

Public Report

Project: RENE-048: Development of Codes and Standards for Marine Energy Converters

Contents

1 Executive Summary 3
2 Introduction 4
3 Background 5
4 Objectives 6
4.1 Objective 1 - Canadian experts' participation in all IEC/TC114 Project teams 6
4.2 Objective 2 - Canadian experts' participation in Canadian subcommittee projects and meetings 6
4.3 Objective 3 – Communication & outreach 7
4.4 Objective 4 – Standards related research 8
5 Results of Project 8
5.1 Project Achievements 8
5.1.1 Achievement 1 8
5.1.2 Achievement 2 8
5.1.3 Achievement 3 9
5.1.4 Achievement 4 9
5.1.5 Achievement 5 9
5.1.6 Achievement 6 9
5.2 Benefits 9
5.2.1 Benefit 1 10
5.2.2 Benefit 2 10
5.2.3 Benefit 3 10
5.3 Technology/Knowledge Development Objectives 11
6 Conclusion and Follow-up 15
6.1 Next Steps 16

1 Executive Summary

The Canadian marine renewable energy industry has made significant progress in the advancement of marine energy technology research and commercialization in Canada. A key requirement for such advances is the development of International Standards for Marine Energy in order for developers, investors, suppliers and prospective end users to gain confidence and the necessary accreditation to accelerate acceptance and deployment. Since its inception in 2007, Canada has played a leading and active role in the International Electrotechnical Commission Technical Committee 114 (IEC/TC114) which is the international standards organization for marine energy. The ecoEII R&D Project was critical in enhancing Canada's participation through the funding of Canadian expert's travel, outreach and communication activities and standards focussed research.

Canadian experts have actively engaged in all TC114 project teams. Over the course of this project, there have been 15 project teams that have focussed on developing standards for various aspects of tidal, wave and river energy systems. Canadian experts have taken leadership positions in 5 of these teams and have also provided critical content and feedback to all of these groups. The net result of these efforts has been the publication of 6 standards.

Communication and outreach has been a critical component of this Project. The Canadian committee has reached out to all stakeholders through quarterly newsletters and frequent website updates. The committee has also attended conferences and open house events to engage and inform the public. All of the research performed through this Project is publicly available to both Canadian and international stakeholders.

The creation of standards for the marine renewable energy industry has created many benefits. Some of these include a reduction in the cost of the resulting technologies; an improvement in the knowledge to support the development of regulations and a reduction in trade barriers which provides improved access to international markets for Canadian companies.

The Canadian subcommittee, in collaboration with external partners, has completed 11 research projects investigating key questions to support standards development. These projects covered the full spectrum of marine energy with 2 on wave energy, 4 on tidal energy and 6 on river energy systems. Canada is the only participating country in IEC TC114 that had a program in place to fund standards specific research.

The current Project has enabled the development of a very strong Canadian standards committee. The Canadian committee plans to maintain its strong leadership position by continuing to work on all IEC TC114 project teams. The 6 published standards form a basis for the set of requirements that are necessary for the full certification system for tidal, wave and river energy systems. There continues to be a significant amount of work required to provide the industry with the documents needed to achieve commercial success in the next 5-10 years. In the long term, the final outcome of this Project will be for Canada to become a global leader in the delivery of clean in-stream tidal, and river-current energy systems and projects.

2 Introduction

This report contains a summary of the work performed by the committee of Canadian experts who have engaged in an international effort to develop codes and standards for marine renewable energy systems. This project has spanned the 3 ½ year period from September 2012 through to the end of March 2016. During this period, there were a total of 33 Canadian experts who partnered with the proponent, Marine Renewables Canada, to actively participate in this project. These experts provided a broad experience base to the project as they work in academic, industry and government organizations that are located from coast to coast.

This Project was primarily focussed on maintaining and enhancing Canada's participation in the development of international marine renewable energy standards. To achieve this objective, the project was divided in the following 4 sub-tasks: participation in international IEC TC114 project team meetings; participation in all Canadian subcommittee meetings; development of outreach and communication functions; and engagement in standards related research activities.

Canadian experts participate in all IEC/TC114 Project teams (PT)

Canadian experts were required to participate in all aspects of standards development. This included scope creation, methodology development and review of draft documents. Canadian experts took a leading role by chairing several Project teams in areas of strategic relevance and importance to Canada. The Canadian experts also established "Shadow Committees" to engage Canadian stakeholders.

