Environmental Effects Monitoring of Tidal In-stream Energy Converters in the Bay of Fundy, Canada: Challenges and Research Needs

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I. Keywords

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II. Abstract

One of the primary technical constraints to the development of tidal in-stream energy converters (TISECs) is uncertainty associated with their potential environmental effects. As the industry moves toward commercialization, international research is focused on the deployment and monitoring of TISECs to observe effects in a variety of real-world situations and thereby better understand potential effects on marine life and the physical environment. Understanding these effects is important to device optimization as well as project consenting in most jurisdictions.

In Canada, most Marine Renewable Energy (MRE) research and development is focused on TISEC demonstrations, with the Province of Nova Scotia's Bay of Fundy being the centre of activity. Between 6 and 8 demonstration projects are planned for deployment over the next 3 years, including those at the Fundy Ocean Research Centre for Energy (FORCE) and others permitted under the Nova Scotia Department of Energy's Demonstration Permit program.

The broad variety of devices demonstrated through these projects include utility scale TISECs (e.g., having a rated capacity of 1 MW or more), small scale devices (having a rated capacity in the tens or hundreds of kWs), devices that rest on the seabed, floating devices, devices with traditional rotating turbines, and resistance-based devices that move through the water. Environmental Effects Monitoring Programs (EEMPs) are requirements for all device deployments.

In developing an appropriate EEMPs for a TISEC demonstration project, researchers and practitioners require a broad knowledge base that includes a sound understanding of the operational capabilities of sensor technologies, and the state of science and research priorities as identified by Canadian and international MRE organizations such as ORJIP and Annex IV. The regulatory regimes applicable to the intended demonstration site must be thoroughly understood, along with those in future deployment sites to ensure that the utility of EEMP results is maximized.

This paper discusses environmental effects monitoring methods being employed in projects planned for Canada's Bay of Fundy and describes the decision-making processes employed by the author in designing EEMPs for multiple project developers. The methods and technologies used in EEMPs are discussed along with the limitations of the various sensor technologies. Finally, opportunities to advance environmental monitoring capabilities through research and development activities are identified.

EEMPs may include a variety of tools including direct visual observation, physical sampling, video surveillance, and acoustic monitoring. Of these, acoustic monitoring is the standard for traditional marine monitoring because it is the most versatile and holds the best potential for the acquisition of robust datasets. High flow environments such as those in the Bay of Fundy present unique challenges to most commercially-available sensors used in marine data collection. While acoustic technologies and data analysis methods continue to develop as in-stream tidal technologies mature, environmental factors such as turbulence, high turbidity, and noise associated with high-flow environments presents challenges to the effective collection and analysis of data.

Monitoring of floating TISECs is further challenged by increased turbulence near the surface of the water column, wave activity, air entrainment, acoustic reflection off the water's surface and floating ice and debris. These conditions introduce acoustic and physical interferences that may limit the ability of the sensor to collect adequate data, or function effectively. Bottom-mounted TISECs present different challenges for environmental monitoring, including the inability to easily access sensors for maintenance, repair, or replacement, and difficulty observing the condition of sensors.

Beyond the technical requirements, the cost of EEMP systems must be proportional to the scale of the platforms and to the impacts that these devices are likely to have on the environment. Managing and analyzing the terabytes of data that can be generated from active acoustic and video sensors can also represent significant costs. Finding a way to capture adequate environmental data while keeping the costs to a reasonable percentage of overall CapEx and OpEx may be critical to the feasibility of some demonstration projects.

Nova Scotia, Canada is home to world-leading ocean technology companies that develop marine sensing equipment for the defense and energy industries as well as the scientific community. From within this sector several companies have partnered with academic institutions over the past several

years to conduct research aimed at developing new sensor systems and monitoring techniques. These activities include collecting discrete data within the water column, designing methods for combining datasets from various sensors, and developing advanced sensors for deployment on TISEC devices.

An example of this work is the development of a coherent hydrophone array by Geospectrum Technologies and Dalhousie University. A hydrodynamic, four-element horizontal hydrophone array was developed to more effectively collect baseline ambient acoustic data by reducing flow noise from data collected by hydrophones mounted on TISECs. Accurate baseline ambient sound level data are essential to the quantification of the additional noise that a TISEC may contribute to the environment. The coherent array was tested in the Bay of Fundy and data collected during high-flow conditions. Signal processing methods were used to analyse datasets from each of the hydrophones in the array and allowed flow noise to be identified and suppressed. The results yielded a lower critical frequency at all flow speeds than that of a single hydrophone (**Figure 1**).

