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Ocean Wave Kinetic Energy Harvesting System for Automated Sub Sea Sensors

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***Abstract*—**This paper presents an overview of the Ocean wave kinetic energy harvesting system. Energy harvesting is a concept by which energy is captured, stored, and utilized using various sources by employing interfaces, storage devices, and other units. Ocean wave energy harvesting in which the kinetic and potential energy contained in the natural oscillations of Ocean waves are converted into electric power. The kinetic energy harvesting system could be used for a number of areas. The main applications that we have discussed in this paper are to how generate the energy from Ocean wave energy (kinetic energy) to electric energy that is to eliminate the requirement for continual battery replacement.

***Keywords*—**Energy harvesting; power system; oceanic; sensors; autonomous.

I. Introduction

IN the last decade, the field of energy harvesting has increasingly become important as evident from the rising number of publications and product prototypes [1]. Nowadays, the demand of the energy is increasing, the renewable energy resources, such as solar energy, wind energy and Ocean energy, have been developing by scientists and researchers worldwide. The Ocean wave energy as one of renewable energy sources are increasing with high technology development. Ocean wave carries not only kinetic potential energy but also gravitational potential energy [2]. There are two factors to be considered for the wave energy, which are wave height (H) and wave period (T). But Ocean wave depends on many factors, such as wind speed, Ocean-temperature, seabed-conditions and etc. The Ocean wave can generate the common kinetic energy for the renewable energy.

Nowadays, the approach of research and development on the methods of Oceanic energy harvesting becomes an important aspect of maritime energy recovery to support mankind. Mechanical energy can be found almost anywhere by converting vibration into electricity [3]. The Ocean energy refers to the energy that carried by Ocean waves, tied, salinity and Ocean-temperature differences [4]. As one of the most feasible future technologies, ocean wave energy may convert into electricity by using devices that are engineered and manufactured for this purposes. This source of energy can be generated to AC or DC of the transmission by a generator that can be driven a device or a power absorber.

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II. Background

Oceans cover almost three-fourths of the earth's surface. The Oceans' waters, the air above the Oceans, and the land beneath them contain enormous energy resources. These energy resources include renewable energy sources, such as offshore wind energy, wave energy, Ocean current energy and offshore solar energy [10].

There are several types of energy harvesting systems that have been under research and develop by scientists with in universities or research institutes. One type of the system consists of a wave power absorber, which is included with a turbine, generator, and power electronic interfaces. In this case, an absorber from the Ocean wave can harvest the kinetic energy.

The renewable energy technologies are improving with the increasing demand of the energy sources, such as solar, wind and ocean. This project focuses on the ocean kinetic energy harvesting system for automated sub sea sensors. The ocean energy refers to the energy that carried by the Ocean waves, tides, salinity and temperature differences [4]. It also has been known that the energy of Ocean waves and ambient vibrations is common kinetic energy to produce the renewable energy. This means that the movement of the Ocean waves creates a vast store of kinetic energy or energy in motion. Waves are generated over a large area of ocean and travel immense distances with only small energy losses. Although the wave energy is concentrated source of wind energy, it can help to balance output variability from other renewable source and maximise the efficient use of electricity networks. The other advantage of this technology via the ocean kinetic energy into generate electricity to be used within transport and industries and farther more its application as a potential localised power supply technology.

III. Ocean Wave Sources

Waves within the Southern Australian Ocean are well recognised by their large size [11]. Fig. 1 shows a comparatively large amount of wave energy that exists of the southern coastal regions of Australia. The wave energy flux P, per unit wave-crest length, of a region is given approximately by the following equation (1) [12]:

$$P = \frac{\rho g^2}{64\pi} H_S^2 T \approx 0.5 T H_S^2 \quad (1)$$

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where ρ is the water density (kg/m^3), g is the acceleration due to gravity, T is the wave period and H_s represent the significant wave height (m). This technique has a number of applications including with the real-time oceanic which is presented at Fig. 1 highlights elevated levels of wave energy density off the south coast of Australia.

