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A Study on Prototype of Wave Energy Conversion Device

Suyash Mahajan¹, Suraj Kanse², Vaishnav Jadhav³, Yash Kadam⁴, Sunil Jadhav⁵

U.G. Student, Department of Mechanical Engineering, Bharati Vidyapeeth College of Engineering, Navi Mumbai, Maharashtra, India^{1,2,3,4}

Associate Professor, Department of Mechanical Engineering, Bharati Vidyapeeth College of Engineering, Navi Mumbai, Maharashtra, India⁵

ABSTRACT: In the world of industrialization, demand of energy is increasing constantly. The available non-renewable sources of energy are present in limited quantity & depleting day by day. To overcome this critical situation renewable sources of energy like solar, wind, geothermal, tidal energy can be used. Renewable sources of energy are present in abundance, this energy can be termed as future energy. Tidal energy is also one of the renewable sources of energy that can be obtained from sea waves. Tides have tremendous amount energy & that can be available for 24*7. Economic, environmental, and technical advantages of wave energy set it apart from other renewable energy resources. Present study describes a newly proposed Mechanical Wave Power Generator that is employed to generate power using up-down & back-forth motion of floating buoy.

KEYWORDS: Renewable energy, Wave power generation, Increasing the efficiency, Maximum movement, Back-forth, Up-down, Buoy.

I. INTRODUCTION

In today's time coal is used as major source to generate electricity, which leads to huge amount of carbon emission results in global warming. If we replace energy generation by coal with renewable sources of energy then it will be helpful in reducing global warming effect. In coastal areas we can use tidal energy for generation of electricity. Waves generated in the ocean are source of renewable energy with very high energy density (energy per unit length) of the waves. Ocean wave energy resources have been assessed at global and regional levels, and the amount of available ocean wave energy is substantial enough to generate serious interest in exploiting it. The statistics states that the amount of available ocean wave energy is capable of contributing significantly to the energy needs of different countries. Tidal energy can be used to generate electricity in such a way that it does not result in the emission of gases responsible for global warming or acid rain associated with fossil fuel generated electricity. Use of tidal energy could also decrease the necessity for atomic power, with its associated radiation risks.

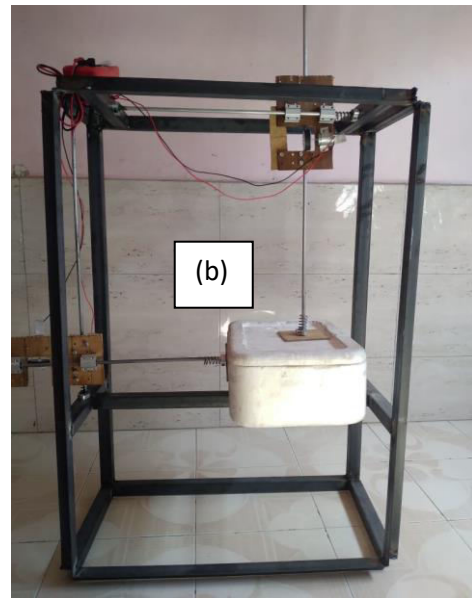
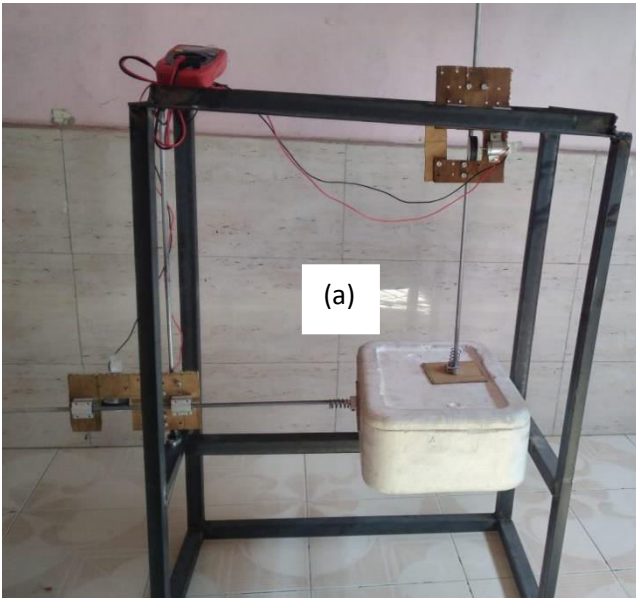
Extraction of tidal energy is major task, lots of works are going on to extract tidal energy efficiently. Ocean waves are an enormous, largely untapped energy resource, and therefore the potential for extracting energy from waves is considerable. The ocean wave energy which has been less harnessed to date, is one of the most reliable (i.e., high accuracy in energy prediction and little energy loss because wave propagates over a long distance with), powerful (i.e., higher density of seawater compared to air/wind) and very attractive renewable energy sources (i.e., availability and forecast-ability) [1–3]. Wave energy possesses far greater power intensity (2–3 kW/m²) compared to solar (0.1–0.2 kW/m²) and wind energies (0.4–0.6 kW/m²) [4]. The literature [5,6] show that the wave energy is hugely available in various coasts with the potential of >100 kW/m average annual power density. Many researchers, academic institutions and energy firms have embarked on finding effective ways to capture this untapped powerful renewable energy source for electricity power generation applications [7,8]. Research during this area is driven by the necessity to satisfy renewable energy targets, but is comparatively immature compared to other renewable energy technologies. So, to tackle this problem we come up with prototype of wave energy converter which will use up-down as well as back-forth motion of waves to extract electricity efficiently from ocean waves.

