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DESIGN AND IMPLEMENTATION OF A NEW WAVE ENERGY SYSTEM TO PRODUCE ELECTRIC ENERGY

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Abstract- The need for electrical energy is rapidly coming into prominence as a result of advancing technology and industrialization and the increasing population. It is inevitable for this energy to clean and cheap, which is a need for more sustainable world in the future. The significance of renewable energy sources is increasing day by day. There have been great improvements in wind and solar technology, which is the first that comes to mind when talking about renewable sources. However, renewable energy sources such as geothermal and wave energy should not be ignored. Covering three-quarters of the Earth, oceans are of great potential for wave energy. As our country is surrounded by sea on three sides, wave energy is of huge potential for our country as well. There have been many studies about wave energy in the world and governments and private institutions have been supporting these studies. While wave energy has many advantages in terms of both its technology and operating costs, it has disadvantages in terms of working conditions and capital costs at first. Academic and scientific studies aim to resolve these drawbacks and make these wave energy systems useable and sustainable to produce electricity. In this study, the systems producing the electrical power from the wave energy is explained briefly and then the wave energy simulator implemented based on the new system in Turkey is described.

Keywords: Renewable Energy Sources, Wave Energy, Modeling.

I. INTRODUCTION

If it is thought that our world is surrounded by 70% of the ocean, the wave energy as a renewable energy source has a lot of potential. Those potential has not overlooked through the eyes of scientists and manufacturers and many applications had been realized. The different systems are designed to the idea of utilization from the incredible power delivered by the oceans waves, and the possibility of producing electrical energy from the wave energy has been proven. Potential and kinetic energy created by the waves is transformed to the rotational energy by the mechanical systems and the electrical energy generation systems are designed thanks to it. These systems are divided into 3 main categories based on their location. These are offshore, near-shore and coastal systems. Electricity generation systems from wave energy are grouped according to their location and working principle as depicted in Figure 1 [1].

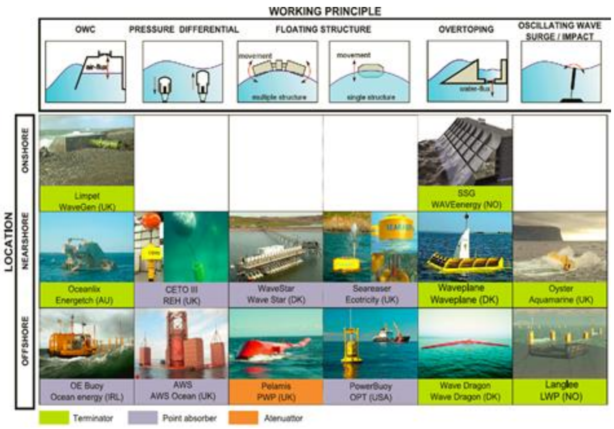

Figure 1. Grouping of systems that produce electrical energy from wave energy [1]

As presented in Figure 1, the systems generating electrical energy from wave energy are investigated into three categories about their location and six categories about working principle. According to Figure 2, these are offshore, near-shore and coastal systems [2].

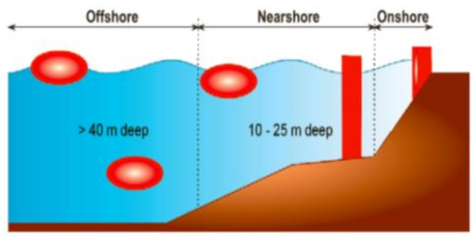

Figure 2. Depending on the location of wave energy [2]

In this study, the wave energy simulator implemented in a laboratory environment will be explained after reviewing these categories.

II. THE ELECTRICAL ENERGY GENERATING SYSTEMS FROM WAVE ENERGY

The electrical energy generation systems generally are the systems that use potential and/or kinetic energy of the direct or indirect water created by the wave. The wave equation can be presented by Equation 1 in general form.

$$J = \frac{\gamma g^2}{32\pi} H^2 T \qquad (1)$$

Most general, the wave energy (J) depends on the density of the sea water (γ), gravity (g), wave height (H) and period of the wave (T) [3].

A. On-Shore Applications

This system basically consists of two parts. The first part is water column while the second air is the colon. The principle of operation of the system, when the water column is located on the rising wave of air column and thus pushes the air compressing turbines is based on return. This is thanks to the rotating air flow alternator produces electricity. When descending the wave and water column is composed of an inward air flow from the outside and in this way, by moving in the direction opposite of the alternator is provided electricity generation again.

B. Near-Shore Applications

These applications are usually about systems used near the coast of 15-25 meters. The closing to the shore provides more advantages in terms of logistics and maintenance costs. Another advantage is that these systems are independent from the shore. There are many different applications whether in general the energy obtained by swinging the wave is converted to the electricity.

C. Off-Shore Applications

These systems are often used in remote locations from coast of the ocean. Because of far from the shore, transportation of the electricity is inconvenient. Also, it is very difficult to repair in case of any failure. They have heavy working conditions since they are in ocean openness. But the waves are quite efficient in terms of energy have great potential. These systems are usually works with principle of electricity production by rotating the turbine in thanks of two element of hydraulic pump.

