DEPLOYMENT AND RECOVERY
OF THE
OPENHYDRO IN-STREAM TIDAL TURBINE

June 20, 2011

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1. Introduction

The following is a summary of the NSPI/OpenHydro tidal turbine fabrication, testing, deployment and recovery in the Bay of Fundy.

The two major components of the In-Stream Tidal Turbine assembly (hereafter referred to "the Assembly") are the Turbine itself, and the steel Subsea Base (hereafter referred to as the "SSB"). The Turbine was fabricated at the OpenHydro facility in Ireland, while the SSB was fabricated at Cherubini Metal Works in Dartmouth, NS. The Turbine and OpenHydro Installer Barge (hereafter referred to as "the Barge"), were transported to Cherubini for assembly with the SSB. The Barge was designed and fabricated for use in deployment and recovery of the Assembly and of a specialized modular design allowing transport.

2. Site Selection

NSPI was awarded Berth "C" in which to deploy the Assembly. Evaluation of bathymetry data for Berth "C" allowed the project team to identify an area which was acceptable for deployment. Key desirable characteristics for the deployment location include: fairly flat, level, and with a minimum amount of loose bottom material. A location with these characteristics greatly simplifies both the design of the SSB and deployment operations. OpenHydro and NSPI utilized ADCP information from numerous sensor deployments, conducted 3D and 2D imaging sonar sweeps of the site, and used surface ADCP sensors to assist in micro siting.

3. Data Collection

As the FORCE subsea cable was not yet installed when NSPI intended to deploy the Assembly in late 2009, a communication system was included to allow on-board data collection to be transmitted for ongoing analysis. Design and integration of this communication module had significant technical challenges due to the harsh environment it would be immersed in for an anticipated two years. Initially viewed as a possible setback, this "wireless" test apparatus concept has drawn positive attention of the industry to the point that other OpenHydro projects such as EDF adopted a similar approach with regards to their first contracted Unit with OpenHydro. The absence of a cable also provided flexibility as to siting, and additional re-location capability. A Tritech Acoustic Modem receiver and transmitter were used during this deployment.

While communication with this acoustic modem failed shortly after deployment, data was collected for various timeframes over the deployment duration of the Assembly on data loggers that recorded the output of the three ADCP's, strain gauges and turbine performance. The ADCPs were manufactured by Nortek Aquadopp. Two were installed horizontally to measure the upstream and downstream current velocities. A third was oriented vertically, to gather information on tidal current speed through the water column, independent of the turbine.

The data logger recorded turbine performance by measuring the mean three phase AC voltage for each coil group on the load banks of the Turbine using a passive circuit located in the data logging enclosure. RPM was calculated from the AC voltage from one of the coil groups using a frequency transducer. The output power can then be calculated from the voltage and current measurements (P = VI) (power could also be calculated from either the voltage or current measurements).

4. Testing

The Assembly underwent a "test tow" in the Bedford Basin on October 26th, 2009 to evaluate the lifting mechanism, communication with the acoustic modem, data collection system integrity, towing behavior, and other components.

5. Deployment

During the licensing process, a local barge services company submitted a formal pleading to Transport Canada regarding the importation of the Barge. This company was concerned about loss of local work, and felt they had the capability to provide the service. The NSPI Project Manager met with representatives from the Company, following which the pleading was withdrawn.

After receiving all necessary permits and licenses for necessary for deployment and completing the testing above, the Assembly was successfully deployed in the Bay of Fundy on November 12, 2009. The deployment team followed the operating plan devised by OpenHydro, and placed the Assembly within 0.6m of the engineered location. Communication with the Assembly was also confirmed after deployment.

This location was reported by NSPI to the departments of Transport Canada and Navigable Waters on November 19th, 2009. Numerous "Notices to Mariners" containing the coordinates and project information were distributed shortly afterward.

Due to the unpredictability of weather, there was always a risk that deployment could be delayed. Safe ports and procedures were in place to ensure safety of equipment and crew in the case of inclement weather. This is also true of the recovery operations.

