Optimization of Power Performance of a Wave Energy Converter

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Background

Whenever there is a natural disaster, power usually goes out in many areas. This forces the local population to rely on gas powered generators, or some form of electrical generator that was already installed on their house. With climate change on the rise, UNF wanted to find a way to provide a renewable energy alternative to these gas generators during times of crisis. This led to the creation of the ***Osprey C.R.E.W.*** The Osprey C.R.E.W. is a wave energy converter (WEC) that uses the vertical motion of the water waves to generate electricity. The WEC is designed to be placed in a beach or other source of waves to provide power for people's homes. Despite over a century head start for fossil fuels, the UNF team fully believes that wave energy will be able to eventually be a fully realized replacement of the gas-powered current generators.

Figure 1. Historical Hurricane Tracks in Florida from 1996 - present [1]

Goals:

- Device needs to be easy to deploy and work with.
- Device needs to be able to generate sufficient power for at least one home in full scale.
- Device needs to be fully self-sufficient without the need for gas or other fossil fuel support.
- Device must be reliable enough to not need constant maintenance and repair.
- Device cannot be significantly more expensive than a gas generator.

Electrical Laws and Rules

Several laws of electricity and magnetism are necessary to complete this mission. First, is Faraday's law of Induction. This law states that any magnetic field moving past a conductor, will generate current [2]. Essentially, as a magnet moves past a coil, electricity can be made. The amount of electricity is determined by several important factors: the speed of the magnet, the amount of wire, the strength of the magnet, and the distance between the magnet and wires. The team dealt with each of these individually as shown in the design section. Another important law to understand is the laws of electrical power. Power is the combination of how much energy is available, and how fast that energy is being used. How much energy is available, is called voltage, while how fast it is being used is current. Multiplying current and voltage gives a value for how much power something is consuming. By knowing how much current a device is creating, and how much voltage is available, the power of a device is easily calculated [3]. This power can come in one of two forms: DC or AC power. DC, stands for direct current. This means that the current goes from the source, through the device being powered, and back to the source. This form of power is seen in batteries and solar energy panels. It is useful because it is easy to work with and simplistic. However, DC power is difficult to move over large distances due to losses. This is why AC power is used. AC power sends a current forward, then calls the current back and sends it back through the load in reverse, then repeats. This creates an alternating sequence of direction for the power. AC is used in the US power grid, making it extremely important that any device with plans to be integrated into it be capable of AC power generation [4]. This is fortunate, as the CREW produces AC power naturally.

Numerical Simulation

A numerical simulation was done to see how different parameters affect the output of the WEC. The numerical simulation was done using the numerical computation software MATLAB and the electromagnetic problem solver FEMM. Using the simulation, the influence of parameters like the size of the coil, the location of the coil, and the size and number of magnets were evaluated. Figure 2 shows the magnetic density plot that results from the magnet configuration. Figure 3 shows how the magnetic flux through a coil loop concentric to the magnets changes based on the radius of the coil and the vertical distance from the center of the magnet.

The dimensions of the coil have a great influence in the output of the wave energy converter. Figure 4 shows how the average power output varies based on the length and the outside diameter of the coil. As it can be observed, there is an optimal coil configuration based on the outside conditions, with a potential of nearly 350 W per device. For the simulations shown in this section 6 magnets of 20 cm diameter and 5 cm in thickness were used.

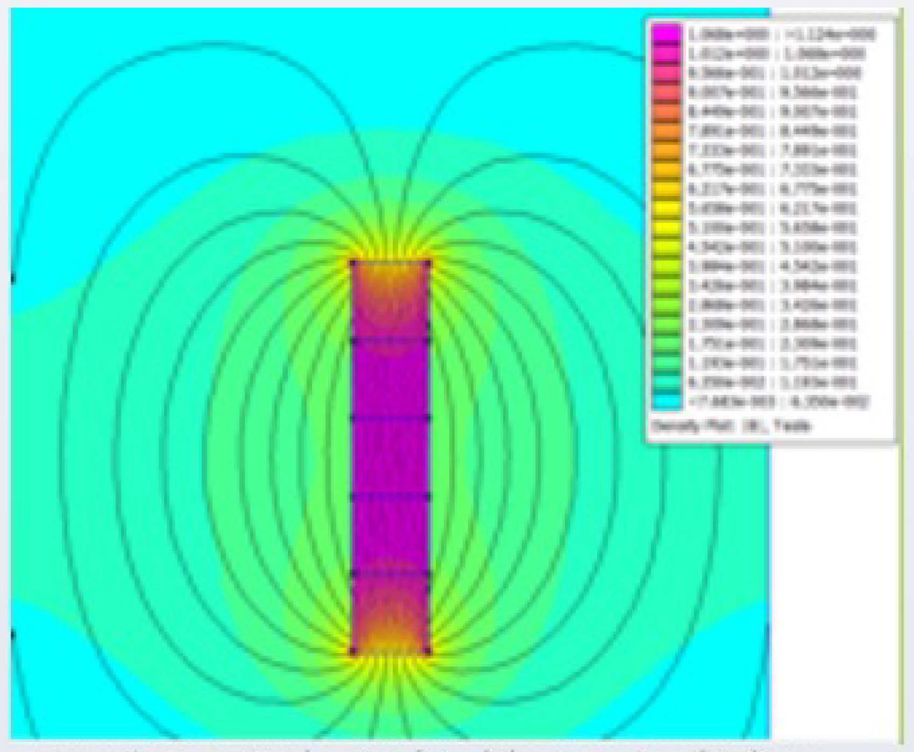

Figure 2. Magnetic density plot of the magnets. This figure was generated using FEMM

