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Research Article

Hydro Electric Power Generation using Tidal Waves

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Abstract

Waves represent a form of renewable energy created by wind currents passing over open water. In this paper design and construction of a prototype wave energy generator with some mechanical and electrical aspects are reported. The main objective is to demonstrate the feasibility of the prototype built in unit and technical data for future developments of the design methods.

Keywords: Renewable Energy, Prototype Wave Generator

Introduction

There are several compelling arguments for using the offshore wave energy technology [1]. Waves occurring in ocean contain considerable power. Actual efforts to harness this energy have been ongoing for many years. Wave-power generation is not currently a widely employed commercial technology, although there have been attempts to use it since at least 1890 [2]. Wave energy devices are at various stages of development, ranging from demonstration to requiring significant R&D. There is considerable work already underway on all these aspects in many countries [3]. This paper describes the performance of the wave energy converter which employs a linear permanent magnets vernier electrical generator (LPMVEG) for, having relatively low phase inductance and electronic unit, which has function of compensation of reactive power.

Tide and wave height

Both tide and wave height data are to be collected in order to establish any sort of wave model for electricity generation. Deciding on a viable configuration involves the collection of wave height and wave period data over time. A statistical model could then be built up and theoretical values determined. A 2m high ocean wave with a period of 10sec has an energy potential flux of 50 to 70 kW per metre of width.

Investigation of the high tides

Ocean wave frequencies are normally in the order of 1~2 Hertz, Commercial technology includes water pressure measurement, ultrasonic distance measurement and changes in capacitance of a sensor as water height rises and falls. All of these technologies are easily operated at read frequencies of 10Hz, so it was decided to construct a simplified design for measuring wave height. In present work vertical tubes were placed alongside of the wave generator unit. The setup was designed in such a way that 1/3 of the tube remained above the surface of the water during investigation of the high tides.

This resulted in a simplified design in determining the wave height measuring unit. The only difference is that the tide height unit has a small hole in the submerged end of the measuring tube, whereas the wave height unit has an open submerged end of the submerged tube. Details of the basic design are shown in Fig. 1.

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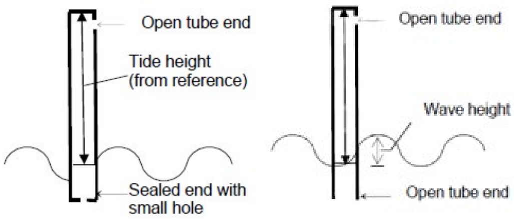

Figure 1.Water piston PVC pipe tubes

Wave enrgy converters

Harnessing the energy provided by oceanic waves is crucial. The direct drive power take off system uses a floating buoy connected to a linear generator LPMVEG and it works upon the difference in height between wave top and wave bottom [4]. The buoy, floating on surface of the water follows the motion of the wave. The buoy is connected to a LPMVEG fixed on a concrete foundation, which stands on the bottom of the ocean as shown in Fig.2

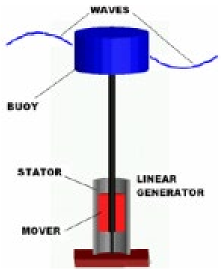

Figure 2. The floating buoy system

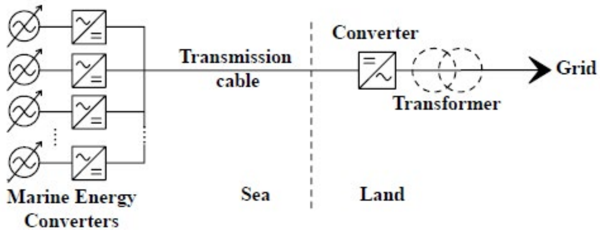

Figure 3.Direct drive power takes off system

Power hidden in an ocean wave

Waves range in size from the ripples in a pond to the great storm waves of the ocean and the tides whose wavelength is half the distance around the earth. Waves are classified according to their period (or frequency) that ranges from less than one second to more than hundred thousand seconds (tides).[5]

