ABSTRACT

Ocean energy is one of the most promising energy resources. Three- fourths of the earth's surface is covered by the oceans. The renewable energy source of ocean mainly is contained in waves, ocean current and offshore solar energy. Very fewer efforts have been made to harness this reliable and predictable resource. A novel concept of on-shore wave energy extraction method is presented. The concept is based upon total energy conservation, where energy of wave is transferred to the flexible converter to increase its kinetic energy. Squeezing action by the external pressure on the converter body results in increase velocities at discharge section. High velocity head then can be used for energy storage or for direct utility of power generation. This converter utilizes the both potential and kinetic energy of the waves and designed for on-shore or near-shore application. Increased wave height at the shore due to shoaling effects increases the potential energy of the waves. This approach will result in economic wave energy converter due to near shore installation. This method is more efficient because it traps both potential and kinetic energy of the waves.

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1. INTRODUCTION

Today most of the world's electric power production comes from fossil-fuelled plants. As the demand for electricity is forecasted to increase, there is an urgent need to find new methods to extract electric energy from renewable sources. The annual wave energy potential along the southern Indian coast is between 5 to 15 MW per meter. But the variation of sea-bed topography can lead to the focusing of wave energy in concentrated regions near the shoreline called 'hot spots'. The best spots for wave energy are at Vizhinjam, off Tuticorin and off Andaman islands. As this is a renewable source of energy the future prospects of this energy are high.

The renewable energy source of ocean mainly is contained in waves, ocean current and offshore solar energy. Three- fourths of the earth's surface is covered by the oceans. Very fewer efforts have been made to harness this reliable and predictable resource. A novel concept of on-shore wave energy extraction method is presented. The concept is based upon total energy conservation, where energy of wave is transferred to the flexible converter to increase its kinetic energy. Squeezing action by the external pressure on the converter body results in increase velocities at discharge section. High velocity head then can be used for energy storage or for direct utility of power generation. This converter utilizes the both potential and kinetic energy of the waves and designed for on-shore or near-shore application. Increased wave height at the shore due to shoaling effects increases the potential energy of the waves. This approach will result in economic wave energy converter due to near shore installation. This method is more efficient because it traps both potential and kinetic energy of the waves.

2. WAVE ENERGY

Waves are generated by the wind as it blows across the sea surface. Energy is transferred from the wind to the waves. Waves travel vast distances across oceans at great speed. The longer and stronger the wind blows over the sea surface, the higher, longer, faster and more powerful the sea is. The energy within a wave is proportional to the square of the wave height, so a two-meter high wave has four times the power of a one-meter high wave.

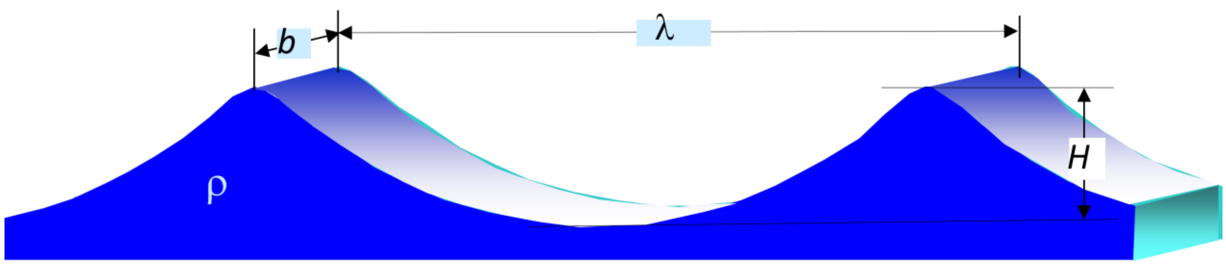

Fig.2.1 Wave Characteristics

The power associated with a wave of wavelength λ, height H and a front b is therefore given by:

$$P = 0.5\ \gamma g H^2\ \lambda b\ \text{ Watts}$$

Where γ is the water specific weight and g is acceleration due to gravity.

A more compact formulation to calculate the wave power in KW/m by using significant wave height (Hs) and Peak time period Tp is given by following

$$P = .42\ T_P\ H_S{}^2\ \text{ kW/m}$$

The significant wave height (H_s) is the mean wave height of the highest third of the waves ($H_{1/3}$).