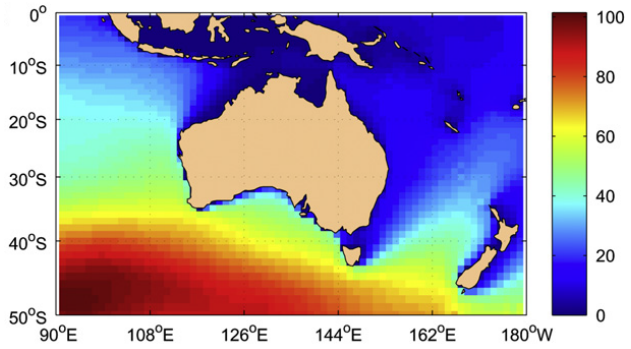


Fig. 1 Wave energy Flux E_w (kW/m) [11]

There are some forms of the oceanic energy sources in the world, such as marine currents, tidal currents and waves [5]. Waves are the forward movement of the ocean's water due to the oscillation of water particles by the frictional drag of wind over the water's surface. Waves have crests (the peak of the wave) and troughs (the lowest point on the wave). The horizontal distance between two crests or two troughs determines the wavelength, or horizontal size of the wave [6]. The elementary waveform is the two-dimensional simple harmonic wave. The one direct ocean wave is also a form of regular ocean wave that is shown in Fig. 2. Irregular ocean waves can be represented by the superposition of an infinite number of simple harmonic waves of different wavelengths, directions, and amplitudes.

The total ocean wave energy can be calculated in joules per unit by the potential and kinetic energy together. If we assume potential energy is a wave of length L and generated by the displacement of the water away from the mean sea level. The kinetic energy of a wave is a result of both horizontal and vertical water particle motions [5].

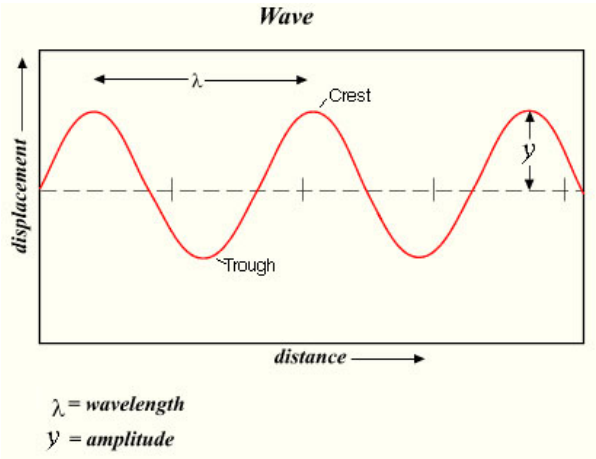


Fig. 2 Regular Ocean waves [9]

There are many factors that can affect the physical characteristics of irregular ocean waves that are wind-velocity, wind-duration, fetch (distance over which the wind blows), influence of distant storms, and etc. [7]. Fig. 3 shows an example of cross section of an irregular wave pattern of the type depicted by an instantaneous profile of a wave train.

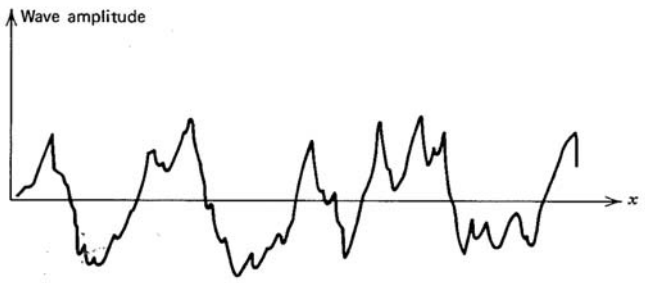


Fig. 3 Irregular Ocean waves [7]

IV. Wave Energy Harvesting Devices

The wave energy harvesting devices primary function is to convert wave energy into a different form of useful energy. An energy harvesting devices ability to convert energy from an oscillating system to a more desirable form of energy is through its ability to destructively interfere with the wave [8].

To appreciate and to understand the benefit of energy harvesting within the oceanic environment, two devices were designed to activate with the ocean wave kinetic energy harvesting systems which are A: a surface buoy device utilizing a series of linear generators and B: a heaving type point absorber device utilizing a rotary generator which is connected to a one way clutch and increasing speed gearbox.