1.1 Construction of Prototype of Wave Energy Converter (WEC):

Wave energy converter consist of a floating buoy, axle housing, belt- pulley arrangement employed for converting reciprocating (vertical) motion into rotary motion as well as reciprocating (horizontal) motion into rotary motion. The

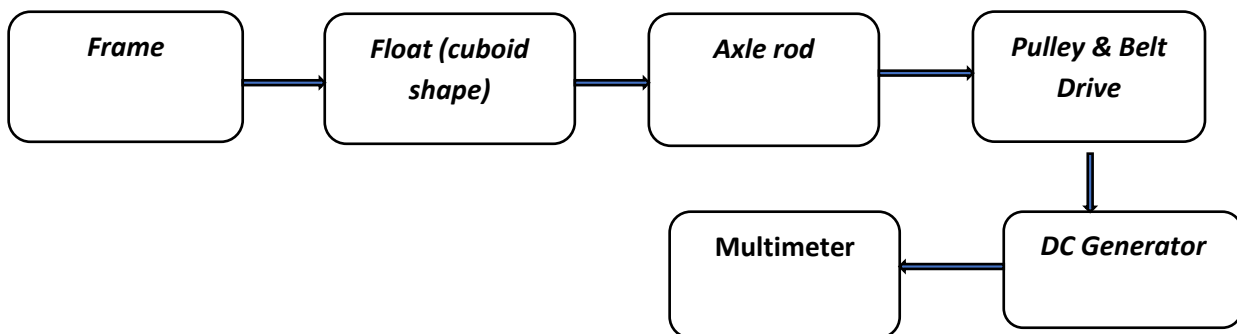


floating buoy is connected to the vertical as well as horizontal shaft with the help of shaft holder. There is friction contact between shaft and pulley and pulley is further connected to the DC generator. There is an multimeter to indicate the voltage acquired. Whole assembly is mounted on a frame which is fixed at bottom. Frame also helps to provide strength to WEC against the waves of the ocean. Construction is shown in fig (a) and (b).



1.2 Working of Prototype of Wave Energy Converter:

Archimedes Principle, stating that anybody completely or partially submerged in a fluid (gas or liquid) at rest is acted upon by an upward or buoyant force, the magnitude of which is equal to the weight of the fluid displaced by the body. The volume of fluid which is displaced is equivalent to the volume of an object fully immersed in a fluid or to that fraction of the volume below the surface for an object partially submerged in a liquid. The magnitude of the buoyant force act on float is equivalent to the weight of the displaced portion of the fluid. For Vertical motion- Waves have movement associated in vertical direction. They move in a cycle of crest(up) and trough(down). So, the Float is used to get the movement. These movement is needs to be utilized to get power. So constructive beam encounters these movement and transmit it into rotational motion. To convert this into rotational motion pulley is used. Pulley is in contact with beam and vertical. movement into rotary. These motion needs to be invested which is done by motor. The motor is connected to pulley using belt. The motor rotates and generate energy which is indicated by the multimeter. For horizontal motion-The waves also have slamming motion (back and forth). These movement is converted using the constructive beam and pulley-belt mechanism. The DC motor is used to generate power which is shown by multimeter.



