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Design, Construction and Testing of a Dragon Wave Energy Converter

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Abstract: Current global concerns on environmental protection and sustainable development for clean energy have led to the creation of new engineering devices. These technologies reduce harmful greenhouse gas emissions in the atmosphere, global warming and reduce dependence on fossil fuels to produce energy. Many countries are now moving towards strategies to achieve maximum power available from the factory to reduce greenhouse gas emissions are concentrated. Wave energy is an emerging technology that is currently under research and development is considerable. Wave energy is essentially an indirect form of solar energy. There is a long maritime border in the south and north of the country, Iran's potential to absorb the energy of the sea talk show. In this thesis, the energy in waves of Iranian ports to use wave energy absorber is investigated, and an experimental model of wave energy converter designed, manufactured and tested in regular waves and it has been analyzed.

Keywords: Wave Energy Converter, Renewable Energy, Wave Dragon, Overtopping, Test Model

1. Introduction

The increasing need for energy, fossil fuel restrictions, environmental pollution, global warming and the greenhouse effect and many other factors, is the use of renewable energy [1]. In general, renewable energy is divided into the following sections: Solar Energy, Ocean Energy, Wind energy, geothermal energy, Fuel Power Plant, and Fuel cells [2]. Among these sources, the seas and oceans is one of the most important renewable energy sources in the world so that the world's total energy consumption in recent years, on average, equal to 15000 terawatt hours per year [3]. According to the International Energy Agency, the total amount of energy in the seas and oceans which contains the energy in sea currents, waves and energy density stored in the oceans equal to 100000 terawatts per year and this amount of energy stored in the oceans and clearly shows [4]. Wave energy from solar can be considered [5]. Temperature changes due to solar radiation at Earth's surface cause the wind and with the wind blowing over the open sea, the waves are formed. Although the exact mechanism sea is very complex but we can say this process has three stages [6].

(a) Wind on the sea level which causes shear stress on the water. Contrasting surface tension and shear stress at this stage cause to the formation of small waves with wavelengths in the centimeter level [7].

(b) Intensify wind, wind turbulent flows near the water surface tension and a cause the formation of oscillating changes in surface pressure distribution is released.

(c) Reinforcing agent against high waves is created in these circumstances the weight. That's why it created waves in this situation which called gravity waves.

Wave energy devices can roughly be categorized into 3 main groups, namely: point absorbers, backbone absorbers, and overtopping converters [8]. Ferris Eris Madsen [9] is the first researcher in the development of Wave Dragon (WD) harvested in 1986. In the early years it developed experimental models and in 1994 it was the application for registration. During the early years of 1995 to 1999 studies on the basic structure of a fixed model, reflecting efficiency, geometry, optimum choice for turbine configuration after it took place. James William *et al.* in 2007 [10] studied the Wave Dragon which conducted on prototype devices. In this case, the low height of the structure is designed to have the most current sea in real terms. This study was conducted during the 2006 storm closed three parameters were analyzed. Each of the data recorded for the amount of flow simulations were compared with the amount that consequently it was a good model for cross flow. The first parameter, which is the turbulent flow simulations were compared with the scale. The second parameter was ascending current independent comparison. Kerry measurement data were compared with the simulated independently. Measurements showed that the elapsed time is independent of wavelength, so it is recommended that use be dependent simulations.

In this study we conducted on wave energy converter Wave Dragon design and test.

2. General Design Aspects

The designed system is based on data and research collection has been selected by the author. In the final system several factors, including cost, construction time, etc. are involved. The value of each factor in the final choice other factors are different. In the following table the impact of each factor on the final design of the index value is obtained.

Table 1. *Evaluation of various energy absorbers.*

	system efficiency	simply making	mass production availability	useful life	emission impact on the environment	Total cost
Point absorber	2	3	4	1	1	3
OWC	3	1	1	2	3	4
Piezoelectric	1	3	3	3	2	2
Overtopping	4	2	2	4	4	1

According to the table above, with high scores and become overtopping waves, according to research in this area is low compared to other transformers, converters waves Wave Dragon was selected to build the plant engineering department. WD consists of three chief elements (see Fig. 1):

(a) Two patented wave reflectors focusing the waves towards the ramp, linked to the main structure. The wave reflectors have the verified effect of increasing the significant wave height substantially and thereby increasing energy capture by 70% in typical wave conditions.