6. Operation

Some time after deployment, communication with the Assembly via the on-board acoustic modem ceased which resulted in no data being recovered via this modem. After a number of efforts to observe the Assembly and evaluate its condition though 2-D and scanning 3-D sonar, camera, and ADCP monitoring, Nova Scotia Power Inc. and OpenHydro decided to recover the Assembly in the fall of 2010, one year earlier than originally planned.

7. Recovery

As licensing for the Barge had expired, NSPI and OpenHydro went through the process again, and again there was a pleading submitted by a local company. Following discussions with representatives from the company, the pleading was withdrawn.

The recovery operation utilized the same OpenHydro Installer barge used to deploy the Assembly in 2009. The initial attempt in mid-November of 2010 was called off due to high winds and delayed until the next acceptable tidal phase for recovery (neap tide). Recovery was completed successfully on December 16, 2010. As with the deployment, OpenHydro had prepared a method plan for the recovery that proved to be both realistic and efficient, and all operations proceeded successfully.

Recovery operations confirmed that the Assembly did not move over the course of its deployment. In addition, a study completed by Atlantic Marine Geological Consulting Ltd. saw no detectable change to the marine environment in the vicinity of the deployment location. Upon recovery, no evidence of impacts was evident on any part of the Assembly or SSB. Biofouling has not been observed after this deployment; the Assembly and SSB appeared clean of growth at the site (from video) and after retrieval (from close inspection in person).

Due to windy and icing conditions in the region in December of 2010, the Assembly was towed to St. John, New Brunswick. No adequate weather window presented itself, and the decision was made to store the Assembly in St. John until the spring, when more favorable weather would allow for safe passage for the tug and barge to Dartmouth, Nova Scotia.

8. Evaluation

The major structural components of the Assembly appear to be in excellent condition, but the turbine blades and acoustic modem are no longer attached. Loss (vs. fracture) of the blades is an indication that the mechanism holding the blades in place was not sufficient to withstand the tidal forces experienced in the Minas Passage. The original collected tidal data indicated lower tidal velocities which translated into forces being significantly underestimated. Preliminary evaluation indicates the blades were likely lost during a predicted major tidal event that occurred after the deployment.

Further analysis of the data collected and a forensic investigation of the machine itself will confirm what forces and velocities were experienced and what impact these forces and velocities had on the Assembly.

The delay in towing from St. John, NB (where it weathered the winter), to Dartmouth, NS has delayed any thorough forensic analysis of the Assembly. The Assembly has recently been returned to Cherubini Metal Works in Dartmouth, NS where a thorough evaluation will be completed. Data downloaded from the data logger is currently undergoing analysis by OpenHydro. Results of all evaluations will be incorporated to improve and optimize future designs.

9. Lessons Learned

The SSB was a large proportion of the project costs, and while it successfully demonstrated the design (ie. held the Turbine in place during the deployment), further evaluation of the subsea base using data collected from strain gauges during deployment will allow design optimization.

Ballasting the SSB also proved to have some challenge due to the viscosity of materials involved. Project personnel worked together to identify an alternative which was employed successfully.

Tidal forces were significantly greater than predicted, resulting in loss of the turbine blades. Evaluation of the data recorded will confirm forces experienced, and what modifications to the design are required prior to redeployment in the environment.

Communication with the acoustic modem failed, and while the modem was no longer present when the Assembly was recovered, it is not clear when this device was lost. Future designs with on-board communication will ensure all exposed equipment is better protected.

The project team had not planned to do visual or physical monitoring of the Assembly as part of the original project plan. As such, arranging for appropriate resources when communication was lost with the acoustic modem was challenging, including vessels, equipment and personnel.

When communication failed, a number of techniques were employed to try and view the Assembly and determine what had taken place. Many of these techniques were not successful due to the high velocities and amount of sediment in the deployment location which severely limited underwater visibility.

10. Going Forward

NSPI remains confident in the development of tidal energy and, assuming further analysis confirms the feasibility of this technology, anticipates re-deployment in the near future. The physical detailed inspection of the components that comprise the turbine, venturi and subsea base will be performed over the coming months. This information will play a critical role in the development of OpenHydro's next generation of tidal turbine designs.

Authorized by: ______________________

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