Canadian experts participate in Canadian subcommittee projects and meetings

The Canadian Subcommittee met regularly to discuss progress and challenges in the standards development process. The intent of subcommittee was to gather Canadian input, to participate and to lead the standards development process to ensure that the international standards reflect the needs of a rapidly growing Canadian marine energy industry.

Communication & Outreach

These tasks were divided into four major areas: documenting conference call and semi-annual meetings; producing quarterly newsletters; maintaining the Canadian subcommittee website; and conducting outreach activities to recruit additional experts.

Standards Related Research Activities

Specific research topics were selected in areas where Canada was either leading a PT or had significant strategic expertise and capacity to provide information to move the specification to the standards stage. Over the 3 ½ year project, 11 research projects were completed with the results being input to the relevant project teams.

3 Background

The Canadian marine renewable energy industry has played a leading and active role in the development of International Standards through the International Electrotechnical Commission Technical Committee 114 (IEC/TC114) for "Marine Energy – Wave, Tidal and other Water Current Energy Converters" since 2007, when IEC TC114 was initiated. To ensure that Canadian input and needs were appropriately reflected in the development of these International Standards, Canada formed the Canadian Sub-Committee in 2007 with experts from industry, academia and the Federal government. In the first several years, the committee grew quickly as the number of standards under development accelerated and the international demand for experts grew correspondingly. This resulted in financial challenges for the Canadian sub-committee as this involvement required substantial funding to support international travel. NRCan did provide some initial funding support, but this and the existing industry support was not sufficient for these increased demands.

In 2011, industry and government collaborated on a series of workshops to develop a national vision and strategy for Canada's marine renewable energy sector. The outcome of this effort was the document - "Charting the Course: Canada's Renewable Energy Technology Roadmap". This document called for Canada to advance its competitiveness through active engagement in standards development. It was this feedback that encouraged NRCan to include, in the scope of the ecoENERGY Innovation Initiative, a research and development call in support of standards development. The Proponent was fortunate to receive support for its proposal. This support enabled the committee to not only engage in standards development activities but to also perform research that addressed critical knowledge gaps which helped accelerate the development process.

Marine Renewables Canada Society was the lead proponent on the Project. This association has maintained a membership of 100, developed over 10 years, and offers regional and an annual meeting for the sector and its international partners. As the sector began to emerge as a young industry, Marine Renewables Canada was developing its capacity to support the technical evolution needed to reduce risks and costs and to broaden the strength of the industry's stakeholders. Leadership in marine energy standards development research and development through this Project was part of that evolution of the organization.

4 Objectives

As mentioned in Section 3, this Project was primarily focussed on maintaining and enhancing Canada's participation in the development of international standards for marine renewable energy systems. To effectively support this overall objective, the project was broken down in to 4 sub-objectives.

- Canadian experts participate in all IEC/TC114 Project teams;
- Canadian experts participate in subcommittee projects and meetings;
- Communication & Outreach;
- Standards Related Research Activities.

4.1 Objective 1 - Canadian experts' participation in all IEC/TC114 Project teams

This objective was focussed on ensuring that 1 - 2 Canadian experts were assigned to each active project team. These experts would work, in collaboration, with the international project team to discuss, draft, evaluate and critique the standard under development. A critical part of this role was the development of a parallel Canadian shadow committee. This shadow committee would support the 2 primary Canadian experts by providing feedback during the document evolution but also reaching out to ensure that all relevant stakeholders were consulted in the process.

Throughout the duration of this project, Canadian experts met the objective of active participation in all TC114 project teams. The funding support provided by NRCan allowed the experts to travel to the highly critical face to face meetings that occurred on either an annual or semi-annual basis. By attending these meetings, the Canadian experts were instrumental in drafting key sections of the standards under development as well as ensuring that the process was moving forward according to the scheduled defined by IEC. The impact of meeting this objective was the creation of a number of standards whose content was relevant to the needs of the tidal industry as well as to the specific needs of Canadian industry. Canadian experts' participation ensured that any Canada specific strategic interests were included in the resulting documents. An example includes design and power performance sections focussed on river in-stream turbines which has been identified as a strategic area of opportunity for Canada.