(b) The main structure consisting of a patented doubly curved ramp and a water storage reservoir.

(c) A set of low head propeller turbines for converting the hydraulic head in the reservoir into electricity.

A model of a wave energy converter of Overtopping is designed and built with the following dimensions.

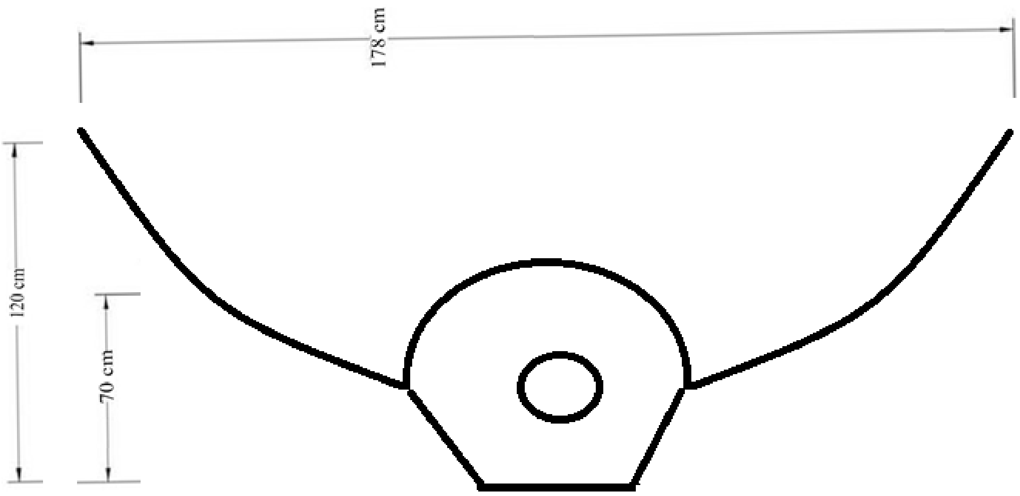

Figure 1. *Main components of the Wave Dragon.*

The power generators is selected on the basis of available devices and according to the mechanism of action of hydrodynamic systems used in this type of transducer. Among the hydrodynamic systems, due to the low fluid head made by *Kaplan type* turbines are used for low hydrostatic pressures and high flow rate is appropriate.

Overall, the average turnover Wave Power wave energy through a vertical plane with unit width, parallel to the crest of the wave to be considered and known as wave energy flux is shown by the following equation:

$$P = \frac{\rho g^2 T H^2}{32\pi} \quad (1)$$

where P is wave power per unit [kw / m], ρ is the density of sea water per unit [kg / m^3], g is acceleration of gravity at the unit [m / s^2], T is wave period in units [s] and H is unit height in [m] wave breasts that are the highest point to the lowest point in the waveform. As well the average energy density is given by the following equation:

$$E = \frac{\rho g H_{mo}^2}{8} \quad (2)$$

The E wave energy density per unit area that the unit [J / m^2], and is the sum of kinetic and potential energy density per unit area.

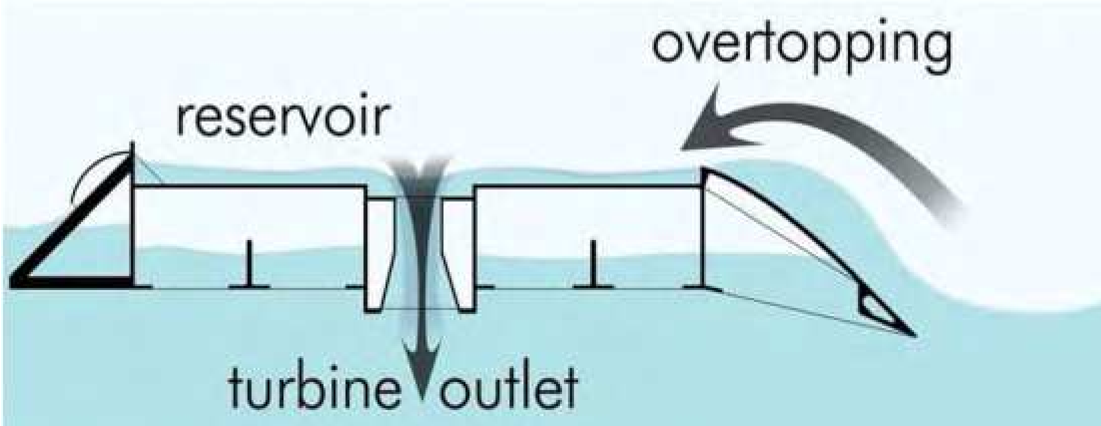

Figure 2. *Schematic of the water flow in the Wave Dragon* [10].

