Design and Analysis of Wave Energy Converter Technologies

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Abstract—**Energy from renewables is the demand of the future. This is due to the fact that majority of the current energy generation technologies pose serious environmental hazards. Among the renewables, hydro, solar and wind power are utilized extensively, and its power plants have been installed as well in various parts of the world. However, wave power technologies are still immature in various parts of the world. This paper reviews and discusses the current state of the art of wave power technologies. Also, it a amalgamates the main concerns in the design of wave energy converters.**

Index Terms— **Energy, Wave Power, Mooring, Power take-off.**

I. Introduction

According to the REN21 (An international, cultural community built to promote renewables); the renewable energy share of the world is 26.2%. Out of which, 15.8% is hydropower, 5.5% is wind, 2.4% is solar and 2.2% is through bio-power. The lowest share i.e. 0.4% is of geothermal, concentrated solar power (CSP) and ocean power as shown in the Fig. 1 [1-3]. In this study, the aim is to perform a test by developing the Gassmann equation for calculating the velocity of carbonate rocks. Therefore, this approach can assist in the understanding of elastic properties carried out on a laboratory scale.

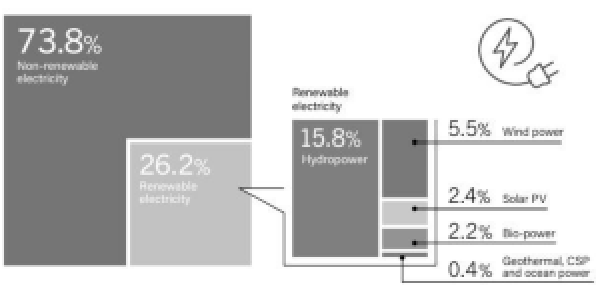

Fig. 1. Global estimated distribution of power generation - 2019 [1].

Since Earth is 71% water and 29% land, hence, ocean power should be utilized. Wave energy converters may be classified into three main types (Point absorber, Attenuator, and Terminator). Point absorbers gain the energy of waves through the up and down heaving motion of the waves [2-7]. Attenuators are placed parallel to the direction of waves and are specially designed to float. Besides, terminators use turbines to generate power i.e. the water falls into a reservoir as waves move, then, the water is returned to the sea after passing through the turbine. Wave energy converters can further be classified based on how they operate. In addition, they can be mainly classified into four types: Oscillating water column, oscillating surge converter, overtopping device and submerged pressure differential. Oscillating water column utilizes an air turbine to generate power. The air column compresses / decompresses due to wave motion. Overtopping device also use a turbine to generate electricity. In this case, the water is stored in a reservoir and then returned to sea after passing through the turbine. The submerged pressure differential is below the water surface and the crest-trough motion of the wave causes the fluid in cylinder to rise and fall and use this pressure differential to generate electricity.

In oscillating wave surge converter, an arm rotates in form of a pendulum through the motion of waves and generates energy. The most successful wave energy conversion device so far has been OWC. However, a self-rectifying turbine is required to generate energy from the interchanging flow of air. The author has studied four main types of self- rectifying turbines: Wells turbine, Impulse turbine, radial turbine and cross flow turbine [7-12].

The Wells turbine has several airfoils around the hub of the rotor. The airflow placed in a flow experiences lift and drag forces. In addition, for a symmetric air foil, the air foil will rotate in the same direction irrespective of the direction of flow of air. The author in his PhD research develops a relation for calculating the aerodynamic efficiency of the Wells Turbine [4, 13-19].

II. LITERATURE STUDIES

The power buoy essentially consists of the following elementary concerns:

- Type of buoy
- Working principle
- Power take off system
- Mooring system
- Corrosion control

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- Encapsulation mechanism

As described in the introduction section, power buoys can mainly be divided into three types namely Point absorber, attenuator or terminator. The type can be selected based on the preferred choice.

As described in the introduction section, operation principle of power buoys can mainly be divided into four types namely Oscillating Water Column, Overtopping device, oscillating surge converter and submerged pressure differential. The type can be selected based on the type of buoy selected.
Power take off system is one of the main concerns in the design of wave energy converters. It is a mechanism to transfer mechanical power generated through waves to electrical power. In Fig. 2, the blue lines show the fluid power, green lines show the mechanical power and red lights show the electrical power.

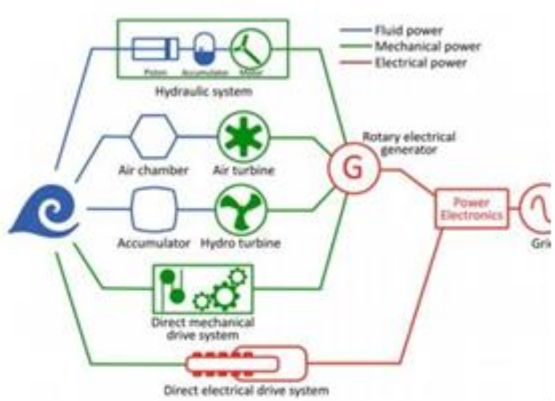

Fig. 2. Global estimated distribution of power generation - 2019 [1].

Air turbines are used mostly in Oscillating Water Column.

The reason being that an oscillating air pressure is generated and a self – rectifying turbine would easily do the job.
The kinds of turbines used in the analysis are as follows:

- Wells turbine (WTGV)
- Biplane Wells turbine (BTGV)
- Turbines of self-pitch control vanes (TSCB)
- Impulse turbine (ISGV)
- Impulse turbine of self-pitch control vanes (IFGV)

The arrangements used for the analysis of these turbines are the ones found to be delivering the best performance from the previous studies [10]. From the analysis, the value of maximum efficiency is 0.47 for ISGV but has a disadvantage of repairs of pivots. In addition, efficiency of TSCB is higher than WTGV. However, maintenance of ISGV is less difficult than TSCB.