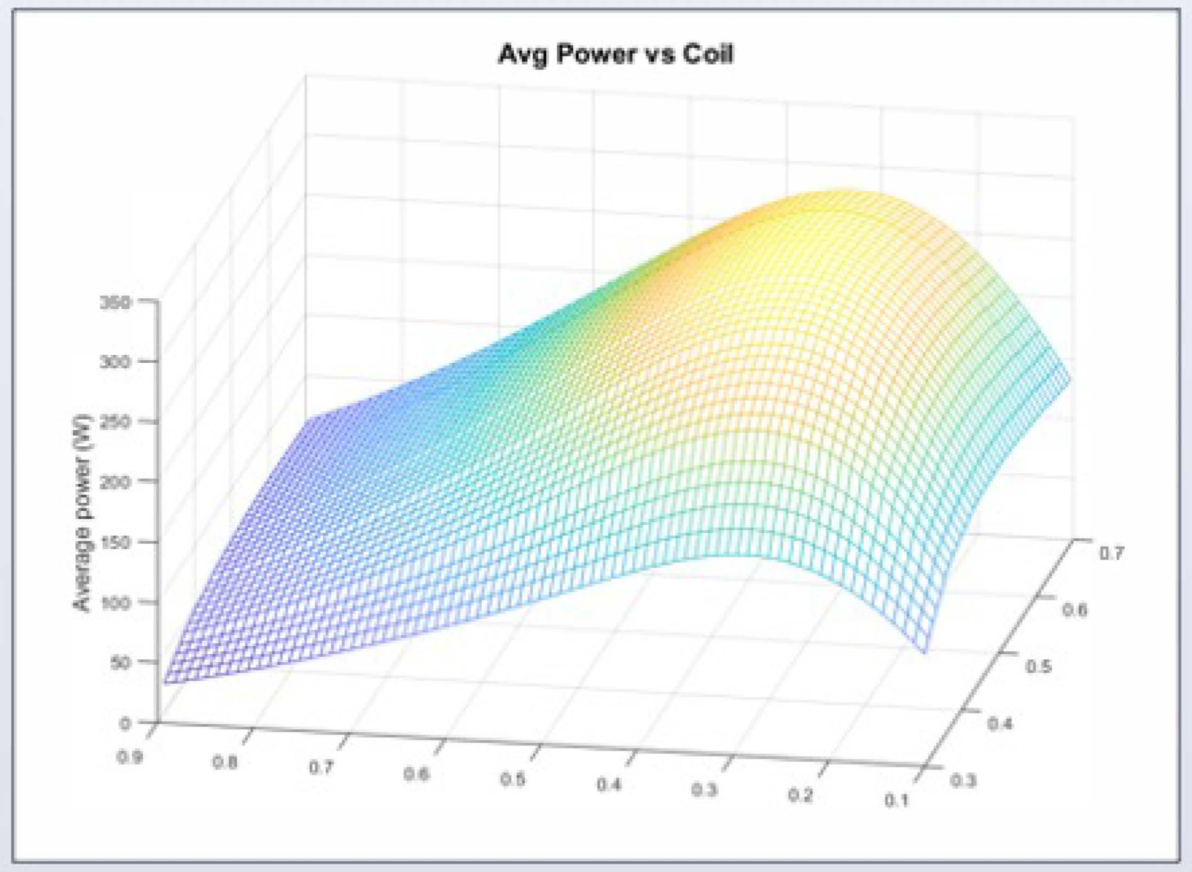

Figure 4. Average power vs coil length vs coil outside diameter

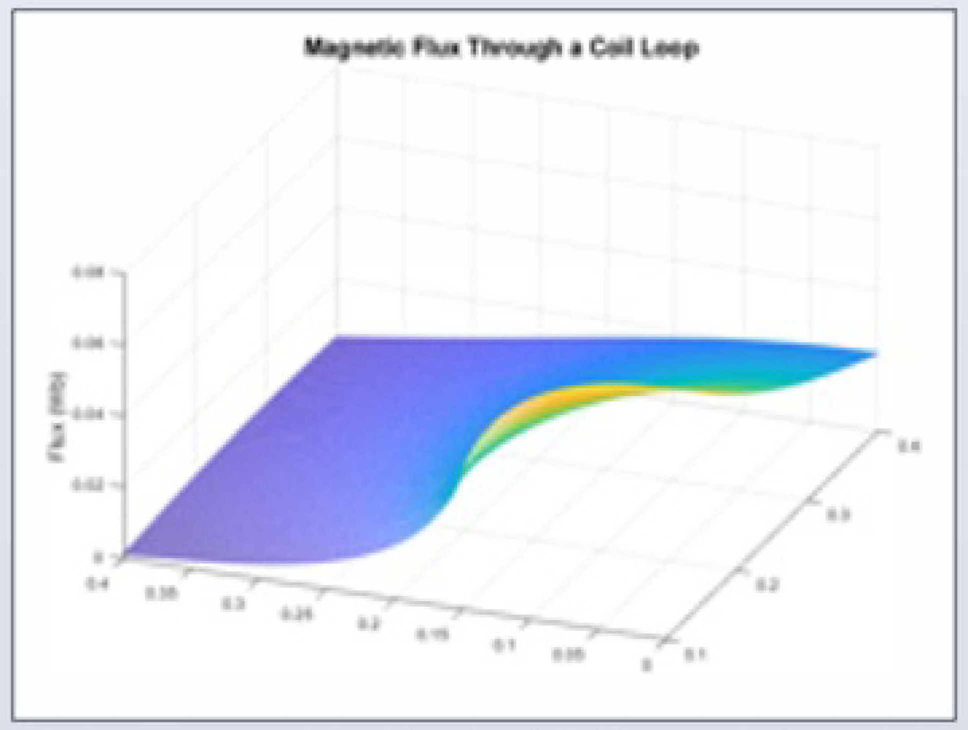

Figure 3. Magnetic flux through concentric loops vs radius of the loop vs vertical distance from the center of the magnet

Figure 5. Three prototypes: Jimmy (Left), Timmy (Middle), and Kimmy (Right).

Meet the "immy's"

Jimmy, Timmy, and Kimmy are the names given to the 3 small scale prototype devices. Jimmy, far left, was prototype number 1. He was a bit large and clunky but managed to produce tangible results. His size was toned down and Timmy, middle, was born. Timmy, unlike his siblings, was made out of PVC pipe instead of 3D printed material. This caused some issues with construction, but his overall design improvements made him a valuable asset. Kimmy, far right, is the youngest of the three. She took the problems of Jimmy and Timmy and put forth her own solutions. Kimmy, also utilizes 20 gage wire instead of 26 gage wire. This increase in size resulted in fewer wire turns and increased weight as well. None the less, Kimmy is a strong energy creator and a valuable test prototype.

Testing

At the beginning, the concept was proved by utilizing a coil to wrap around a circular object and move magnets from one side to another side. An oscilloscope was used to read and display outputs when the magnets was through the object, which are show in those picture below. Next step, using plexiglass, a wave tank was built to test Jimmy, Timmy, and Kimmy. At one end of the wave tank there is a flap hinged