4.2 Objective 2 - Canadian experts' participation in Canadian subcommittee projects and meetings

This objective was focussed on ensuring that Canadian committee members met on a regular basis to facilitate effective and thorough communication. The large number of Project partners (33), the significant number of international teams developing standards, and the associated research projects required significant and frequent coordination to avoid duplication and maximize the productivity of the partners.

This objective was met through the use of monthly conference calls and semi-annual face to face meetings. Throughout the project, conference calls proved to be a very effective method of identifying potential challenges early in the process. These challenges were often dealt with immediately or before the next conference call. Attendance at the calls also tended to be excellent with typically 15-20 members calling in. Large and more strategic issues were left to the semi-annual face to face meetings. These meetings were especially productive as it allowed Canadian experts to provide detailed updates to fellow committee members as well as to reach out for specific assistance or expertise. The face to face meeting also provided the opportunity for an update on research progress. As these research programs were targeted to assist knowledge gaps on specific standards under development, it was important to confirm that the work was still in alignment with the initial objectives. The industry indirectly benefitted from this objective as these meetings ensured that Canadian experts were working effectively and were being provided with the support necessary to produce standards in an efficient, timely manner.

4.3 Objective 3 – Communication & outreach

This objective was critical in ensuring that the other 3 objectives could be successfully executed. All of the tasks related to organizing conference calls, semi-annual meetings, creating a quarterly newsletter, updating the website and disseminating information to all industry stakeholders fell within this objective. The Proponent took the responsibility for executing this objective.

Marine Renewables Canada (MRC), as the Proponent, provided the majority of the resources required to organize and create agendas and minutes for the monthly conference calls. The online Web-conference service, FUZE, was also administered by MRC. In a similar manner, MRC organized all of the logistics related to the semi-annual face to face meetings. This task included hotel bookings, meeting rooms as well as any specific audio-visual support required for the meeting.

To ensure that the work being performed was communicated to the general public and to all relevant stakeholders, a quarterly newsletter was initialed early in the Project. This newsletter highlighted specific work being undertaken and how that work was relevant to the marine renewable energy industry. In a similar manner, the website was frequently updated to include the committees' progress and also to encourage others to get involved in the standards development process. Industry outreach objectives were also pursued through presentations given at conferences and industry open house events. Standards related presentations were given at all of the Marine Renewables Canada annual conferences including the International Conference on Ocean Energy held in Halifax in November 2014. These type of outreach activities are highly beneficial to the marine renewable energy as they increase both the public's understanding and the acceptance of this new industry.

4.4 Objective 4 – Standards related research

During the standards drafting process, it is very common to encounter issues where the existing body of knowledge is not sufficient to accurately provide the guidance required. In these cases, specific research was required to provide these answers to ensure that the development process is not stalled for an indeterminate amount of time. Within the IEC TC114 committee, Canada was the first country to specifically fund an initiative to address these knowledge gaps quickly and efficiently.

Each year, a call for proposals was issued early in the year based on the feedback from Canadian experts who indicated the most significant knowledge gaps slowing progress on the drafting of their standard. An Applicant's Guide along with proposal templates as well as a list of frequently asked questions/answers was distributed by Marine Renewables Canada to all industry stakeholders. The proposals were then reviewed by several members of the Canadian committee (Chair, Vice-Chair and one other member) as well as 1-2 external reviewers. Over the course of the Project, this process was found to be very effective as a total of 11 research projects were completed and the results of this work were fed directly into the relevant IEC project team. The standards benefitting from this research were therefore more thorough and contained more accurate/complete information, and also had a timelier release to be available for use by the entire industry. Canadian research projects targeted all areas of marine renewable energy, namely tidal, wave and river energy systems.

5 Results of Project

5.1 Project Achievements

Below is a list of the achievements of the Project, including a description of the result and why this achievement was critical in the success of the overall Project.

5.1.1 Achievement 1

Through the 3 ½ years of this Project, 6 international standards (technical specifications) were published. These standards are the first of many documents that will be used to instruct the industry on how to complete certification of marine energy converters. The demand for these documents is high as the latest figures from IEC Central office show total sales of 67 documents (22 copies of TS62600-200; 19 copies of TS62600-1; 19 copies of TS62600-100; -201=4; 3 copies of TS62600-101; 2 copies of TS62600-10). The sales are to stakeholders not only in Canada but in Europe and Asia as well. These sales are direct evidence of the interest and demand from industry.