The design floats on the surface of the wave the linear generator system is contained within the hollow buoy. The frame acts as a submerged body, opposing the motion of the wave; this induces motion in the linear generators (as shown in Fig. 4).



Fig. 4 Surface Buoy Harvesting System

The energy can be harvested from ocean waves using a permanent magnet linear generator. Four linear generators were

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designed to fix inside of the hollow buoy to obtain maximum energy from the wave.

The submerged energy harvesting system is shown in Fig. 5. A sealed cylinder is designed for the submerged system to attach a float buoy to a floating buoy through a rod and piston. The device will sit at some optimal depth below the ocean surface to harvest energy from the ocean waves.

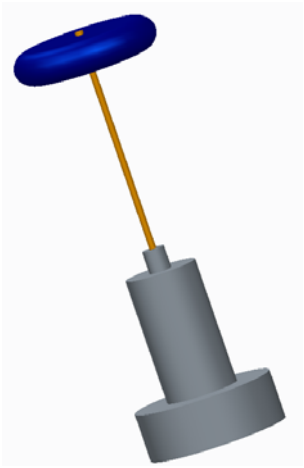


Fig. 5 Submerged energy harvesting system

The bottom section of the device contains a gearbox and generator. The device will generate energy by the motion of the moving piston, connected to a spool to induce rotary motion. The linear motion of the piston applies a radial torque the spool, which in the causes an input rotary motion of the input shaft of the gearbox.

The submerged energy harvesting system electrical system would transfer the electricity produced by the rotary generator to a set of rechargeable batteries. The current produced by the rotary generator will be in a DC form as required for storage in the batteries. Possible automation system may be included depending on further design analysis and integration.

V. Simulations and Modeling

The ocean wave has different situations or conditions without forecast. It is essential that the physics of ocean wave need to be researched. The total ocean wave-energy can be calculated in joules per unit by the potential and kinetic energy together. The potential energy is a wave of length L that is generated by the displacement of the water away from the mean sea level. The kinetic energy of the wave is a result of both horizontal and vertical water particle motions [5].

1. Irregular Ocean Waves

The total energy (potential energy and kinetic energy) of the ocean wave can be calculated by:

$$E = \frac{1}{2}\rho g A^2 \tag{2}$$

where g is the acceleration of gravity (9.8 m/s^2), ρ is the density of water and A is the wave amplitude (m), E is the energy.

$$v = \frac{L}{2T} \tag{3}$$

where L is the wavelength (m), T is the wave period (s) and v is the speed of the wave (m/s).

$$P = \frac{1}{2}\rho g A^2 \frac{L}{2T} \tag{4}$$

The Equation (4) shows a relationship between power P and wave period T and wavelength L

$$L = \frac{gT^2}{2\pi} \tag{5}$$

Solve the Equation (4) and (5) together

$$P = \frac{\rho g^2 T A^2}{8\pi} \tag{6}$$

With consid$A = \frac{H}{2}$, Equation (6) can be written

$$P = \frac{\rho g^2 T H^2}{32\pi} \quad [5] \tag{7}$$

Based on the characteristics of the Ocean wave, the simulation can be made using the Matlab. Fig. 6 shows the irregular Ocean wave simulation by different wavelength and height.

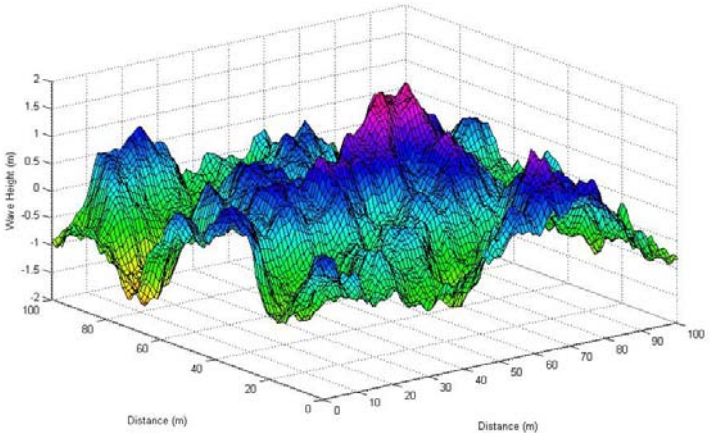


Fig. 6 Simulation of irregular ocean waves

2. Regular Ocean Waves

Regular ocean wave simulation is also required for the analysis and research. The Fig. 7 shows the Ocean wave simulation with strong wind strength. The wind strength can be changed manually. The other factors (e.g. the wave length, wave height, wave speed and frequency) also are presented (as shown in the Fig. 7).