III. WAVE ENERGY POWER PLANT MODELLING IN LABORATORY ENVIRONMENT

The design and application of the systems which generates the electricity from the wave energy is quite inconvenient and costly. However, the analysis of the new system only must be realized in the wave pool or in case of sea/ocean. These increase the costs and causes to loose the time. Because of these, the idea of modeling wave energy appeared for testing the designed systems at the lab environment. The aim of this study is to test and analysis the system which produces the electricity from wave energy in lab environment by designing the characteristic of the wave energy mechanically. To do this, to examine the characteristic of the wave energy is needed first.

A. Wave Energy Characteristic

The waves that occur in the oceans and seas are the physical phenomena depend on the wind. It occurs in certain time intervals, in many different frequency and height. For this reason, the designed system must be the system benefiting from this randomness energy. A period of the wave occurring at sea in its simplest form is depicted in Figure 3.

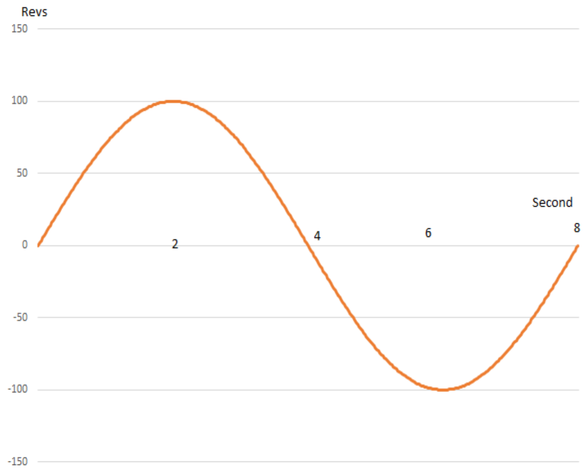

Figure 3. Transferring the system in a period of the wave Mechanical movement Speed-Time graph

In its simplest form, the speed-time graph of the mechanical energy transferred the electricity generation system from the wave energy is represented in the figure. According to the design of systems and power transfer method, in general the period is sinusoidal. In general, the amplitude of the wave are combined by the random and intermittent or continuous form of many sinusoidal chart. Therefore, to produce electrical energy from the wave energy has a little complexity and cumbersome according to the wind energy. It is possible to resolve the random mechanical energy electrically. The wave energy can be simulated by realizing the mechanical energy of the wave by using an externally motor. It is possible that this is obtained by controlling the speed of a dc motor.

B. Modeling System

The mechanical energy obtained in terms of wave energy is simulated by an external motor, after obtaining the wave characteristic. There are several methods and application for this simulation. The mechanical energy given by the wave energy can be provided to the system. In terms of speed control units, desired speed and torque values can be obtained from the motors (AC or DC). The greatest benefit of this is in the fact that the analyses and tests can be realized in a laboratory environment without challenging conditions. Thus, it can be highly economized from time and costs. Due to simulate the wave energy, the motor is turned left and right in a certain times for determined period and frequency. Then this bidirectional rotational movement is converted to the unidirectional movement. After this case, a speed-time characteristic can be depicted in Figure 4.

The mechanical energy must be regularly for producing electrical energy from the mechanical energy whose characteristic is presented in Figure 4. To stabilize the mechanical energy, a mechanical circuit is used at the output of the alternator. Therefore, the output mechanical energy is stored by attached a special designed flywheel to the output of the alternator. After flywheel, the speed-time characteristic of the system is presented in Figure 5.