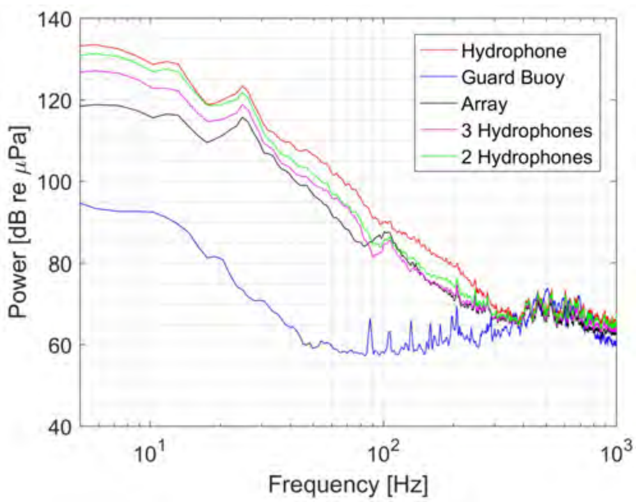

Fig. 1 Comparison of hydrophone, coherent array, and guard buoy signals captured during prototype testing in the Bay of Fundy

Many TISEC developers are partnering in the development of new technologies such as the coherent array as part of their overall R&D program. Such technologies and methods can provide an advantage to developers better informing their testing programs and facilitating consents.

The overall goal of developers, researchers and practitioners is the development of lower-risk means of demonstrating TISEC technologies in conjunction with EEMP systems to allow environmental effects to be more easily assessed. Ongoing work by the author and associates includes the development of methods for increasing the effectiveness and resiliency of monitoring systems for small-scale floating platforms to lower environmental risks associated with small-scale tidal developments, which are inherently cost sensitive.

References

[1] *Bennet, F., Culloch, R. and Tait, A. 2016. Guidance on effective Adaptive Management and post-consent monitoring strategies. Deliverables 5.2 & 5.4., RiCORE Project. 45 pp. http://ricore-project.eu/wp- content/uploads/2016/07/RiCORE-D5-2D5-4-Adaptive-Management-and-Post-Consent-Monitoring- Strategies-Final.pdf*

[2] *Cape Sharp Tidal. 2018. Advancing Environmental Science & Protection. http://capesharptidal.com/eemp/*

[3] *Catapult Offshore Renewable Energy. 2016. Tidal Turbine Collision Detection: A review of the state-of- the-art sensors and imaging systems for detecting mammal collisions. https://ore.catapult.org.uk/wp- content/uploads/2016/05/Tidal-turbine-collision-sensor-development-sensors-review-report.pdf*

[4] *Copping, A., Sather, N., Hanna, L., Whiting, J., Zydlewski, G., Staines, Gill, A., Hutchison, I., O'Hagan, A.M., Simas, T., Bald, J., Sparling, C., Wood, J. and Masden, E. 2016. State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. http://tethys.pnnl.gov/publications/state-of-the-science-2016*

[5] *EPRI (Electric Power Research Institute). 2011. Fish passage through turbines: applicability of conventional hydropower data to hydrokinetic technologies. EPRI Report 1024638 prepared by Alden Research Laboratory, Palo Alto, California. http://tethys.pnnl.gov/publications/fish-passage-through- turbines-application-conventional-hydropower-data-hydrokinetic*

[6] *Fundy Ocean Research Centre for Energy. FORCE Environmental Effects Monitoring Plan. 2016. fundyforce.ca/environment/monitoring/*

[7] *Fundy Ocean Research Centre for Energy. Environmental Effects Monitoring Program Annual Report: 2017. 2018. http://fundyforce.ca/wp-content/uploads/2012/05/Q4-2017-FORCE-EEMP.pdf*

[8] *Fundy Ocean Research Centre for Energy. Environmental Effects Monitoring Program Quarterly Report: January – March 2018. 2018. http://fundyforce.ca/wp-content/uploads/2012/05/Q1-2018-EEMP-Report.pdf*

[9] *G. Hastie. 2013. Tracking marine mammals around marine renewable energy devices using active sonar. https://tethys.pnnl.gov/publications/tracking-marine-mammals-around-marine-renewable-energy- devices-using-active-sonar*

[10] *Hutchison, I. and A. Copping. 2016. A Coordinated Action Plan for Addressing Collision Risk for Marine Mammals and Tidal Turbines. http://tethys.pnnl.gov/events/annex-iv-workshop-collision-risk-marine-mammals-and-tidal-turbines*

[11] *MacNeil, A., Hodgins, L, Eddington, J., Batt, J., Kregting, L., Bibeau, E., Molloy, S., (2017) Tidal Turbine-Fish Interaction Pilot Study in the Aquatron Controlled Lab Space, EWTEC, Cork, Ireland, September*

[12] *Molloy, S., Chandler, C., Hanlon, J., Hood, J., (2014) Opportunities for the ocean technology industry in tidal power, Martec, Indonesia, October*

[13] *Nova Scotia Department of Energy. 2018. Marine Renewable Energy Legislation. https://energy.novascotia.ca/renewables/marine-renewable-energy/marine-renewable-energy-legislation*

[14] *Nova Scotia Department of Energy. Our Electricity Future: Nova Scotia's Electricity Plan 2015-2040, 2016. http://energy.novascotia.ca/sites/default/files/files/FINAL%20Our%20 Electricity%20Future(1).pdf*

[15] *Offshore Energy Research Association. 2016. Researching Tidal Energy – Marine Life: the Nova Scotia Experience. http://www.oera.ca/wp-content/uploads/2016/05/Researching-Tidal-Energy-FINAL-May- 2016.pdf*

[16] *P. Romero-Gomez, M. Richmond. 2014. Simulating blade-strike on fish passing through marine hydrokinetic turbines. http://dx.doi.org/10.1016/j.renene.2014.05.051*