Wave Dragon-shaped device that affects the dimensionless wave period is as follows:

$$Q_N = \frac{1}{\lambda_{dr}} \frac{Q}{b\sqrt{gH_s^3}} \tag{3}$$

constant λ_{dr} is the ratio of the free surface energy $E_{f,\ dr}$, relative to the incident wave energy $E_{f,d}$ is. This constant based on linear wave theory is defined as follows:

$$\lambda_{dr} = 1 - \frac{\sinh(2k_p d(1-\frac{dr}{d}) + 2k_p d(1-\frac{dr}{d})}{\sinh(2k_p d) + 2k_p d} \tag{4}$$

Where kp is the wave number in the peak period, d is the water depth and d_r is the device's draft.

To analyze the performance of the overflow, without the spill flow rate range R compared with Frey height shown in the following equation:

$$R = \frac{R_c}{H_s} \tag{5}$$

3. Construction

Tank construction is done in several stages. The foundations of the structure to withstand fluid pressure on it as well buoyancy force exerted on the floor buoyancy structural design and builds the foundations shown in the figure 3. In the second step the foundations covered by plywood layer and seamlessly shall see. This process is shown in the figure 4. Because the Ramp is curved, so material should be used in its manufacture that we can easily make the curve. That's why we use EPS. For cutting polystyrene and curvature of an element is used. The device has a current source with an output of 4 mA and a voltage of about 14 volts and a wire element (50) is made. This machine makes precision cutting EPS will be hot cutting element. Ramp parts made of EPS are as shown in figure 5. To build a Wave focuser plywood layer we use. Board placed for 48 hours in direct sunlight to dry. Repeat this process three times until the desired shape us takes three-layer boards. Three layers, we made in the previous step, was mounted together. To increase impact resistance and sealing of the device, the model we built fiberglass. Fiberglass model will explain the process to continue (see Figure 6 and 7).

In making this model and the strength of it should be used Kaplan turbine. The turbine is a reaction turbine, axial flow and circulation to the entrant who uses concepts. Input, is the torsional tube that rotates around the valve guide. Kaplan turbine blades used in the construction of a. The blade is inserted into a channel and it will attach to the walls of the channel. Then one side and the other side shaft to the propeller shafts to electric motors or generators are connected. View turbines made as follows:

Power generation method: ACOutput voltage: AC: 0.1-18VOutput current: 10-300 mARated speed: 3000 rpm

To make fiber glass Gelcoats and first base material is resin. Cover resin, epoxy resin and vinyl ester resins and gelcoats are suitable for the production of which has sufficient abrasion resistance and strength.

After selecting resin fillers (ASTM D38) should be added to it. In general, the internal volume, foam fillers occupy up to 3/1. For example, if we have a maximum of 3.1 liters per liter of resin mixed with filler.

The first component that should be added to the resin is cobalt. Cobalt would speed up polymerization of the resin is at the end of the cooking. About 15 grams per liter of cobalt resin is added to it and must be mixed thoroughly with the resin. A resin is mixed with cobalt, is not responding to the required catalyst to be added.

After adding cobalt, the second material that should be added is aerosol. aerosol as a white powder which is very dangerous. Aerosol in a few steps to the resin is added to the mix. Aerosol makes the viscosity of the resin mixture is exceeded and prevents sag. Add aerosol the resin is experimental and depends on temperature and the amount should be added to the resin to prevent resin to sag. Aerosol increased resistance to radiation UV, resistance to environmental factors and be hit.

Then talc filler is added to the resin. Talc is a powder that must be added to the resin and mix well to be in several stages. The amount of talc added to the resin, aerosol value is 4/1. Talc increase resistance and prevent breakage gelcoats are crisp and gelcoats. After adding these materials to prepare resins gelcoats, they must be used within 48 hours. Gelcoats until the hardener has been added and the catalyst can be kept Molding time and part inserting, we add to gelcoats.