(Flow chart: working of WEC device)



II. RELATED WORK

Mike Mekhiche, Kathleen A. Edwards published paper on “system-level design, development and validation methodology” on April 14, 2014. Which includes the methodology that, at the surface, a float moves in response to ocean waves along a spar with a reduced response to waves due to a heave plate at its base. Relative motion between the float and spar drives a pushrod into the spar. A mechanical actuator converts the linear motion into a rotary action that drives a vector-controlled electric generator, this paper attempted to address the complex multi-discipline and concurrent engineering process required to successfully design, develop, test and validate such Wave Energy Converters as OPT’s Power Buoy [9]. Ricardo Gobato, Aleksander Gobato, Desire Francine Gobato Fedrigo studied the Pelamis system to capture energy of ocean wave in August 6, 2015. Pelamis fluctuates with the movement of waves and drives a series of floats, which consequently move a cylinder which pumps oil to a generator that produces hydraulic energy. It has enormous potential thanks to the use of tides that can be optimized so that their cost / benefit and production increase exponentially. But this system is not matured yet, research work is required in this field [10]. Christopher F Ferguson published the paper in 2011 on Submerged Pressure Differential Wave Energy Converter. The seafloor pump works through the use of pressure differentials. A contained shaft slides along a larger, hollow shaft. When the inner shaft goes out, the lower pressure created draws water in through a one-way valve at the end. When the shaft goes back in, the higher pressure forces the water out through a second one-way valve. With the continuous motion of the waves, this provides a steady stream of water into the pressurized reservoir. This is an inexpensive and easily constructed wave energy converter appears to be a viable method of power generation, and is worth further consideration and testing [11]. A theoretical and experimental study of the capsizing of Salter’s duck in extreme waves was done by M. Greenhow, T. Vinje on 22 October 1981. The experimental work took place in the Edinburgh Wave Power Project’s ‘narrow tank’, using a 10 cm diameter model and an ‘absorbing’ wavemaker controlled by a digital computer. The tests were designed to analyze the response of a model Salter’s duck to a deep-water plunging breaker. From the measurements the Edinburgh Wave Power Team has concluded that it is possible to engineer a duck that will survive storm conditions off the coast of Scotland and elsewhere [12].

Loránd SZABÓ, Claudia OPREA, Clement FEȘTILĂ published paper on Study on a wave energy-based power system. The buoy, floating on the water's surface follows the motion of the wave. The buoy is connected to a linear generator fixed on a concrete foundation, which stands on the bottom of the ocean. The system is mechanically simple, with few moving parts. By optimizing the shape and operation of the buoy 30% absorption efficiency can be achieved. The overall performances of the proposed wave energy converters exploiting the huge clean electric energy of the oceans and of seas were proved to be those expected by the designers [13]. Vivek raj M. Solanki on March 2021 designed and Developed Ocean Wave Energy Power Generation System. The system consists mechanical arrangements by which continues wave energy would be captured and this captured energy further transmitted and converted into mechanical energy. So, the float has direct contact to ocean wave as the wave passed through system the float will capture energy and simultaneously the gear are in action and start rotation according to intensity of wave. Thus, the connected gear transmitted energy to generator and generator produces electricity which is stored or directly use. The system is continuous work in same cycles. With this type of design, the gearbox to produce continuous power with single generator. Also, by placing two generator one can produce in upward motion and other one will produce energy in downward motion. This can be alternative way to fulfill the energy demand and prevention against energy crisis [14].