Table 1.Wave classification based on frequency period

Waves	Frequency Period
Ripples	fractional seconds
Wind chop	1 to 4 seconds
Fully developed seas	5 to 12 seconds
Swells	6 to 22 seconds
Surf beats	1 to 3 minutes
Tsunamis	10 to 20 minutes
Tides	12 or 24 hours

Terminology	Description
Crest	The high point of a wave
Trough	The low point of a wave
Wave height	Vertical distance from trough to crest
Wave length	Horizontal distance between adjacent crests
Wave period	The time in seconds for a wave crest to travel a distance equal to one wave length
Wave frequency	The inverse of the wave period
Wave celerity	The ratio of wave length and wave period

Wave	Frequency	Wavelength	Speed and media
Sound	2000 Hz	0.17 m	340 m s^{-1} in air
Microwave	6 GHz	0.05 m	3.0×10^{8} m s^{-1} in space
Water waves	8 Hz	50 mm	400 mm s^{-1} on water
Sonar	30 kHz	45 mm	1350 m s^{-1} in water
Radio waves	375 kHz (2)	0.8 m	3.0×10^{8} m s^{-1} in space
Ultrasound	3.5 MHz	0.46 mm	1600 m s^{-1} in body tissue

Power hidden in an ocean wave can be determined by the following theoretical equation (1):

$$P = \frac{\rho q^2 a^2 T}{8\pi} \quad \textbf{(1)}$$

Where

- P is power per unit length of wave front (W/m)
- ρ is density of water (kg/m^3)
- q is gravity (m/s^2)
- a is amplitude of water wave (m)
- T is the period of wave (s)

Principle of Electromagnetic Induction

The schematic view of the linear generator used for the experimental work is shown in Fig.4.

Figure 4.Linear generator system with Neodymium Magnets

Magnetic induction is defined by the force it exerts on a conductor carrying an electrical current. An induction generator consists of two main parts: the rotor and the stator. The terminology originates from the rotating generator where the rotor is the rotating part and the stator is the non-moving static part. Between the rotor and the stator is a small distance called the air gap. The air gap is a mechanical necessity that allows the rotor to move relatively to the stator. When the rotor moves relatively to the stator a time varying magnetic field is created in the stator coils. This time varying magnetic field produce electricity on the copper wires.

Experimental Investigation

The schematic view of the built in prototype wave energy generator is shown in Fig.5 , Fig.6 and Fig.7. It consists of linear generator system, buoy, floating on surface of the water and other instrumentation.

Figure 5.Built in prototype plant with instrumentation

The main components of the system include. Neodymium Magnets, copper coil, float and a testing tank of (4×2×2) feet respectively. The float is the portion of the wave energy generator that moves up and down on the surface of the ocean. In this prototype, electricity is generated due to the relative motion of the float (coil) relative to the magnet assembly on the stationary shaft. For this particular prototype, a cranking device is used to create the initial motion (rotational motion), which is converted to linear (up-down) motion using a cam system.

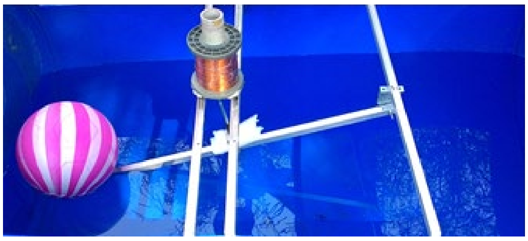

Figure 6.Built in prototype plant with Neodymium magnets

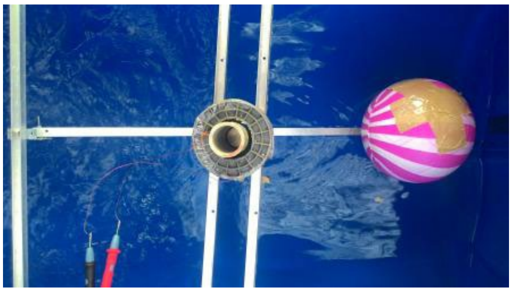

Figure 7.Built in prototype plant with float

Power calculations in regular waves

The results of power generated by a single float is shown in the table III below. The investigated wave height is 0.1 to 0.3 meter and the wave period is varied from 2 sec to 4 sec. In each test the applied damping has been optimised in order to extract most energy. The incident power in regular waves can be calculated as using equation (2) and the Capture with Ratio is calculated by equation (3) as suggested by [6]. The Capture Width Ratio is an expression used to indicate how much energy the float can absorb [6].