To coat the model with fiberglass, the model is built well-polished and with a clean cloth, good clean and we put the model in the right place. Gelcoats prepared by brush to the desired level heading. After half an hour to an hour wait until we hit gelcoats Gelcoats dry. After drying a layer of fiberglass 220 grams Gelcoats prepared and heading to the desired level. With a brush gelcoats on the glass and we can wait two to three hours to dry the first layer. Then another layer on the first layer and the second layer push and push again gelcoats by brush. Wait for the dried layers make any twists and bends on the surface to be strengthened. Sealing the fiberglass needle mat type model and it will strengthen the model (see Figure 6 and 7).

Figure 3. *The foundation of the tank Wave Dragon.*

Figure 4. *The tank of the Wave Dragon.*

Figure 5. *The ramp of the Wave Dragon.*

Figure 6. *Front view of The Wave Dragon in the coast.*

Figure 7. *Sink of the Wave Dragon.*

4. Experimental Results

Accurate measurement of water flow, a necessary step both economic and qualitative point of view. Sensors are used to measure the flow of water entering the turbine has a gear sensor is Hall Effect magnetic sensor integrated into the device, there are a number with every turn (away) emits an electrical pulse.

Hall Effect current sensor has three wires (see fig 8 and 9):

Red wire sensor power (VCC), it can be connected to 5 or 24 volts DC.

Black: GND.

Yellow sensor output (pulse putput).

By counting pulses from the sensor output, the water flow rate can easily be calculated using a conversion formula. (Per liter per hour).

To calculate hydrostatic pressure gauge we use a level sensor (see fig 10). Height recorded at any time multiplied by the density and the acceleration of gravity and hydrostatic pressure at various times were calculated. A sensor in the device used for this purpose can measure height up to 8 cm. The sensor output is an analog data that show us numbers between 0 and 1024. To calculate the water level to an Arduino board and a water level sensor is needed. Water level sensor has three wires that power the red wire sensor (VCC), black wire GND and the yellow wire is the sensor output.

The test simulated periods of three wave 5 seconds, 7 seconds and 10 seconds with 5 centimeters height, 8 centimeters and 1.0 meters wide. The reason for this wave conditions, compared to the current passing through the turbine, the inflow to the reservoir and power is generated. Draught of the devices in all tests constant 5 is centimeters. Figures 11-19 presents the measured voltage versus time in various wave height and various periods.

