Uni-Directional Impulse Turbine for the Powering of Offshore Monitoring Systems

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Industry Partner: Harris Corporation

Description: Numerical modeling and experimental testing of turbine for wave energy conversion. The University of Central Florida and Harris Corporation have joined efforts to design, build and analyze a wave powered abandoned oil well monitoring system for use in the Gulf of Mexico. This system proposes a fully automated oil leak detection system which is self-powered by the local ocean energy which is converted to electricity, conditioned and sent from the surface buoy to the ocean floor to supply power for an abandoned oil well monitoring system.

Executive Summary

This project involves an innovative design, development, laboratory prototype testing, and optimization of a wave power generation system which includes a set of mechanical devices and a permanent magnetic generator. The objective of this project is to build a wave power generation system that is light-weight, low-cost, small size, and easy to deploy. For this project, two laboratory prototypes have been built using machine components. The prototypes were mounted onto a 6-DOF motion platform that can oscillate vertically to simulate wave motion, which drives a shaft to produce electricity using a permanent magnetic generator.

The project began with a literature review, a Matlab/Simulink simulation, a 3-dimensinal viscous CFD (computational fluid dynamics) simulation, and mechanical Pro-E design. Such preparation work was essential to the study of ocean wave generation. Next, two prototypes were developed and tested. The first prototype shows that a simulated wave moving up and down with an amplitude of 15-cm, can generate between 35 to 40 watts electricity. The experiences gained in testing of this prototype helped design and build the second prototype. The second prototype uses two sprockets and a longer chain giving more mechanical advantages. In addition, a more efficient generator that requires less torque reduces frictional losses imposed on the shaft. Test results have shown that the power output increases from 37.34 to 206 watts. Afterwards, two alternative prototypes were tested. One uses a light-weight but large size aluminum flywheel to increase flywheel inertia; the other is specially designed to make it possible for the system to generate power in both directions.

In order to make the generator run more continuously and, thus, generate more power for a given wave input, a load control mechanism was designed to dynamically control the electric load based on the shaft RPM. This requirement is needed when there is no pulling force of the wave at the down-stroke and the load is not applied so that the flywheel runs continuously. Tests of the second prototype were done for a number of different configurations – a combination of different wave amplitude and frequency.

To improve the efficiency of the system, an updated mathematical simulation model was designed for system optimization. The optimization was to study how to choose the radius of sprocket, the inertia of the flywheel(s), the ratio of the gear set, and the controlled electrical load such that maximum power can be generated, given a fixed wave amplitude and frequency. This allows for different design parameters to be varied to optimize design.

In addition to the prototype tests, the buoyancy force of the waves on a small buoy has been studied. For these experiments, the output of the force is recorded by a computer based data acquisition system and the results help verify the computation fluid dynamics model used in the mathematical simulation.

Due to the nature of wave motion, the electrical power output is not stable in voltage output and frequency. For this reason, a Wave Energy Conversion (WEC) simulation model was built for stabilizing the variable frequency, variable voltage output and for satisfying the grid requirements of constant voltage, frequency, and power. Using experimental three-phrase AC voltage data of the generator, a three-phase breaker is turned on and off by the control system to output DC voltage. The simulation is helpful to the design of a micro-controller to be used in load-control and power stabilization for future preparation once the buoy power system is deployed in the ocean.

Based on the finding of the experimental and analytical results of the mechanical design it was found that a different design concept would have more success in the field. Similar to the team's research in that bi-directional buoy motion is converted to uni-directional rotor rotation, a bi-directional impulse turbine was proposed. The bi-directional impulse turbine can be used in oscillating wave columns as it is able to convert bi-directional flow into uni-directional rotation.

The measured power output, RPM, torque, and the overall optimized system parameters such as the radius of sprocket, the inertia of the flywheel(s), the ratio of the gear set and the controlled electrical load added to the generator, are helpful to the design and optimization of a functional prototype running in the ocean. For the power output, the current laboratory prototype is capable of generating an average of 136W under the movement of a motion platform with 12cm in amplitude, 0.3Hz frequency, and 0.10kg-m^2 moment of inertia, and 206W with 10cm in amplitude, 0.3Hz frequency, and 0.25kg-m^2 moment of inertia.

The research group spent much efforts trying to leverage research funding. A joint proposal with Rostech, Inc. Oviedo, FL, was submitted to the U.S. Department of Energy for applying funding for Phase I SBIR, in an effort to continue the research and commercialize the laboratory prototype. And because of this project, the University of Central Florida has cooperation with the Harris Corporation for the powering of a far offshore buoy system named OceanNet. The company is very interested in developing a clean energy supply local to these far offshore buoys which drastically lowers the expenses involved in traveling out the buoys and refueling. For this reason they have funded the work of 7 senior design teams in the process of two years and are continuing support with the research project to obtain a commercially viable design and the construction of an offshore wave energy converter.

In addition, the research group attended various national and international conferences to attract attention to the work wave energy research in the state of Florida. Several presentations were made. Two conference papers were published and a journal paper based on the load control optimization scheme is revised and resubmitted to *IEEE Journal for Oceanic Engineering* for publication.

Florida has a long costal line and good power delivering infrastructure. The success of this system could provide clean, scalable, and supplementary electric power to Florida coastal communities with lower costs in the long term, and lessen burden from main power grids and fulfill responsibilities of environmental protection.