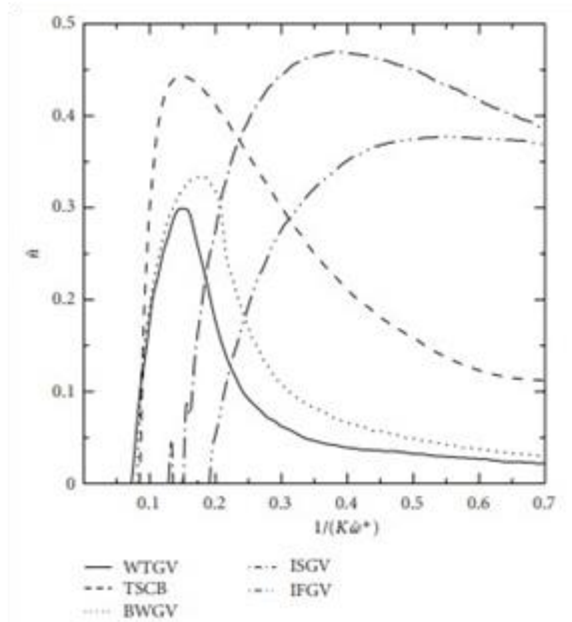

Fig. 3. Comparison of efficiency of different turbine types in irregular waves [3]

The hydraulic converters are suitable to use when the energy generation is due to the contact of the equipment with the waves. It can therefore be used with point absorber and attenuator. The fluid in the cylinder rises and falls due to wave motion and is passed to a hydraulic motor which in turn drives the electric generator. This produces power. However, this hydraulic converter may cause environmental risks as the fluid may contaminate the sea. In addition, hydraulic components are costly to maintain and repair.

Hydro turbines are utilized in overtopping devices where seawater is used as a working fluid to run the turbine. The sea water accumulates in a reservoir and flows back to the sea after passing through the turbine. CFD analysis and experiments are performed to determine the performance of turbine. Moreover, it is found that the hydro turbine is efficient in various wave conditions [11].
In direct mechanical drive systems, the mechanical system consists a combination of gears, pulleys and flywheel. In direct electrical drive systems, electromechanical principles are utilized. The heaving motion of the buoy is kept around permanent magnets, which induces voltage in the coil. The coil is connected to the buoy. However, rectification is needed before actual power output.
The mooring system comprises of the following main components [12]:

- Mooring line
- Anchor

The mooring line materials used commonly are chain, wire and synthetic rope.

Chains are abrasive in nature and can be used for offshore moorings. Grades, which are least corrosive, should be used. However, regular checks are required. The cost therefore, lies in the medium range.
The cost of rope is low. Spiral strand ropes can be used for long term mooring applications due to its elasticity. Synthetic rope:
Fiber ropes are made of polyester, or nylon. They are suited for deep water applications but fish bites can be a problem. Cost of it is considered high.
The anchors can be of several types including gravity, drag embedment, suction, vertical load and drilled.
The holding capacity is generated through their weight. The weight provides friction between floor of the sea and the anchor.
They are buried inside the sea bed and the anchoring capacity is basically related to its depth below sea bed. Suction:
The holding capacity of these type of anchors is generated by embedding the piece into the ground. Embedding can be done either through mechanical means or by creating a pressure difference.
They are basically drag embedment anchors but are free to rotate. Hence, it has both horizontal and vertical holding capacities unlike drag embedment anchors.
Horizontal and vertical holding capacity of this type of anchor is obtained by cementing a hole in a warped piece of wood or rock.
The requirements of long-term mooring are identified in the offshore standard DNVGL-OS-E301, ‘Position mooring’ [13]. In addition, it refers to the standard DNVGL-OS-C101, (July 2015), ‘Design of offshore steel structures, general - LRFD method’. In this standard, minimum requirements for different types of anchors are defined [14]. DNVGL-OS-C101 again refers to the list of standards for mooring line materials. In these standards, minimum requirements of mooring line materials for long-term mooring are defined [15, 16, 17].
Control of corrosion of offshore steel structures is described in the standard ‘DNVGL-OS-C101 ‘[13]. It describes that for on shore steel structures, coating / paints should be introduced. Besides, for submerged steel surfaces, cathodic protection should be used. Surfaces which are cathodically protected are designed to withstand a potential of -0.8V to -1.1V in the marine / sea environment.

Moreover, the inspection and monitoring of corrosion and the installation of system for corrosion control are identified in the standard DNVGL-OS-C401 [18]. Since the equipment involves electricity generation through mechanical power, hence, everything needs to be properly sealed in order to avoid malfunctioning of the equipment. Gaskets or O-Rings should be properly installed for each component. Parker O-Ring Handbook [19] may be utilized to select the type and size of the O- ring.

III. Results and Analysis

This paper summarizes the main issues concerned with the design of the power buoys. The development of power buoys ensures the utilization of the kinetic energy in the waves. Also, it will serve as a clean source of energy generation which is the need of the future. In addition, development of these technologies on a large scale could lower the rate of unemployment. An optimized design which addresses to all the factors discussed in this paper may be proposed and implemented.

However, testing and troubleshooting require hefty amount of funds. Therefore, the implementation of the optimized design may be initiated by the developed countries and the findings from the prototype may be recorded. Then the developing countries may adopt this practice. This will ensure maximum utilization of the energy resources.

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