Figure 8. *Water flowmeter sensor.*

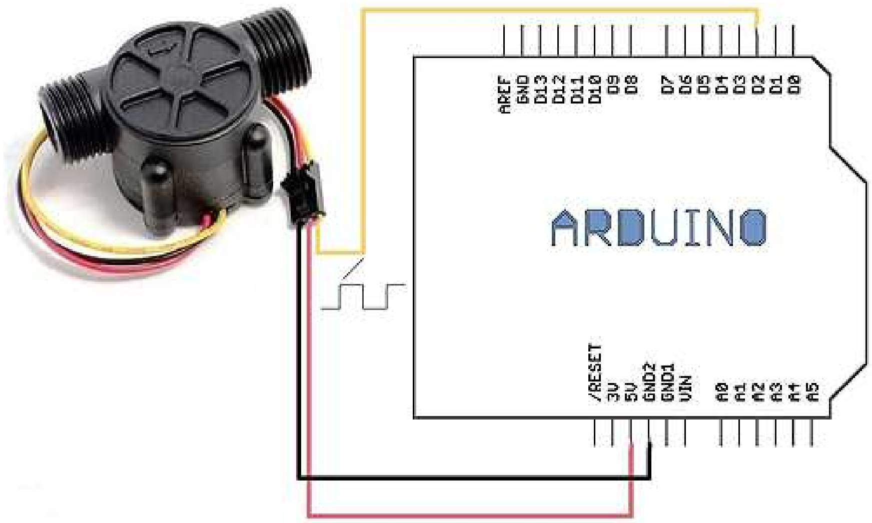

Figure 9. *Connection of flowmeter sensor to the Arduino.*

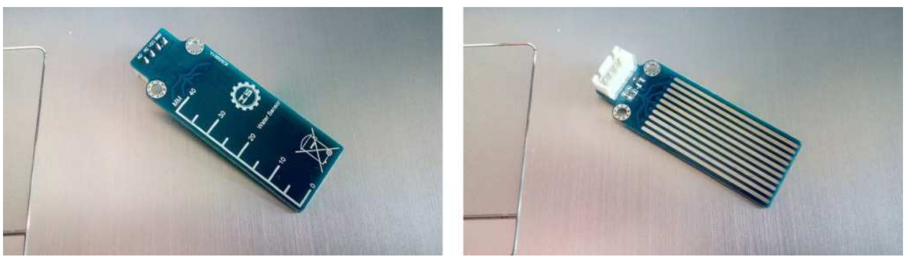

Figure 10. *Level meter.*

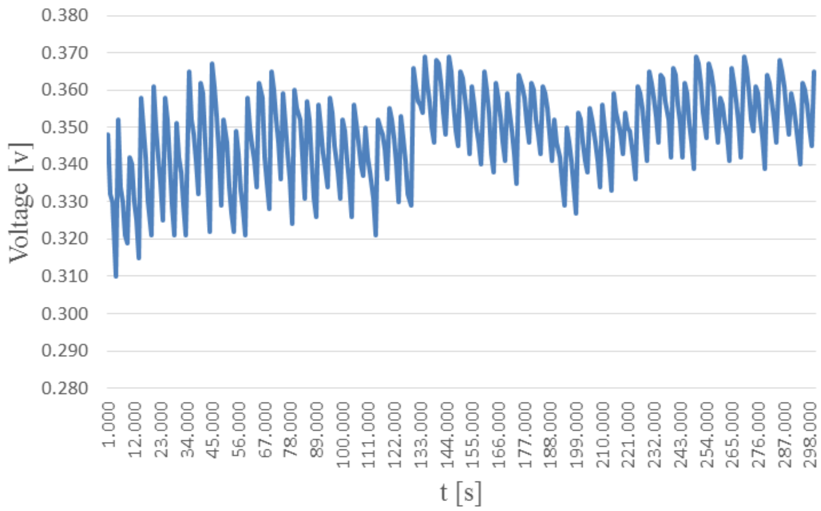

Figure 11. *Measured voltage versus time in 5. centimeters wave height and period of 5 seconds.*

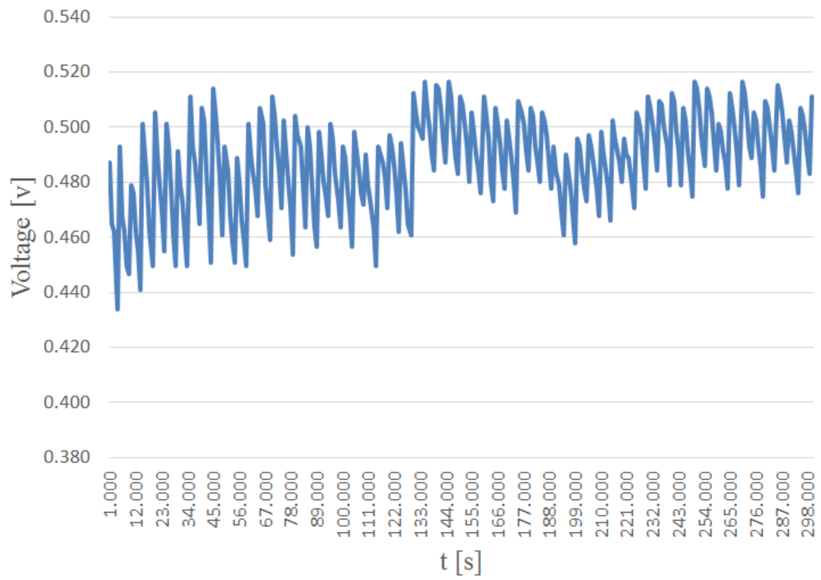

Figure 12. *Measured voltage versus time in 8 centimeters wave height and period of 5 seconds.*