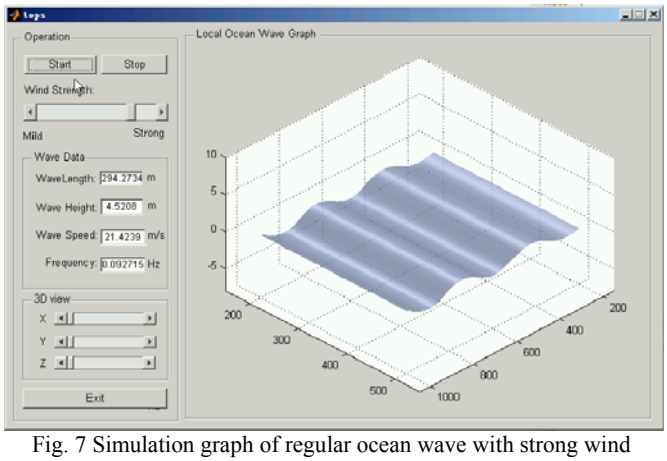


Fig. 7 Simulation graph of regular ocean wave with strong wind strength

To simulate the regular Ocean waves, the relation (8) is applied which is assessed by:

$$Z_{(x,y,z)} = H \times \cos(k \times \sqrt{(x-x_0)^2 + (y-y_0)^2} - \omega t) \quad (8)$$

where
Wave Height:

$$H = \frac{3.5325 \times V_{wind}^{2.5}}{1000}$$

Velocity:

$$V_{ocean} = \frac{gT}{2\pi}$$

Wavelength:

$$L = \frac{gT^2}{2\pi}$$

Wave frequency:

$$f = \sqrt{\frac{2}{3}} \frac{g}{2\pi T}$$

where

$$T = \sqrt{\frac{2}{3}} \frac{\pi V_{wind}}{g}$$

3. Ocean Wave with Surface Buoy Harvesting System

The energy can be harvested from Ocean waves using a permanent magnet linear generator. The generator can absorb the wave motion from different direction. It is ensured that wave motion from any direction can be harvested by the triangular configuration. The simulations graphs of Ocean wave with Surface Buoy Harvesting System are shown in Fig. 8.

6 volts is considered for the output of the device. The voltage can be determined by the number of coil turns, area of coil, magnetic field and velocity, which can be calculated by the equation (9)

$$V_{EMF} = NABv \quad (9)$$

where
V_{EMF} = Electromagnetic induced voltage, v
N = Number of turns
B = Magnetic field
V = Velocity, m/s
A = Area of coil, m^2

