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IN-STREAM TESTING OF THE OCEANA ENERGY HYDROKINETIC DEVICE

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INTRODUCTION

The hydrokinetic industry's focus has been large, utility sized devices deployed in tidal basins. Obviously the potential for total power generation is greatest in these deployments but the application of hydrokinetics to rivers can have a significant impact on populations living near swift flowing rivers. The cost of electrical power for rural populations is often ten times the cost of grid based electrical power.

Under a grant from the Alaska Energy Authority, Oceana Energy Company (Oceana) has designed, built, and tested a river hydrokinetic device. This paper summarizes the design and test results for this river hydrokinetic device.

DEVICE DESCRIPTION

To date, Oceana has focused on tidal hydrokinetic device solutions and continues to work towards commercialization. A river version of the Oceana device is configured with only slight modifications to the tidal design (Figure 1).

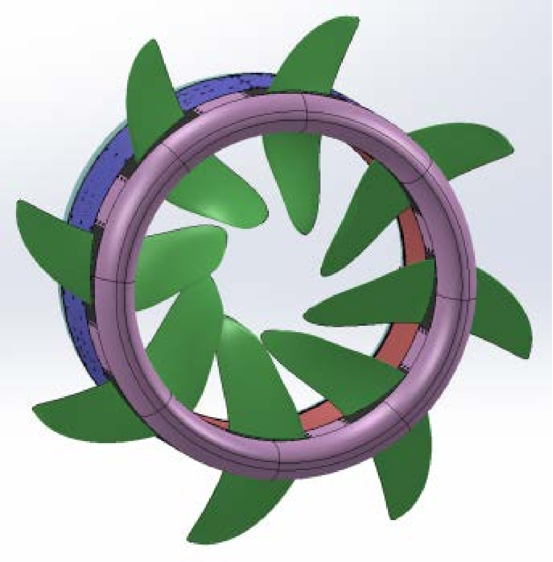

FIGURE 1. OCEANA ENERGY RIVER DEVICE

The salient features of the Oceana hydrokinetic device are summarized as follows:

- A ring provides intermediary support for the hydrofoils. This reduces the strength requirements for the hydrofoils, which in turn reduces the device sensitivity to turbulence and allows the use of larger spans. Additional advantages of the annular configuration include a simple means for attaching interchangeable hydrofoils and balancing loads over the support ring.
- The hydrofoils are designed for uni-directional river flow; this constitutes the primary difference relative to the tidal design. The hydrofoils are constructed of composites and utilize a simple bolt-on attachment scheme.
- The power generation and bearing systems are integrated into the support ring. The rotor composes the hydrofoils and the inner ring surface, while the stator composes the outer portion of the ring.
- The electrical generator is a patented 72 pole, 9 phase synchronous permanent magnet electrical generator optimized for torques and speeds indigenous to local river current speeds. Gearboxes are averted by the generator design thus avoiding associated maintenance and complexity issues.
- A permanent magnet axial bearing system reacts against the large hydrodynamic drag forces and provides a wear free solution within the harsh environments typical of most rivers.

The river device tested was ~2m (6.5 ft) tip to tip or sweep area diameter. The diameter was based on compatibility with the Carderock facility limits and river conditions.

TOW TANK TESTING

Rivers deployments have additional environmental challenges over their tidal counter parts, namely abrasive sediments that can accelerate wear to blades, bearings, and other components or debris that can cause impact damage. Another challenge is the turbulent nature of the currents which produce non-steady input/output and can accelerate fatigue issues.

To obtain clean baseline performance data on the device, a preliminary testing was conducted in a tow tank. Oceana has a Cooperative Research and Development Agreement with the Naval Surface Warfare Center, Carderock Division in Bethesda, MD (Carderock). Under this agreement Carderock provides computational and testing support using their tow tank. The tow tank portion of the David Taylor Model Basin was constructed in 1937 and was designated an ASME landmark [1]. The carriage system used (#2) is a 15 m wide by 6 m deep by 545 m (50 ft X 20 ft X 1800 ft) long tank with a carriage that bridges across the tank. Four 450 hp motors are used to precisely drive the carriage while pushing the submerged device through the undisturbed water. The carriage is shown in the dry dock location in Figure 2.

FIGURE 2. TOW CARRIAGE IN THE DRY DOCK.

The device underwent preliminary rotational and submersion tests prior to testing at Carderock. Final assembly at Carderock is shown mounted to the lifting mechanism in Figure 3.

FIGURE 3. DEVICE ON LIFTING MECHANISM.

The generated electrical power was dissipated in an adjustable resistive load bank. By selecting different resistors to include in the electrical load, the voltage, current, electrical power output and rotational speed of the generator was varied. A very small electrical load results in a high rotational speed, high voltage, and low current. The test matrix included variations in the load bank settings.

A suite of performance parameters were measured including the following: axial drag force, generator electrical currents, voltages (20 signals), tri-axial accelerometers, and proximity sensors to measure rotational speed. In addition, a wide variety of still and video photometric coverage was provided by Carderock.