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

$$CWR = \frac{P}{D.P_W} \quad \textbf{(3)}$$

Where

- P_w is incident power per unit length of wave (W/m)
- P is the generated power (W)
- D is the float diameter (m) 0.16m
- ρ is density of surface sea water (kg/m^3) 1020 kg/m^3
- g is gravity (m/s^2) 9.81 m/s^2
- H is height of water wave (m)
- T is the period of wave (s)

Table 2.Power Output by A Single Float

Test	Power Output		
	Wave height H (m)	Time period T (s)	Power Output (P_w)
1	0.1	2	19.5382
2	0.12	2	28.135008
3	0.17	2	56.465398
4	0.18	2	63.303768
5	0.16	2	50.017792
6	0.23	2	103.357078
7	0.27	2	142.433478

Table 3.Power Generated By A Single Float

Test	Power Generated					
	Wave height H (m)	Time period T (s)	Power Output (Pw)	Ammeter reading (A)	Voltmeter reading (V)	Power generated (W)
1	0.05	0.59	1.440942	0.1	0.87	0.087
2	0.1	0.76	7.424516	0.2	1.33	0.266
3	0.13	1.01	16.67487	0.4	1.81	0.724
4	0.18	1.49	47.16130	0.7	2.53	1.771
5	0.25	1.7	103.7966	1.4	4.12	5.768
6	0.24	1.92	108.0384	1.3	3.68	4.784
7	0.22	1.89	89.36381	1.2	3.64	4.368
8	0.21	1.73	74.53139	1.1	3.02	3.322
9	0.3	1.98	174.0853	1.6	5.26	8.416
10	0.28	1.9	145.5205	1.6	5.23	8.368
11	0.295	1.95	165.7804	2.2	7.34	16.148
12	0.32	1.96	196.0697	2.3	8.4	19.32
13	0.37	1.96	262.1283	2.4	9.1	21.84
14	0.41	2	328.4371	3.1	11.2	34.72
15	0.45	2.2	435.2134	3.8	12.3	46.74

Table 4.CWR

Test	Wave height H (m)	Power Output (Pw)	Power generated (W)	CWR (%)
1	0.05	1.440942	0.087	0.087
2	0.1	7.424516	0.266	0.266
3	0.13	16.67487	0.724	0.724
4	0.18	47.16130	1.771	1.771
5	0.25	103.7966	5.768	5.768
6	0.24	108.0384	4.784	4.784
7	0.22	89.36381	4.368	4.368
8	0.21	74.53139	3.322	3.322
9	0.3	174.0853	8.416	8.416
10	0.28	145.5205	8.368	8.368
11	0.295	165.7804	16.148	16.148
12	0.32	196.0697	19.32	19.32
13	0.37	262.1283	21.84	21.84
14	0.41	328.4371	34.72	34.72
15	0.45	435.2134	46.74	46.74

Results and Discussion

- Experiments were carried out in a prototype wave energy generator.
- This wave powered generator generates electricity by moving magnets through coils of wire.
- When a magnet moves through a coil of wire, an electrical current flows around the coil. If the magnet moves one way through the coil, the current will flow in one direction, and if the magnet moves the other way through the coil, the current will flow in the other direction.
- If the magnet moves quickly through the coil, a large current will be generated, and if the magnet moves slowly, a small current will be generated. While the magnet is stationary within the coil, no electricity will be generated.
- The magnitude of the voltage generated is proportional to the number of turns in the coil of wire the more turns in the coil the higher the voltage.
- As the wave periods become longer the power in the wave is found to increase proportionally.
- CWR increases for wave period above 1.95 s.

Effect of Wave height and time period

The effect of wave height on power output is shown in Fig.8. The effect of wave height on power generated is shown in Fig.9 and Fig.10. Investigations show that wave height affects the power output of the prototype unit. At a time period of 0.59 to 2 sec the wave was semi developed and after an interval of 2 to 3 sec the fully developed waves were found to yield better efficiency of the system.