5.1.2 Achievement 2

Canadian experts were extremely active on all Project teams and showed exceptional leadership as they took team convener positions on 5 Project Teams (PT62600-1, PT62600-10, PT62600-30, PT62600-300, MT62600-1). Without this leadership, many of these teams would

have struggled to make progress, and as a result, several of the 6 published standards would still be in the drafting stages.

5.1.3 Achievement 3

The Canadian subcommittee, in collaboration with external partners, completed a total of 11 research projects. These projects covered the full spectrum of marine energy with 2 on wave energy, 4 on tidal energy and 6 on river energy systems. Canada is the only country in IEC TC114 that had a program in place to fund standards specific research and therefore many of the existing knowledge gaps were addressed by Canadian research. The impact of this achievement was the improvements in the quality and confidence in the content contained within the document and the quicker release of the final published document to interested stakeholders.

5.1.4 Achievement 4

The Canadian committee, with funding support from NRCan, was able to successfully host the international IEC TC114 Plenary and associated project team meetings in Vancouver, BC in 2014. It is a significant responsibility to host this international meeting and many countries do not have the resources or support for such an undertaking. Without countries stepping forward to host the international meeting, progress on standards development is greatly slowed. More significant and strategic issues can only be handled during a face to face meeting and this meeting provided the venue for these interactions and advancements to occur.

5.1.5 Achievement 5

Throughout the course of this Project, the Canadian committee not only increased to a total of 33 experts, but also built a network of shadow committee members and stakeholders with interest and experience in standards development. This objective is key to building a sustainable and successful marine renewable energy industry in Canada. This database is managed by the Proponent and is available as a resource for the industry as required for projects in Canada but also for supply chain opportunities throughout the world.

5.1.6 Achievement 6

The Canadian committee has helped increase public understanding and awareness of marine renewable energy industry and the importance of standards development. The committee has been extremely active in disseminating the work from this Project through quarterly newsletters, website updates, conference presentations and industry open house events. In a similar manner to achievement 5, this work is critical in creating a vibrant new industry in Canada and abroad. The sales of the published standards documents provide a strong example that the industry understands the importance of these documents and is ready to implement their guidance and requirements.

5.2 Benefits

This section includes a description of the benefits that have accrued and are expected to accrue as a result of the Project. The following are the 3 main benefits from this project that will be described in greater detail below:

- **Reduced costs and cost efficiencies**;
- **Improved knowledge to support regulations ensuring technology uptake;**
- **Support of Canadian companies and technology development**

5.2.1 Benefit 1

Reduced cost and cost efficiencies

The development of standards, in particular TS62600-2 Design Requirements and TS62600-10 Mooring Requirements provides technology developers with the guidance required to reduce the potential errors that may occur in the design and manufacture of their products as well as to increase the consistency of their product once in production. For the technology developers, these improvements result in a reduced product cost and therefore a greater probability of success in a highly competitive international energy market. There will also be a greater confidence amongst investors, regulators and project developers to implement these technologies in Canada. This greater confidence is evident in projects now going forward at FORCE and the Digby region. The degree to which this benefit has been achieved is relatively small at this point. Much greater benefit is projected in the next 5 – 10 years as the industry achieves a more commercial, industrial status.

5.2.2 Benefit 2

Improved knowledge to support regulations ensuring technology uptake

The work performed though this project, and in particular, the 11 research projects, have substantially advanced the knowledge of all stakeholders in this energy industry. The energy marketplace is highly regulated on safety, reliability and financial returns, all of which requires risk mitigation, assurance and warranties. The first 6 published standards are critical in laying the foundation for a thorough and methodical certification process. The certification of marine renewable energy systems is a critical requirement in establishing equipment and performance warranties, achieving insurability and satisfying financiers. These are all absolutely essential pieces to the movement of marine energy from pre-commercial to industrial development and an internationally competitive renewable energy solution. The degree to which this benefit has been achieved is greater than Benefit 1. A strong foundation of knowledge has been established through this Project; though in a similar manner, greater benefit is projected in the next 5 – 10 years as additional standards are released and a full certification scheme is developed. It is important to note that the certification scheme is also being developed by IEC under their conformity assessment group.