3. WAVE ENERGY CONVERTER (WEC)

Wave energy is the energy from ocean waves, and this energy can be captured to do useful work – for example, electricity generation, water desalination, or the pumping of water. Machinery able to exploit wave power is generally known as a wave energy converter (WEC).

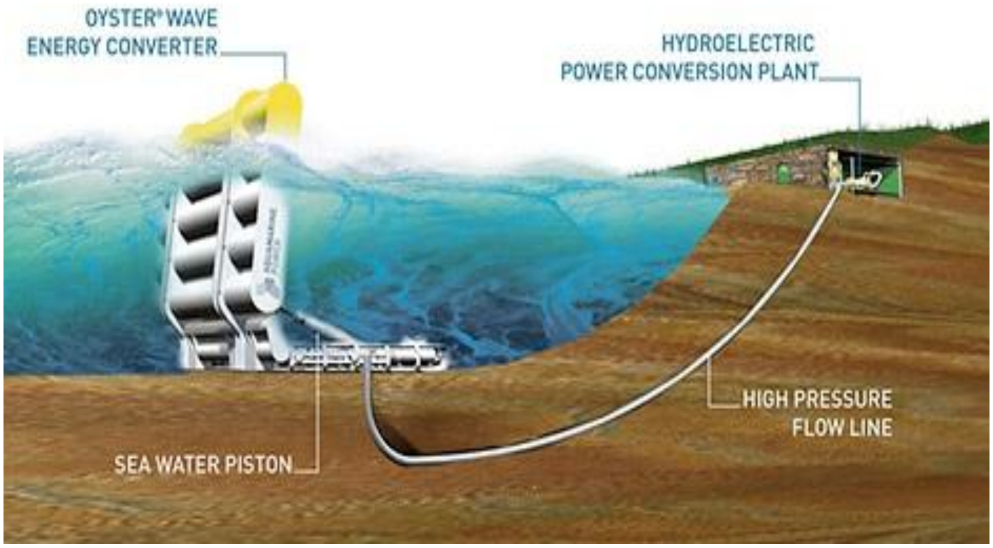

Fig.3.1 Oyster Wave Energy Converter

The potential for development of wave, ocean current and tidal energy is the subject of growing international investigation. Ocean contains abundance of untapped energy whose small fraction can meet the requirement of whole world. Ocean energy mainly covers energy from waves, tide and thermal. Although since the 1970's, the wave energy is under consideration as a potential source of renewable energy, but this field is still in its infancy. The energy contained within waves is huge. A rough estimate tells us that in some places values of more than 50MW/km of wave front are expected. Many attempts to design wave energy converter (WEC) devices have been made in the past, and many have failed due to the hostile environment the devices have to endure. Despite long research the technology has not yet settled down to one or two basic forms as has happened with most major inventions. This technology faces multidimensional challenges and involves a broad range of engineering disciplines, including civil, electrical, Mechanical, Marine, Naval Architecture and control engineering. Main challenge and a critical issue is regarding structure design, which must be extremely robust, keeping in view the safety and cost constraints.

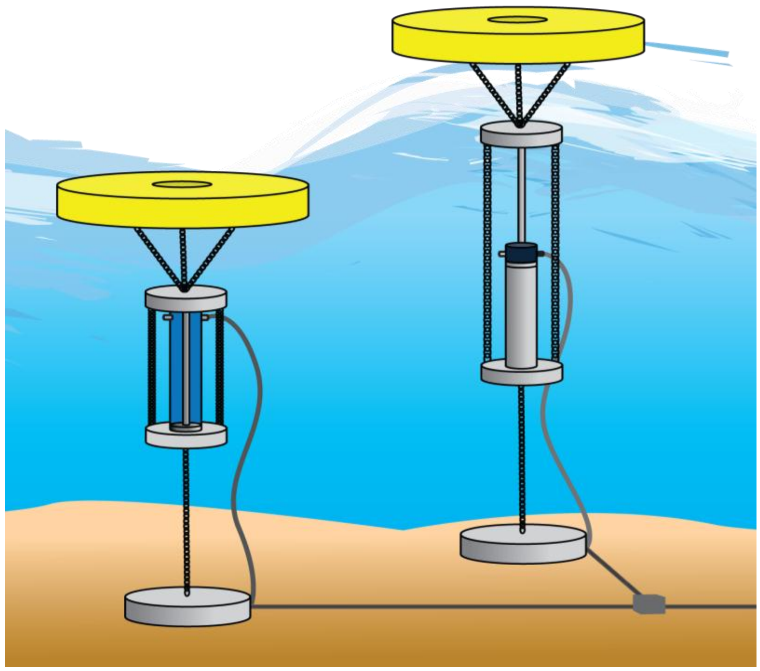

Fig. 3.2 Wave Buoys Wave Energy Converter

4. TYPES OF WAVE ENERGY CONVERTERS ACCORDING TO LOCATION

Wave Energy Converters are mainly classified according to the distance of the WEC from the shore.