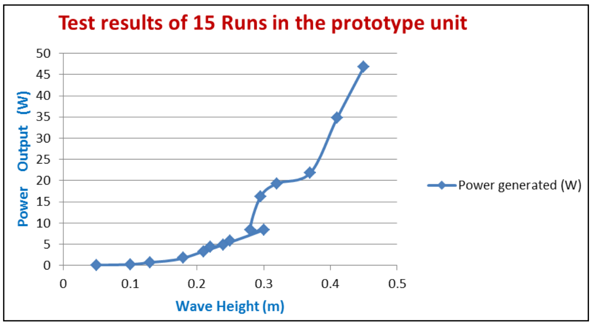

Figure 8.Power production in regular waves of time 0.59 to 2.2 s

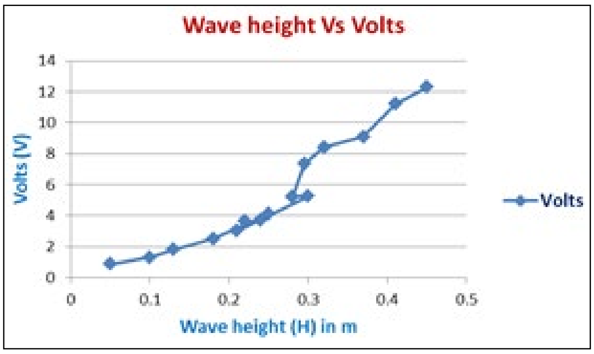

Figure 9.Voltage distribution at different wave heights

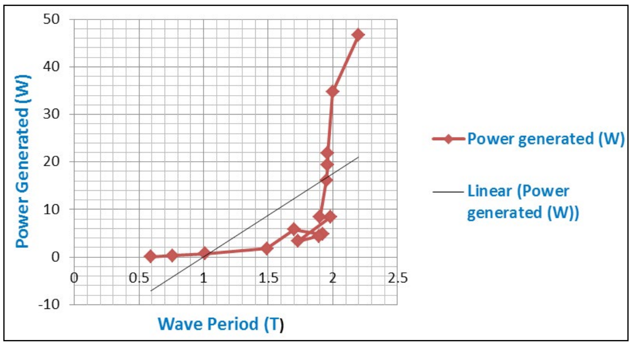

Figure 10.Effect of Wave period on power generated

Effect of Wave period

As the wave periods become longer the power in the wave is found to increase proportionally to the wave period, but as the power output remains the same the CWR decreases as shown in Fig.11.and CWR gradually increases for a wave period above 1.95 s.

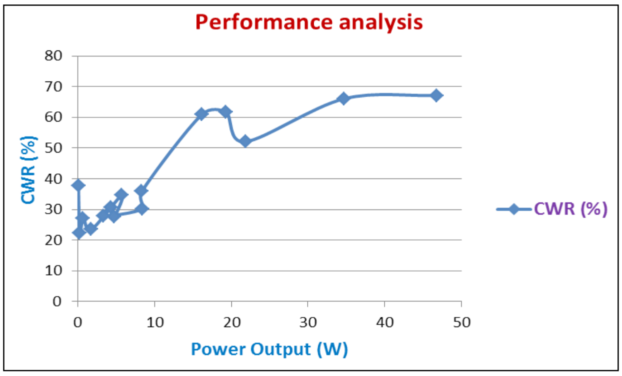

Figure 11.CWR analysis

Conclusion

A prototype of the Wave energy generator is built up and preliminary testing of the unit showed that it will be supportive to build a commercial power generation unit from this laboratory testing.

Operation and testing investigation details have been reported out, when tested in realistic conditions.

Experimental investigations shows that it is possible to generate useful power from marine waves across oceans.

It also promotes zero emission power generation technique. There are a lot of options possible when it comes to the collection of the kinetic energy of ocean waves. There are also enormous methods to obtain useful electrical energy from collected wave kinetic energy. This project will promotes further research on wave kinetic energy. Compared to wind and solar energy, wave energy presents considerable technical advantages, because it is more predictable, persistent and spatially concentrated [7].

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