5.2.3 Benefit 3

Support of Canadian companies and technology development

Through the work performed in this Project, Canadian committee members as well as Canadian stakeholders have developed expertise through the execution of standards development and research. All 11 research projects were performed by primarily Canadian academic, corporate and government organizations. As a result, this work has produced a strategic advantage for Canada in the areas of tidal resource assessment, river energy systems, and wave energy resource assessment and device development. The net benefit of this support will be the proliferation of Canadian marine energy projects and the development of a supply chain to

support international projects in the long term. The stakeholders that benefit from this Project are diverse and include utilities, marine energy technology developers, site developers and regulators. This benefit was achieved at a good level; however, there is huge potential for even greater achievement as the industry grows internationally and Canadian companies continue to develop the expertise to take advantage of this increasing market. In a similar manner to above, the real opportunity will come to fruition in the next 5 – 10 years as renewable energy systems obtain greater overall global energy market penetration.

5.3 Technology/Knowledge Development Objectives

This Project had a separate stream (sub-project) specifically focussed on research that addressed knowledge gaps encountered during the development of standards. The Canadian committee developed a process for an annual call for research proposals that addressed specific areas of interest. This call was sent out to all Canadian stakeholders through the network established by Marine Renewables Canada. A review panel was assembled that evaluated the proposals against an agreed criteria and rating system. Over the 3 ½ years of this Project, 11 research initiatives were completed. A brief summary of each is provided below along with the specific standard that this work supported and the resulting benefit to the energy industry in Canada and/or abroad.

Research Projects 2012-13

Impact of channel blockage, free surface proximity and foundation on the performance of tidal/river energy converters – Phase 1

It is generally recognized that Tidal Energy Converter (TEC) performance may vary depending on the degree of flow restrictions within a channel. This research performed both numerical simulations as well as experimental tests to quantify the performance enhancement resulting from blockage. The effects of the water surface and foundations were also investigated.

The results from this research were fed into the tidal performance document (TS62600-200) and is currently being used during the drafting of the river performance document (PT62600-300). This project provided valuable information to Canadian and international technology developers on the impact of flow restrictions, including the proximity of the free surface and the size and design of the turbine foundation.

Research Projects 2013-14

Impact of channel blockage, free surface proximity and foundation on the performance of tidal/river energy converters – Phase 2

This research was an extension of the work initiated in 2012. In 2013, the scope was broadened to gather additional experimental data to further validate the results. The summary is provided in the Phase 1 description above.

River Current Resource Assessment & Characterization

This project focussed on developing guidelines for the assessment of the river current resource. The work was divided into two parts. The first part investigated general guidelines for river

current assessment for different stages of project development: reconnaissance, pre- and full-feasibility and layout design. The second part of the report focused on the impact of ice on the resource assessment and, in particular, a characterization of different river ice processes.

The results from this research were used as a seed document for the river resource assessment project team (PT62600-301). This research established Canada as one of the leaders in river resource assessment work and was the beginning of both industry and government engagement in developing expertise in this specific type of resource assessment. This work was critical in helping to quantify the size of the river market which is one of the drivers that accelerates the market.

Research Projects 2014-15

Evaluation of performance assessment procedures for a floating river energy converter

The development of the tidal turbine power performance assessment document (TS62600-200) identified unknowns related to measuring the water speed approaching a floating tidal turbine and how to deal with turbines which were non-circular in cross section. This research program specifically addressed these knowledge gaps by performing numerical simulations as well as experimental tests using Mavi Innovation's floating 20 kW turbine test bed.

The results from this research have been passed onto the standards team and will be included in the next revision of the document. The work is also applicable to the river performance group (PT62600-300). This work advanced the industry's understanding of non-circular turbines (vertical axis or crossflow turbines) and the special considerations that needed to be taken into account when dealing with floating turbines as opposed to seabed mounted machines.