The testing sequence involves the following: (1) positioning the carriage at the far end of the tank; (2) lowering the device into the water; (3) start of instrumentation recording; (4) ramp carriage speed up to predetermined value until it nears end of travel; (5) decelerate carriage to a stop; and (6) reversing steps (1) to (3) in preparation for the next test sequence. Shown in Figure 4 is the device submerged in the tank during a typical test.

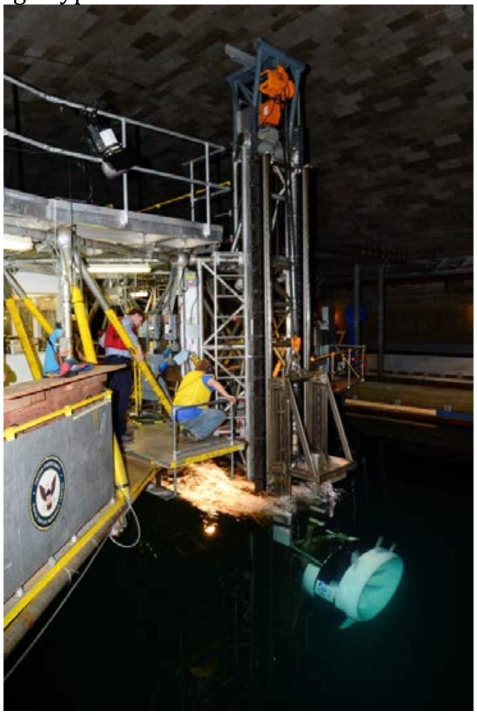

FIGURE 4. TOW TANK TESTING

A high-frequency datalogger recorded parameters that fully characterized the performance of the unit. The measured power and rotational speeds are presented in Figures 5 and 6, respectively.

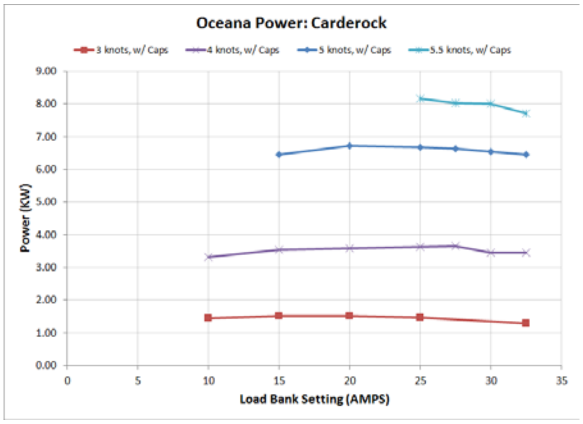

FIGURE 5. MEASURED POWER CURVES

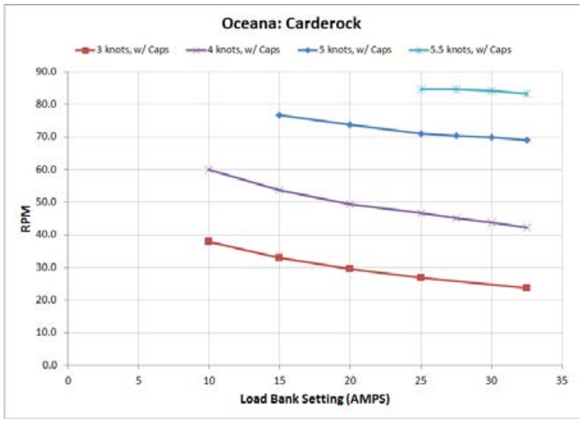

FIGURE 6. MEASURED ROTATIONAL SPEEDS

After achieving pre-deployment performance goals at Carderock, the device was shipped to Alaska to prepare for the river deployment.

RIVER TESTING

The river testing was conducted on the Tanana river near the village of Nenana which is about an hour southwest from Fairbanks, AK. The Alaska Center of Energy and Power (ACEP), based at the University of Alaska, Fairbanks, has established the Alaska Hydrokinetics Research Center (AHERC) which operates the test site on the Tanana.

AHERC has developed an anchor in the river and a barge platform for conducting the tests. A jointly designed raising and lowering mechanism was used to deploy the test device. The barge configuration, including an illustration of the test mechanism, is shown in Figure 7.

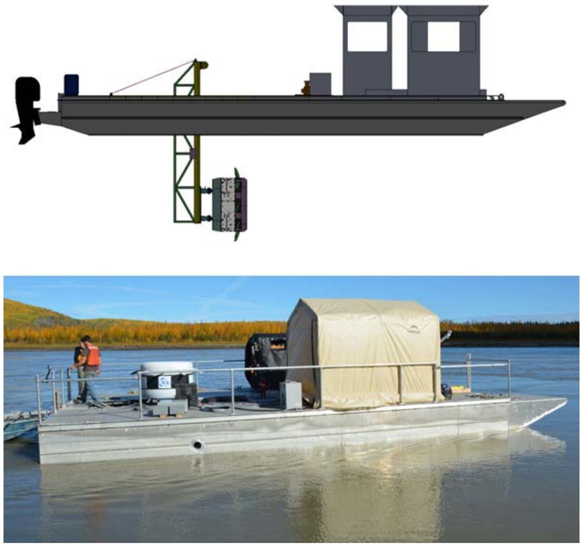

FIGURE 7. AHERC TEST BARGE

AHERC has spent the last several summers developing a debris diversion system, which is essentially a wedge shaped floating device that deflects floating debris away from the barge (Figure 8). In the picture is an approximately 20 m (60 ft) log floating by the barge.