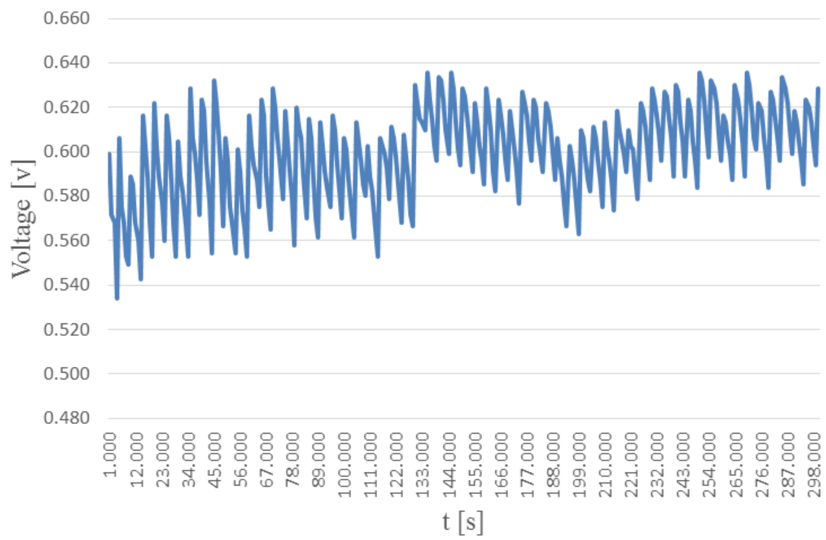

Figure 13. *Measured voltage versus time in 10 centimeters wave height and period of 5 seconds.*

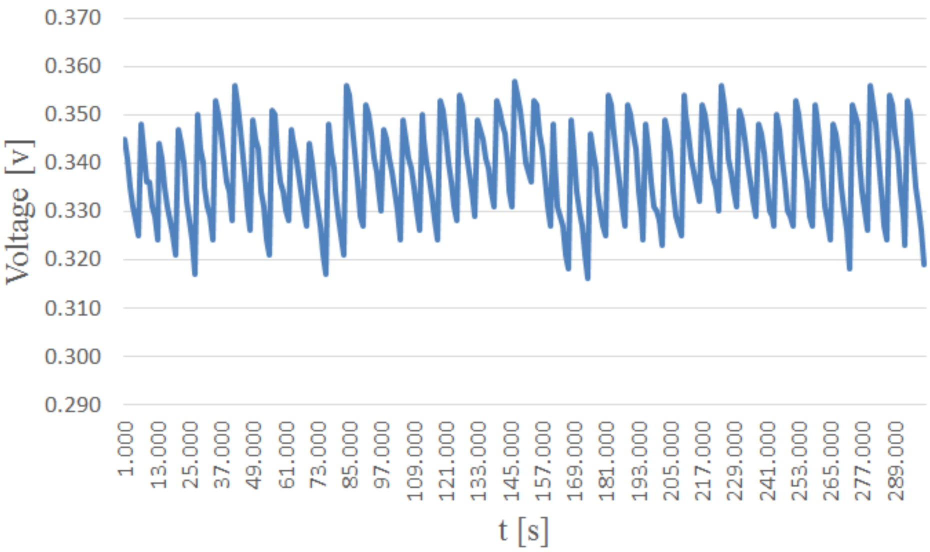

Figure 14. *Measured voltage versus time in 5 centimeters wave height and period of 7 seconds.*