at the bottom. The top of the flap is connected to an electrical motor, which turns to generate waves. These waves are used for Jimmy, Timmy, and Kimmy to test their performance. At the other end, there is a beach-like ramp for the waves to break. This helps avoid wave reflection.

To test the medium-size prototypes a wave pool is being built. The pool itself was built with cement blocks and a waterproof tarp. The beach-like ramp is made of sand, and the wavemaker will be a piston made of aluminum frame and plexiglass.

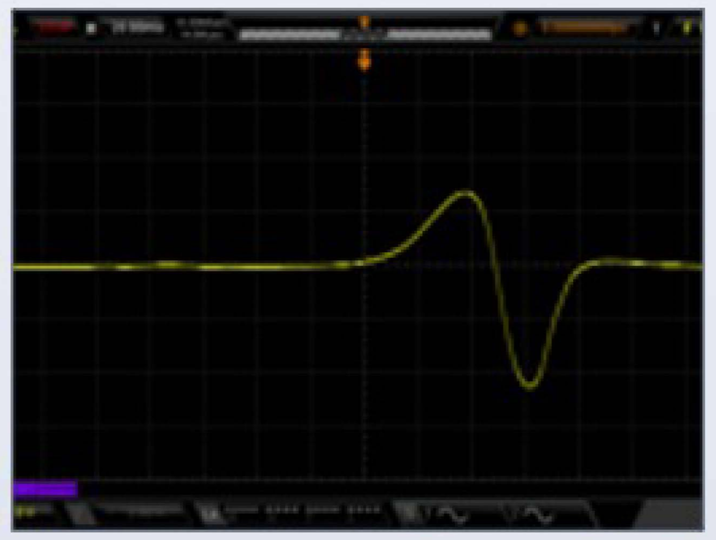

Figure 6. Voltage was generated as the magnets go through the coil.

Future Goals:

The Jimmy's test results were very promising. By hooking up a circuit, these devices were able to generate a sustained current strong enough to power an LED strip without assistance from outside sources. This success, prompted the plans to upgrade from small scale testing, to mid-size testing. For this, a wave pool is in construction and will soon be completed. This will be used to see how larger forces act on the device, as well as how the power generation scales with size. The team hopes that as the size increase, the power output will substantially increase as well. The device will then be modified and updated the same way small scale devices were. As new data is acquired, the device can slowly be optimized until it is finally ready for full scale testing, and then deployment.

More Info:

Find us at:
http://ospreycrewunf.club/

Acknowledgments

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