FIGURE 8. DEBRIS DIVERTER UPSTREAM OF BARGE

The device and instrumentation were nearly identical to that tested at Carderock. Some external capacitors were changed to improve the electrical power generation.

Figures 9 and 10 are a sequence of photographs with the device just prior to lowering in the water and the second is as the device begins to rotate as it enters the water. The device was eventually lowered to approximately 2 meters (6.5 ft) below the water level.

The Tanana river is glacier fed, so by September when the tests were conducted, the flow rates had dropped to below 1.8 m/s (3.5 knots). The water level continued to drop during our 2 weeks on the river. The original plan was to test for at least another week on the river but because of the decreased flow those testing days will be utilized next summer in July when historical flows are closer to 2.6 m/s (5 knots).

FIGURE 9. INITIATION OF DEVICE LOWERING

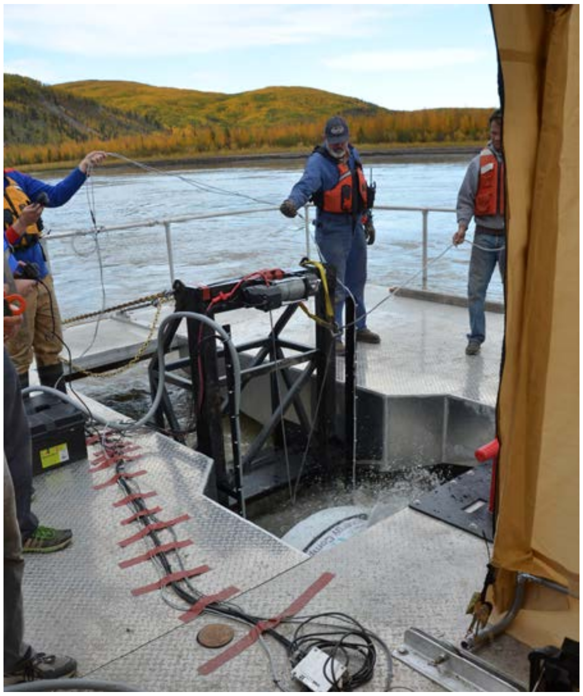

FIGURE 10. DEVICE ROTATING AT WATER ENTRY

A large amount of performance data was collected to characterize power generation as a function of river flow. In addition, a team from the University of Alaska, Anchorage was taking measurements on the flows, turbulences, and river bathymetry. Detailed data analyses are still being performed and will be presented later.

As explained previously, a capacitance adjustment was made that improved power output. The corresponding corrected power output curve is presented in Figure 11. The blue line represents the measured Carderock data was adjusted based on the performance increase observed from the Tanana tests. Since the river flow was below 3.5 knot speed, the adjustment power was extrapolated to the higher speeds using a cubic function of current speed.

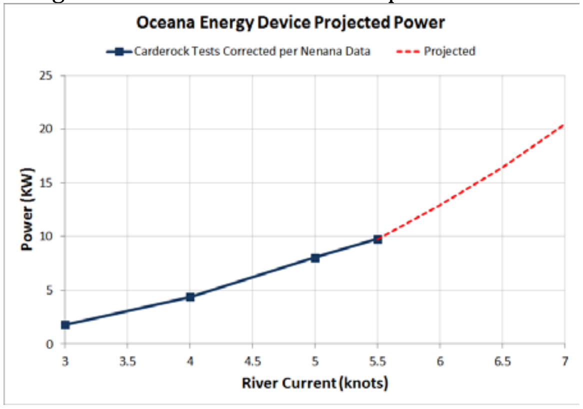

FIGURE 11. POWER GENERATION CURVE

As previously explained, one of the main benefits of the Oceana annular design concept is that it can be scaled to other sizes, employing the same general design concept. Hence, the power output at other sizes can be easily estimated. If the device was doubled in sweep diameter the power output would increase by a factor of 4.

CONCLUSIONS

The next generation Oceana Energy hydrokinetic device was built and tested in 2014. The results followed predictions and were very encouraging. Another longer duration series of tests are scheduled for July of 2015.

ACKNOWLEDGEMENTS

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The Naval Surface Warfare Center Carderock Division provided hydrodynamic analyses and test support on the carriage tests. Also, the photographs in Figures 2 through 4 where taken by Ryan Hanyok of their photometric department.

The Alaska Hydrokinetics Research Center and the Alaska Center of Energy and Power (ACEP) both of which are associated with the University of Alaska, Fairbanks provided the testing support on the river. Finally, the friendly people of the village of Nenana, Alaska allowed use of their land during the testing.

REFERENCES

[1] The David Taylor Model Basin, A Historical Mechanical Engineering Landmark, ASEM International, January 30, 1998.