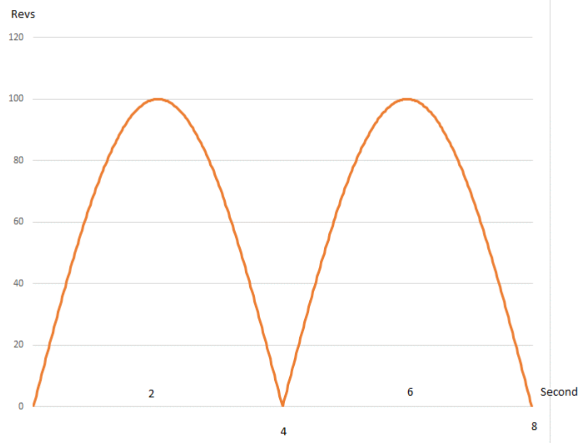

Figure 4. Speed-time characteristic for the output of the redactor

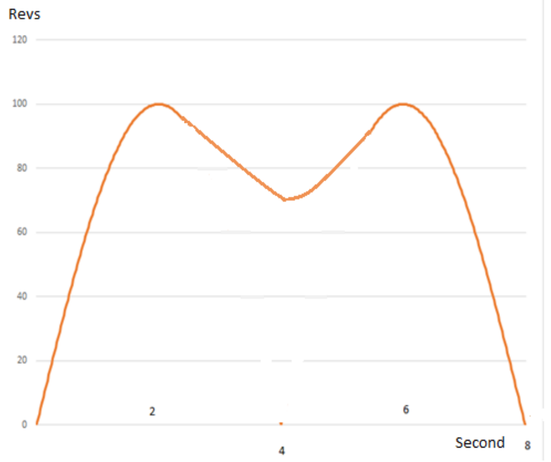

Figure 5. Flywheel output speed-time

The figure also shows a speed-time characteristic which modeled in a lab for one period of time. If this process is repeated for a few periods, a better waveform then a rectified sinusoidal waveform can be obtained. After this state, high quality and network connectable electrical energy with constant voltage and frequency is obtained from more stable and regulated mechanical energy compare to previous version. Almost every wave can be simulated in a laboratory environment by changing the parameters of the wave such as amplitude and periods. The motor is driven as a real wave, and can be simulated instantaneously. In this way, the simulator is revised and the design characteristics are changed by using different electrical systems for different electrical energy requirements. It provides to gain time and energy saving. There are different options to produce electricity from rotational systems according to their characteristics.

Although the used method is being same, the systems can differ according to the properties of the devices used. While the periods of the real waves which create the wave energy have much randomness, the input range of the alternator that should be used must be wide even if this randomness is decreased mechanically. Then, a converter should be used for more quality electric energy at the output of the alternator.

One of the more important problems of these systems is discontinuous form of the waves. Therefore, even there is not wave, the system needs energy. Because of this, a battery charge-discharge system should be used which stores energy when the energy demands decrease and supplies energy when the energy demands increase. This brings additional cost to the system, but it is necessary for continuous and reliable energy. The wave energy power plant realized in Turkey is modeled and simulated in a laboratory environment with this study. The system simulated in this study is depicted in Figure 6.

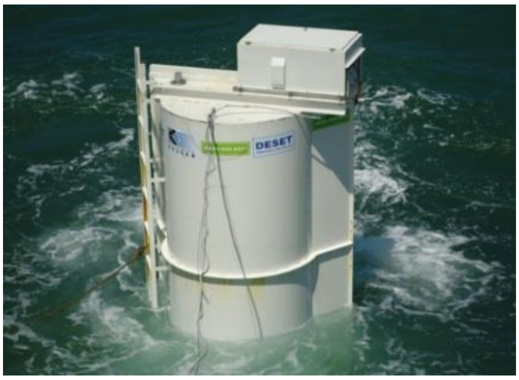

Figure 6. Modeled wave energy power plant

While the electrical part of the system producing, electrical energy from mechanical energy in a real system depicted in Figure 6 is connected to simulator in a laboratory environment, the electrical results are obtained from the analyzer (Figure 7, Figure 8). When the results are analyzed for 200 seconds, it is observed that the results are identical with obtained from the sea. This is showed that the system producing electrical energy from the wave energy can be tested in a laboratory environment easily before launched to the sea.

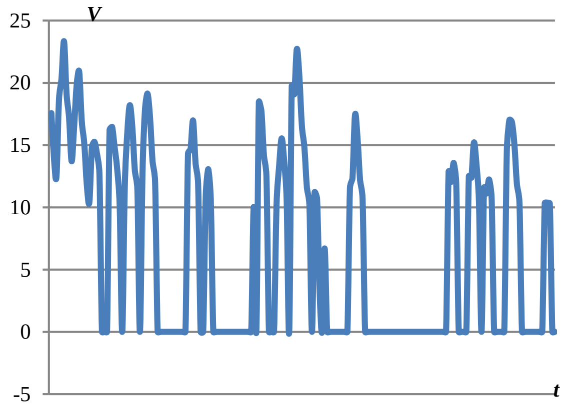

Figure 7. Voltage-time characteristic

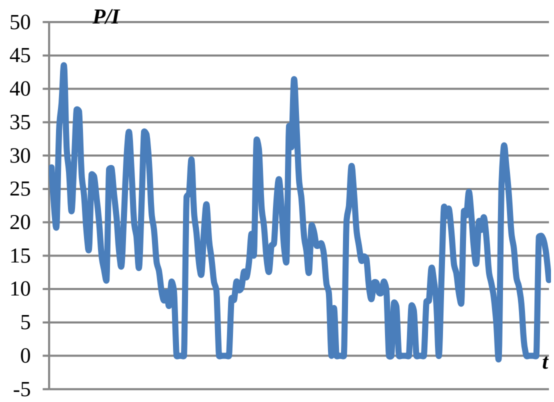

Figure 8. *P*/*I*-Time characteristic

IV. RESULTS AND CONCLUSIONS

At the end of this study, it is emerged that the system producing electrical energy from the wave energy can be tested and analyzed without launching to the sea. Since the test and analyze of this system at the sea is very hard process, this study is realized. The energy transferred from the wave to the mechanical equipment and the electrical energy power plant is simulated in a laboratory environment, thus it provided convenience to test the system before launch to the sea. The problems in the system can be detected in advance and then it can be solved easily and cheaply. In this way, the new wave power plants can be designed easily in a laboratory environment and this work will be the subject of M.Sc. thesis of first author.

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BIOGRAPHIES

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