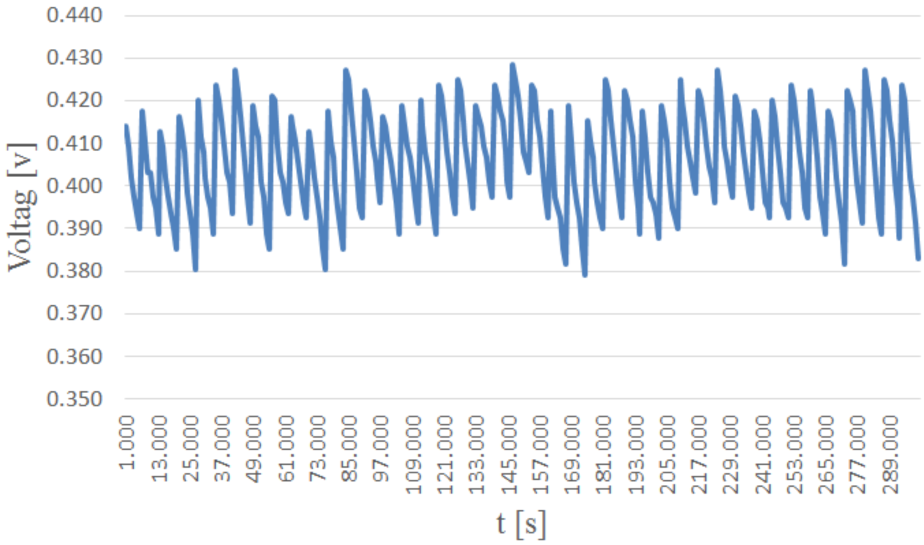

Figure 15. *Measured voltage versus time in 8 centimeters wave height and period of 7 seconds.*

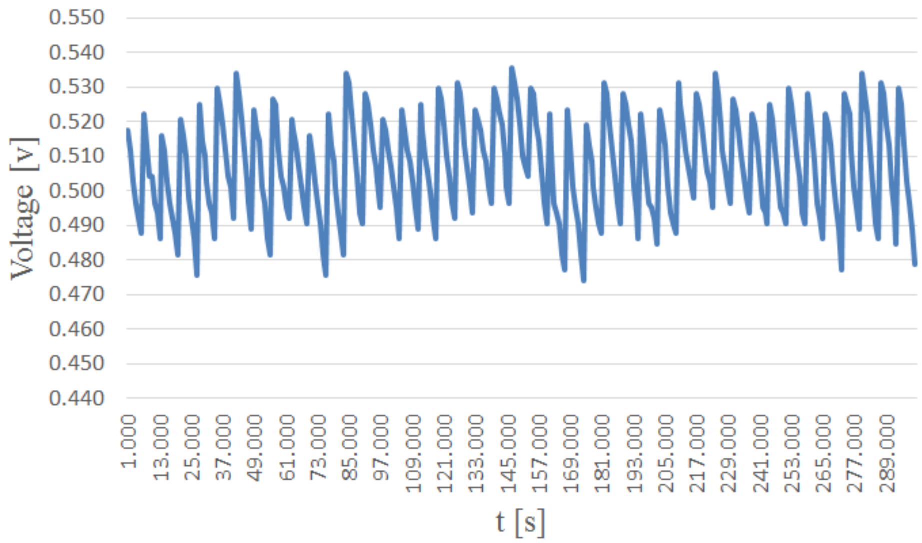

Figure 16. *Measured voltage versus time in 10 centimeters wave height and period of 7 seconds.*

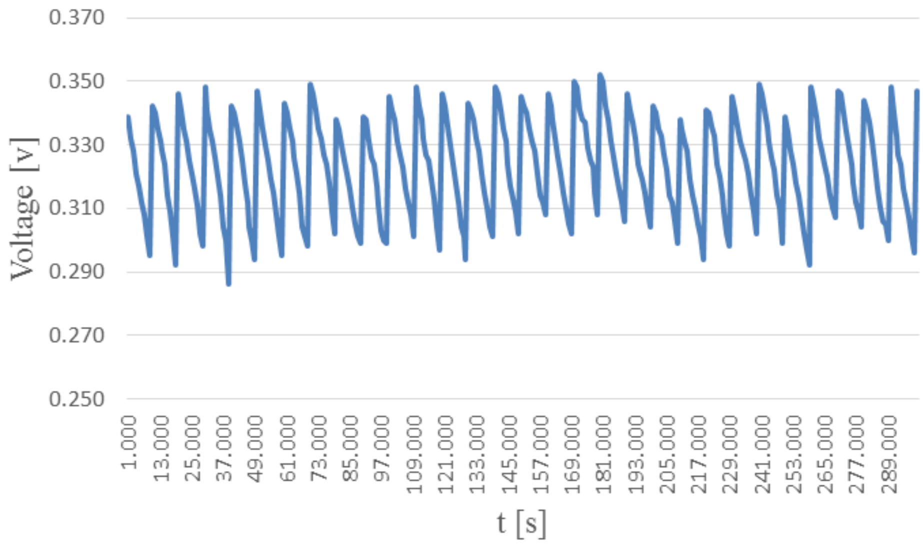

Figure 17. *Measured voltage versus time in 5 centimeters wave height and period of 10 seconds.*

