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Wave Energy Collector: Theoretical Model For Harnessing The Potential Energy of The Ocean Waves

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Abstract

Offshore wave energy has the potential to be one of the most environmentally gentle forms of electricity generation with a least visual impact from the shore. Currently the potential of hydro-resources is about 2 TW on the land, the wind-resources of about 72 TW and the ocean-resources more than 2.46x103 TW [10]. Today India is facing a huge demand-supply gape in the field of power sector. To fulfill the demand of the growing population, industries and service sector, there is immediate requirement for large scale research and development of several kinds of the power generation unit suitable for the individual ocean circumstance.

The current paper is focusing on the potential of wave energy in the Indian offshore, it will discuss about the proposed model suitable for offshore energy generation, and the current developments in the field of offshore technologies.

Keywords: Wave Energy, Wave Energy Collector.

Introduction

In present era, energy availability and its distribution is of prime importance. Conventional resources of energy are depleting day by day, hence it is very much required to harness the most economical and powerful non-conventional energy resource e.g. WAVES ENERGY. For the next dive in the utilizations of the renewable/sustainable energies, we are under compulsions not only to cope up with the global warming but also to conserve natural ecosystem and to coexist with nature. To protect the environment for future generations it is vital that we move rapidly to a more sustainable lifestyle, reducing carbon emissions of greenhouse gases and consumption of limited conventional resources.

Wave essentially stores concentrated wind energy. The waves being created by the progressive transfer of energy from the wind as it blow over the surface of the water. It could play a major part in the world's efforts to combat climate change, potentially displacing 1-2 billion tonnes of CO_2 emission per annum from conventional fossil fuel based sources. Such installations would also provide many employment opportunities in construction, operations and maintenance. As an indigenous resource that will never run out, wave power would provide India with security of supply. The price of oil continues to be high in India. The present contribution of power generation from nuclear plants is small. Uncertainty in the protective measures against all environmental hazards indicates that development of renewable energy is important for India.

The Wave Energy Collector is hydraulically actuated mechanical device which collects energy from the waves and thereby generates electricity. As India is bordered by a long coastline, this machine has ability to unlock the immense clean energy resource with great potential. The power generated by the machine can be directly feed to the grid from offshore and can be used economically.

Ocean Energy Resources

Ocean energy comes in a variety of forms such as marine currents, tidal currents, geothermal vents, and waves. All are concentrated forms of solar or gravitational energy to some extent. Moreover, wave energy provides "15-20 times more available energy per square meter than either wind or solar" [12]. The most commercially viable resources studied so far are ocean currents and waves.

Ocean Currents

Ocean currents are of two types: marine current and tidal current. The rotation of the earth influences both of them and. Marine currents are generated due to the temperature difference of the water within the ocean. as water gets warmer at equator it moves towards pole where it get cooled, sink and flows back to equator. The motion of this water conveyor is cyclic

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and variation on the speed's up & down is seen over a period of about ten year [14]. Gravitational forces between the moon, the sun and the earth cause the rhythmic rising and lowering of ocean waters around the world that result in Tide Waves. The tide increase dramatically when it reaches continental shelves, bringing huge masses of water into narrow bays and river estuaries along a coastline.

Ocean Waves

Waves arise from the transmission of energy from the sun to wind and then to water. Solar energy creates wind which then blows over the ocean; this high speed wind generates waves in the ocean. This wave can travel thousands of kilometre with minute energy loss. Most importantly, waves are a regular source of power with an intensity that can be accurately predicted several days before their arrival and more predictable then solar or wind. Wave power systems convert the motion of the waves into usable mechanical energy which in lum can be used to generate electricity. These systems can be floating or fixed to the seabed offshore, or may be constructed at the edge on a suitable shoreline.

"The utilization factor for wave power typically 2 times higher than that of wind power [3]. It means if a wind power plant only delivers energy corresponding to full power during 25% of the time (i.e. 2,190 h out of the 8,760 hr. / yr.) a wave power plant is expected to deliver 50% (4,380 h/yr.).

Wave Energy Collector

There are essentially two forms of energy, generally associated with sea waves. One form of energy is associated with the motion of the waves and the other is associated with the hydrostatic head between the crest and trough of the wave. Considering only the sinusoidal wave motion of the sea waves, the power in such a wave is given by [12]

$$\mathbf{P = \rho g^2 T H^2 / 32\pi \ kW/m}$$

Or

$$\mathbf{P = 0.55 H_s^2 T_z \ kW/m}$$

The significant wave height of 2m and wave period of 7sec. gives 15.4 kW/m [1] [13]

The wave energy collector device is mainly for offshore region where sufficient wave height is available.