WCWI Extended Research Program

This project leveraged the unique collection of wave energy expertise developed in the West Coast Wave Initiative (University of Victoria). The project was divided in 3 separate tasks:

- Quantify the major factors affecting wave resource uncertainty and determine the validity of transferring these results to a different location. This work will be completed using a combination of numerical SWAN model simulations and actual wave buoy test data using buoys deployed off the BC's west coast.
- Develop numerical models and methodologies to account for wave energy converter interactions and available wave resources within wave energy converter farms. This will be the first step in understanding how to best locate wave energy converters to maximize the power output of an array of devices.
- Acquire mooring line load data to assist with the design and operation of mooring systems used for marine energy systems.

The results from the first two tasks were used in the baseline wave resource assessment document (TS62600-101) as well as the document that provided guidelines for wave energy performance at a 2nd location (TS62600-102). This work was internationally important as many companies were trying to determine the best method to take the test results completed at one

site and use them to predict the performance at a different location. The results from the final task provided actual test data and analyses that were directly applicable to the Mooring requirements document (TS62600-10).

Impact of channel blockage and free surface proximity on the performance of cross-flow hydrokinetic turbines

Following on from previous Canadian research on blockage effects, this research focussed on assessing the impact of blockage effects on crossflow turbines. This research performed numerical studies to develop correction curves for cross flow turbines. These correction curves were then compared with typical axial flow turbine curves to demonstrate the differences. Additional work was also performed to discriminate between vertical and lateral confinement of a channel.

The results of this work will be used for the next revision of the tidal turbine power performance assessment document (TS62600-200) and will be directly fed into the drafting of the river performance document (PT62600-300). This work further enhanced Canada's reputation as a leader in understanding the effects of blockage on tidal and river turbine performance.

Research Projects 2015-16

River Energy Converter Environmental Condition & Load Verification

This research focused on collecting a cohesive dataset that encompasses resource assessment (flow speeds), mooring loads, turbine performance, and safety margin measurements for several different turbine devices installed and tested at a single river location. This included data and techniques developed to assess river environmental conditions and to verify safety margin of the system using measured parameters as input to computer simulations.

The results from this research provided recommendations for equipment settings and processes necessary to measure environmental conditions and mooring and anchor loading data. The information on resistance and safety factors was required for the Design Requirements (TS62600-2) and Mooring Requirements (TS62600-10) documents. The research output also informed both the performance assessment of tidal and river energy converter systems (TS62600-200 & PT62600-300). This research further established Canada's strategic advantage in river energy systems.

Simulation of Long Term Wave Energy Device Power Performance

The objective of this research was to generate data to enable testing of the wave energy converter performance assessment methodologies defined by TS62600-100 and TS62600-102. In order to achieve this objective, the project developed, through computer modelling, several time-domain simulations of 10 year deployments of two different wave energy converter types at four strategic locations around the world.

This research was an international collaboration of researchers from University of Victoria and the University of Edinburgh. This work has advanced the industry's knowledge on how different types of wave converters perform in different wave climates. It has also provided a validated dataset that technology developers can use to assess the performance of their device.

Quantifying Extractable Power in a Stretch of River Using an Array of Marine Hydrokinetic Turbines (MHKs)

Previous research had completed a reconnaissance level resource assessment which defined an upper bound to the power generation potential of major rivers. There was; however, no methodology to translate this predicted power into an actual extractable turbine power. This project worked through a full feasibility study of an actual river location (Winnipeg River at the site of the Canadian Hydrokinetic Turbine Test Centre) and developed formulas and guidelines for turbine spacing along and across a section of a river. It also compared, numerically, the wake structure and dissipation length between turbines to better estimate overall extractable power from a turbine array.

The results from this work have been used directly in the drafting of the river performance document (PT62600-300). Canada continues to demonstrate leadership in river energy systems as it not only convenes this project team but also is responsible for drafting many of the critical sections.

Guideline for Reliability Assessment of Marine Energy Conversion Systems (MECs) and Design Parameters for River Current Energy Conversion Systems for Different Safety Levels

The design of Marine Energy Conversion Systems must determine the overall system reliability under the expected mechanical and environmental demands and this represents a key requirement of the design and performance specifications. Current draft standards defined various limit states, (such as: ultimate, fatigue, serviceability, etc.) and partial load factors based on the knowledge gained from the offshore wind industry. These load factors were not calibrated to the external conditions relevant to wave, tidal and river current energy conversion systems. This research project developed a technical guideline for the reliability assessment of marine energy converter systems, for different limit states using an alternate design approach based on probabilistic methods. The project also calculated relevant load factors for river current energy conversion systems for different safety levels, considering several design concepts provided by a Canadian technology developer.