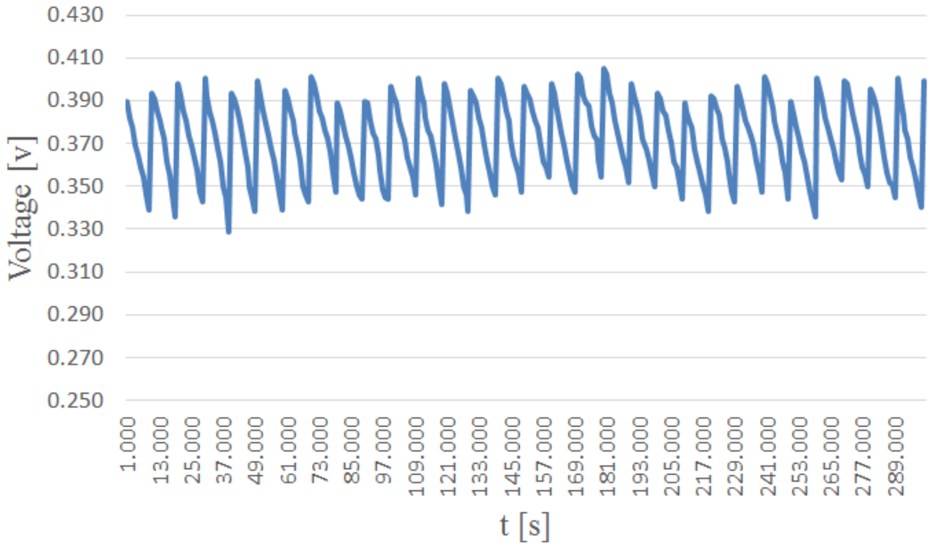

Figure 18. *Measured voltage versus time in 8 centimeters wave height and period of 10 seconds.*

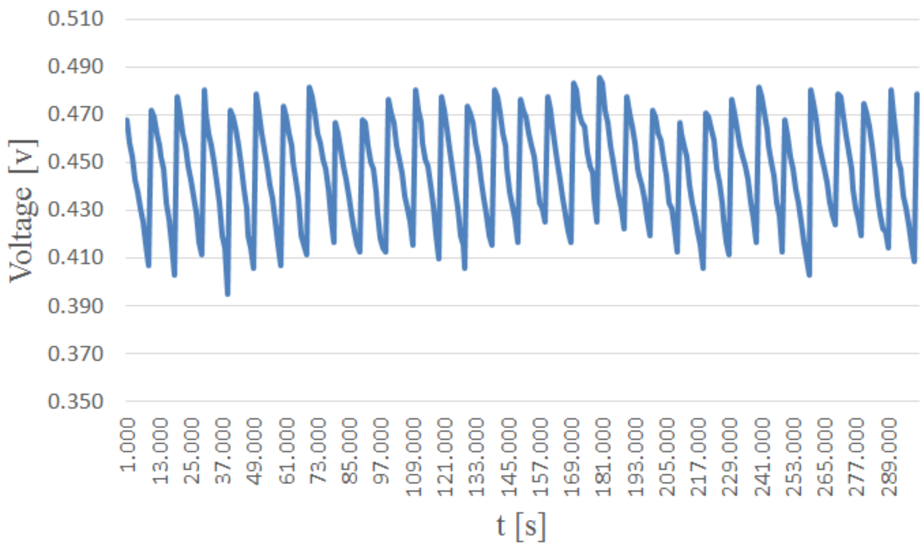

Figure 19. *Measured voltage versus time in 10 centimeters wave height and period of 10 seconds.*

5. Conclusion

In the analyses of the Wave Dragon only minor adjustments have been made on the wave reflectors. Their curvature has been slightly increased and it is recommended to increase their height over MWL to avoid energy loss due to frequent overtopping. it is demonstrated that adjusting the crest freeboard to fit the occurring wave situations is advantageous. The experimental tests of the Wave Dragon show an overall efficiency of 12% and to an approximately 20% net efficiency. It seems possible to produce electricity at a cost of 1 $/kWh which the average price in the U. S. is about 12 cents per kilowatt-hour and a typical U. S. household uses about 908 kWh a month of electricity.

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