$$A = \pi D L_{magnrt} \quad (10)$$

and
D = Diameter of magnet, m
L_{magnet} =Length of magnet, m

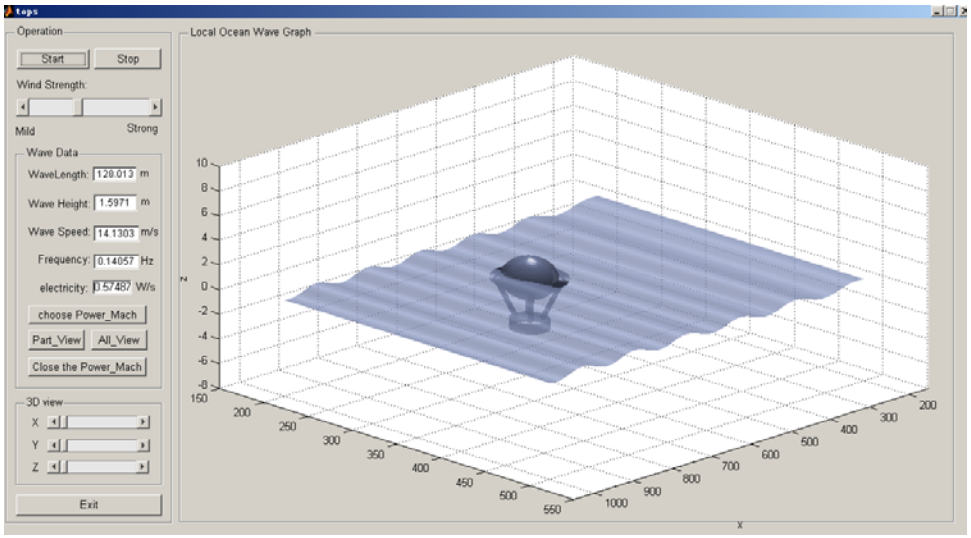


Fig. 8 Simulation of Surface Buoy Harvesting System

4. Ocean Wave with Submerged Energy Harvesting System

To understand the requirements of the methods, begin with a very simplified representation of the resource and employ elementary wave mechanics. A general rigid body motion is composed of three modes of motion (surge, sway, heave) and three rotational modes of motion (roll, pitch and yaw) in the directions of about the (x, y, z) coordinate axes. The simulations graphs of ocean wave with Submerged Energy Harvesting

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System are shown in Fig. 9.

The modeling process is the best described by considering a single translational mode in a long-crested incident wave field and the initial presentation follows [13].

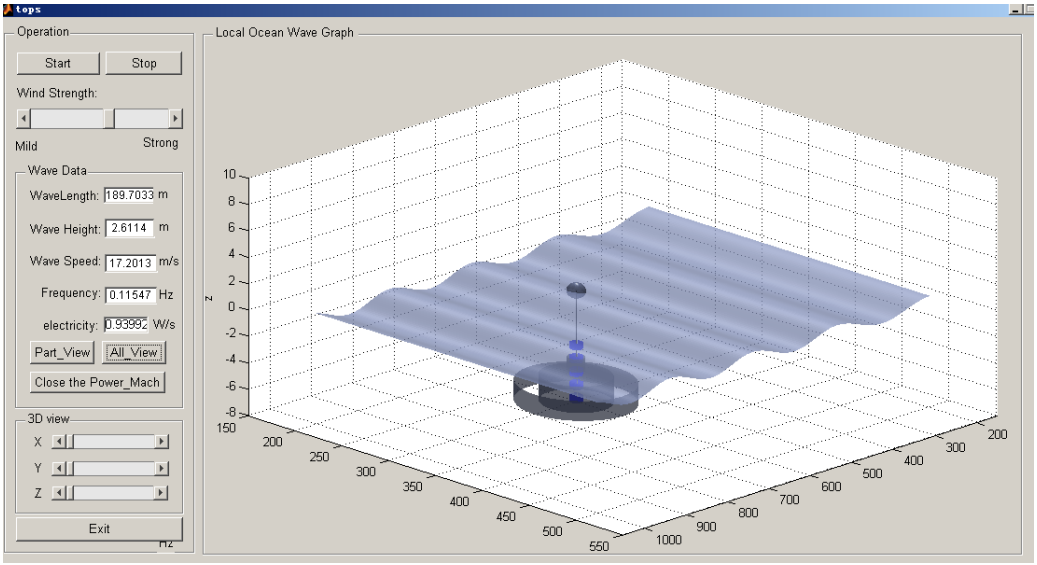


Fig. 9 Simulation graph of Ocean Wave with Submerged Energy Harvesting System

VI. Conclusion

The objective of the project is to research, analyse and optimise the kinetic energy harvesting system for sub sea sensors. In this study, many ocean devices or systems have been researched as the background knowledge, such as oscillating water column, pelamis, wave dragon and floating point absorbers. To optimised the work of the two devices in oceanic environment, the Ocean wave with energy harvesting systems simulation has been done including the irregular and regular ocean waves. The characteristics of regular ocean waves are the basic knowledge for the simulation using Matlab programs.

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