The results from this work have been forwarded to the project team that has just initiated the process to update the published Design Requirements document (TS62600-2). The existing document does not address river current turbines so a new section will be added using the information provided by this research.

Characterization of Low-Frequency Tidal Turbine Noise

Acoustic measurement of tidal turbine noise has so far proved problematic due to contamination from flow noise in high flow environments. Accurate and representative measurement of acoustic noise is a key input in the assessment of tidal energy devices' impact on marine life. This research project collected long-term acoustic measurements using fixed sound recorders and subsequently performed data analysis to characterize the tidal turbine noise relative to the low-frequency recorder flow noise. All of the testing was performed on the OpenHydro turbine deployed at FORCE. Acoustic measurements were collected using two autonomous acoustic recorders, housed in high-flow moorings to reduce turbulent flow around the hydrophones. One hydrophone measured actual turbine noise in the near-field area (approx. 100m from the turbine) and a second measured far field (2km) for direct comparison. The recorders were deployed for two months to provide data collected in a variety of sea conditions and during different turbine operational phases. This research was complementary to FORCE's environmental monitoring programme, another project funded by NRCan, as it is intended to focus on the mid-field (between 100 and 1000m from a turbine.

Results from this work will be provided to the acoustic characterization project team (PT62600-40) that is currently in the process of creating their first draft document. This research is critical in furthering the understanding of the impact of marine technologies on the environment and is a critical step in increasing the public's acceptance of this new energy technology.

Tidal and River Energy Converter Debris Impact Load and Cable Snag Risk Quantification

Debris and ice impact issues are common concerns for tidal installations at FORCE and for many of the potential river installations. This research project performed numerical analysis to characterize impact loads and snagging risk from marine operations. The results defined characteristic impact loads for various sizes of debris and ice using surface floating and mid-water-column marine energy converters (MEC). The snag risk of mid-water-column marine energy converter technologies was also evaluated through numerical analysis of operational towlines and by assessing the depth proximity of towline catenaries to potential MEC installations.

The impact loading data was provided directly to the Design Requirements (TS62600-2) and Mooring Design (TS62600-10) documents. In addition to generic load cases, actual environmental data (hydrodynamic current and bathymetry) for a potential turbine site was used to ensure a realistic case study could be provided as a reference point. This type of research greatly increases the industry's understanding of the potential operational risks which is a critical step in increasing stakeholder confidence and accelerating the industry towards commercialization.

6 Conclusion and Follow-up

The immediate outcome of the proposed Project will be the acceptance and use of the new IEC standards. These standards will form the basis of a certification system which in turn will lead to greater confidence amongst investors, regulators and project developers to implement this

technology in Canada as well as abroad. As these are internationally agreed standards, it will also provide Canadian technology developers, project developers and suppliers with the ability to take the expertise that they have developed locally (at FORCE, CHTTC for example) and market these products and services internationally. The global acceptance of the IEC TC114 standards lowers the market barrier for all Canadian industry stakeholders.

In addition to a strong Canadian stakeholder presence in the tidal industry, Canada's strategic focus on standards development for river current energy systems will be a longer term project outcome. Leadership in this market segment will continue as Canadian companies are developing both the technologies and the projects that will provide highly valuable products and services for the international market.

In the long term, the final outcome will be for Canada to become a global leader in the delivery of clean in-stream tidal, and river-current energy systems and projects. In-stream tidal energy will form the basis for a new industry in Canada and to have a substantial impact on the economies of Nova Scotia, the Atlantic Region and Canada.

6.1 Next Steps

The current Project has enabled the development of a very strong Canadian standards committee. Canadian members are involved in all project teams with several individuals leading key teams. Canada has also developed a strong reputation internationally for actively engaging in the standards development process and taking leadership with respect to performing innovative research specifically focused on addressing knowledge gaps inhibiting standards development.

The Canadian committee plans to maintain its strong leadership position by continuing to work on all IEC TC114 project teams. The 6 published standards form only part of the set of requirements that are necessary for the full certification system for tidal, wave and river energy systems. There continues to be a significant amount of work outstanding to provide the industry with the documents it needs to be commercially viable in the next 5-10 years.