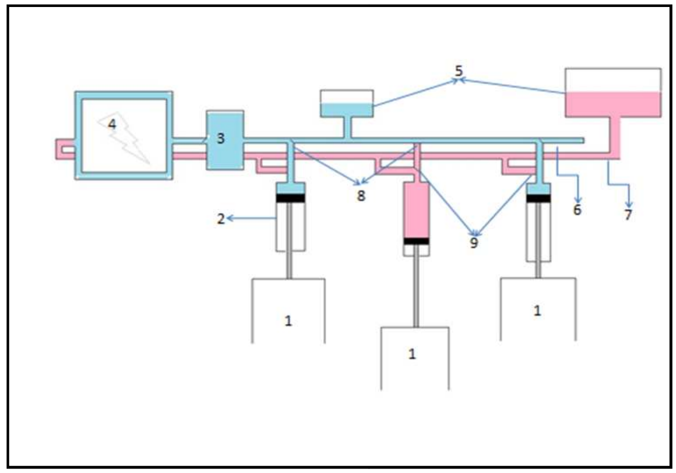
Fig: 2 Drawing for Proposed Model of Wave Energy Collector

Layout of the proposed model

The system, proposed here, will be a huge mass body that will be supported by a large number of piston cylinder and float systems. this will utilise the hydraulic head between trough and crust.

The proposed model consists of Components:

1. **Float:** it is a bottom open air column which oscillate with the wave motion according to "Archimedes Principle".
2. **Piston& Cylinder Assembly**: it is mounted on the float and piston will move up and down according to the motion of float.
3. **Header:** header will provide a continuous and elevated head to the turbine.



4. **Turbine & generator unit**: the discharge from the header will actuate the turbine which is coupled to a alternator for production of electricity.
5. **Air tight fluid tank:** in a reciprocating hydraulic pumps these tanks reduces the friction losses.
6. **High pr. Fluid line:** this receives discharge from the cylinder when piston moves upward.
7. **Low pr. Fluid line:** this will work as reservoir of the expanded fluid coming out from the turbine and feed the cylinder when piston moves downward.
8. **Discharge valves**: these valves are one way opening valves which will open only when the pressure in the cylinder reaches to the opening pressure for which valve is designed.
9. **Suction valves**: these are also one way opening valves which will get opened as piston start moving downwards.

Working of Model

The working of the proposed model is based on the principle of buoyancy. If a body having weight less than the buoyant force applied by the fluid, it will copy the pattern of flow of fluid. The bottom open float will oscillate up and down as the wave form though and crust. The suction created at the junction of the surface of water and float bottom will pull it downward. The piston joined to the float will move to and fro in the cylinder thus creating a pressure difference inside it. During downward motion the suction valve will open and the cylinder will be filled by the working fluid. During upward motion the pressure will increases till design pressure is reached and the discharge valve will open in the high pressure fluid line. This high pressure fluid will accumulate in the header which will ensure the continuous and increased pressure of discharge. The pressurized fluid will expend in the turbine where the pressure energy will rotate the turbine and this rotation will be used by the generator which is coupled with the turbine. The turbine thus used must be a low head high discharge turbine.

The following calculations are made to obtain the theoretical values of the main parameters i.e. head and discharge of the single unit of such kind. Some data are taken from the recognized agencies and few are assumed as design data.

The average significant wave height and wave period is taken 4m and 7sec [13]. As two float can accommodate per wavelength of the wave. Thus Power associated with float per unit wavelength

$$P_f = \eta * P$$

$$P = .55 * 4^2 * 7 \text{ kW/m}$$

$$= 61.6 \text{ KW/m}$$

Assuming that the efficiency of the power transfer from wave to float is 50%.

$$P_f = .5 * 61.6 \text{ kW/m}$$

$$= 30.8 \text{ kW/m}$$

It means that theoretically this much power per meter will be transferred to the piston of the pump through float.

Let us assume the length of the float is 2m thus total power available at one unit is 61.6 kW.

Piston Cylinder Assembly

The power required to run a reciprocating pump is given by:

$$P_p = \frac{\rho * g * A * L * h_m}{1000} \text{ kW}$$

L = significant wave height = 4m

Equating the power required to the power available at the piston of the pump and putting the values of all constants we get a relation between the monomeric head (**h_m**) developed in the pump and the diameter **(D)** of the pump as:

$$D^2 * h_m = 2.0008$$

Taking the diameter of cylinder

D =0.5 m

h_m = 8.0032 m of water

Theoretically this much head will be developed by the single unit, with discharge 0.981m^3/cycle

Or

q= 0.1401 m^3/sec.

This much discharge will be available at single unit of reciprocating pump used in the model with pressure head of 8.0032 m if the cylinder of .5m diameter used in the system.

Benefits

No fuel is required neither any waste is produced. The system is less expensive to operate and maintain as compared to any thermal or nuclear power plant. It can be installed far from the coastline area (up to 5-10 km). The space required for the plant is much less than any other thermal power plant. The floor area generated can be used for hybrid power generation unit such as wind turbine or solar cell installation.

Conclusion

From above analysis we found that 28.35 m^2/kW area will be required. Using 1 km^2 area of the ocean theoretically we can generate more than 35.28 MW which is much greater than the land used to power generated ratio of any other plant. Since India has 7500 km coastline, only 10% utilization of wave potential will leads to generate sufficient amount of energy to fulfill the energy requirement of Indian economy. Installing these types of devices in the Indian offshore will ensure the protection of the coastline, which will help to prevent anti-social activities.

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Parameters used for calculation	
P_f, P_p	Power available at float and pump
P	power per meter wave front (kW/m)
h_m	Head developed by single unit (m)
ρ	Sea water density (1000 kg/m^3)
A	C.S. area of cylinder (m^2)
H_s	significant wave height (m)
T_z	wave period (s)
L	Length of stroke