III. METHODOLOGY

We have done study of availability of ocean energy that can be used to replace conventional source of energy like coal, from that we come to know that ocean have lots of potential for generation of electricity. Then we studied various mechanism through which we could produce wave energy. Many of the WEC devices were using only one motion of the waves so that their efficiency was low so in order to improve the efficiency of WEC device we started research on what kind of design our project should have so that we could increase our efficiency. Then our design was done & selection of material was our next step. Material where selected based on their resistant property to ocean waves & their durability. After design is finalized, we fabricated the actual prototype of WEC device. When we manufactured prototype completely, we tested it in a tank filled with water and done multiple tests on it, so that we could analyse our errors and solve them to find out our success.



IV. EXPERIMENTAL RESULTS

Readings for different float movement is taken for up-down and back-forth movement up to height of 15cm and 35 cm respectively. From this movement power for each motion is calculated by formula:

$$\text{Power} = \text{Voltage} * \text{Current} \dots\dots\dots(1)$$

After calculating power for individual motion, total power is calculated by adding powers of all motion,

$$P_T = P_U + P_D + P_R + P_L \dots\dots\dots(2)$$

After calculating total power, power for one minute is calculated by considering 8 waves are formed in 1 minute,

$$\text{Power for 1 min} = P_T * \text{Number of waves per minute} \dots\dots\dots(3)$$

$$P_{min} = P_T * 8$$

After calculating power for 1 minute power for one hour, one day and one year is calculated by,

$$P_{hr} = P_{min} * 60 \dots\dots\dots(4)$$

$$P_{day} = P_{hr} * 24 \dots\dots\dots(5)$$

$$P_{yr} = P_{day} * 365 \dots\dots\dots(6)$$

| Vertical Float Movement (CM) | Direction of Movement | Voltage(V) | Current(A) | Power(W) | Total Power Per Wave(W) | For 1 Min (W) | For 1 Hr (W) | For 1 Day (KW) | For 1 Yr. (KW) |
|------------------------------|-----------------------|------------|------------|----------|-------------------------|---------------|--------------|----------------|----------------|
| 15 | Up | 0.64 | 0.021 | 0.013 | 0.092 | 0.74 | 44.4 | 1.06 | 386.9 |
| | Down | 0.76 | 0.025 | 0.019 | | | | | |
| | Right | 1 | 0.03 | 0.03 | | | | | |
| | Left | 1 | 0.03 | 0.03 | | | | | |
| 35 | Up | 1.4 | 0.05 | 0.075 | 0.21 | 1.68 | 100.8 | 2.419 | 882.93 |
| | Down | 1.5 | 0.049 | 0.075 | | | | | |
| | Right | 1 | 0.03 | 0.03 | | | | | |
| | Left | 1 | 0.03 | 0.03 | | | | | |

(Table 1: Result table)

Above observations indicates that more the vertical and horizontal movement of the float, more the power will be generated by our Wave Energy Conversion Device. Vertical movement of the float depends upon the height of the ocean waves, so more the height of ocean waves more power can be generated.

V. CONCLUSION

The ability for generating electricity from waveenergy is huge. The ocean is a huge resource, and harnessing the energy in ocean waves represents an important step towards meeting renewable energy targets [15]. Many wave energy conversion devices are not matured enough to meet commercial energy demands. Most wave power plants are mostly small-scale single-point devices. Only by large-scale and integrated development of WEC devices, can achieve better



commercial utilization. So that, a multi-point wave energy generating device having multiple oscillating floats at the same time, or a multi-motion wave energy absorbing devices being arranged in a group to form a large capacity wave energy power plant, can make the installed capacity of the wave energy generating device reach Million watts [16]. In our project we made the prototype which will use both up-down and back-forth movement of ocean waves. Due to use of both motion of waves it is helpful to increase the power output from the waves. There is no complexity in design of our prototype, it can be transported easily from one place to other place. Since this is the basic design of our prototype further modification in prototype can be helpful to increase the power output. Future research should consider a system engineering approach, as each subsystem of a WEC are all closely related and every subsystem should be optimized by considering the other subsystems. In addition to this, individual WECs will often operate as part of a small group of WEC or any huge wave farm, so interaction between these devices should be taken into consideration for future systems analysis.

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