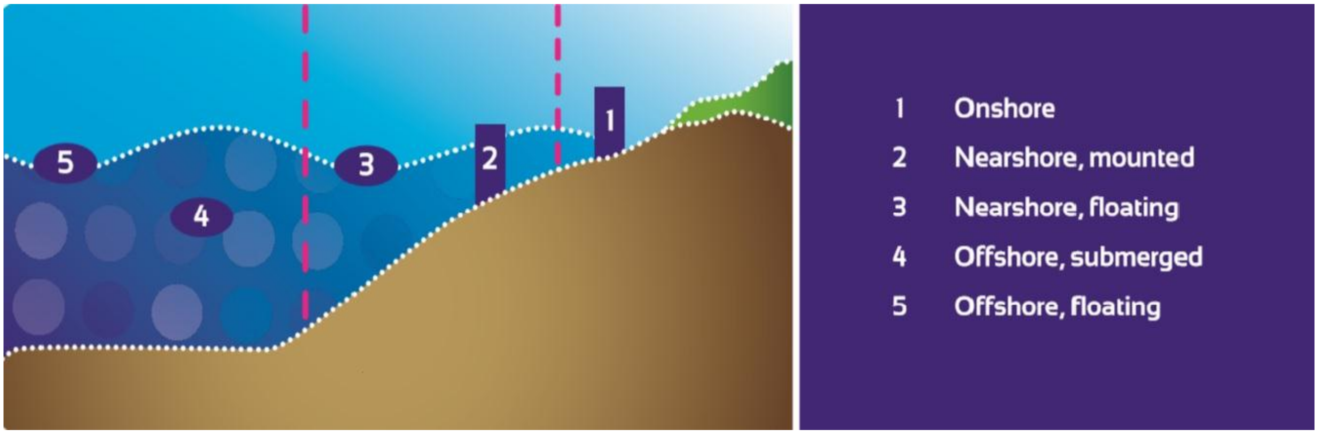

Fig. 4.1 Types of wave energy converters according to location

4.1 Onshore:

Devices lie on the bottom or on very shallow waters, commonly integrated into coastal structures, such as breakwaters or rocky cliffs. Their advantages are: easy installation, absence of moorings, reduced cost of maintenance, lower transmission losses and short distance to the shore and the grid. On the other hand, they present location constraints, less energy, and high visual impact.

4.2 Nearshore:

These devices are located at depths up to 20 m and relatively close to the shore. This depth range is suitable for big devices mounted on the bottom by gravity or floating. Those that are bottom mounted can also use the whole movement of the wave, which is impossible for floating devices.

4.3 Offshore:

These devices are usually floating structures, but can also be submerged at depths of more than 40 m. They are the most promising type of device of them all, because at those depths, losses due to friction are small, so they are installed where the highest energy flow takes place. Reliability and survival are the biggest challenges this kind of devices are facing.

5. REVIEW OF OCEAN ENERGY DEVICES AND CONCEPTS

Several reviews have been written on wave energy converters. Here we will summarize few developments

5.1 Iwave WEC:

This is a simple and easy to maintain device, where all critical parts are above the sea level. It comprises of a floating device tethered with chains to piles driven to ocean bottom. The wave action raises the heavy partially buoyant piston that drives the overhead crankshaft by half turn. The receding wave drops the piston completing the balance half turn. One revolution is obtained for every wave. Using gear box and generator the current is produced continuously.

In this device all electrical and critical parts are above water and hence are easily accessible. Being a near shore device it can be accessed easily and economical maintenance is possible. The evacuation of the current is easy and no expensive cabling is required. In this device, the wave energy is directly converted to mechanical energy that produces the electricity. Hence the energy losses are minimum. Other devices that convert wave energy have substantial energy losses.

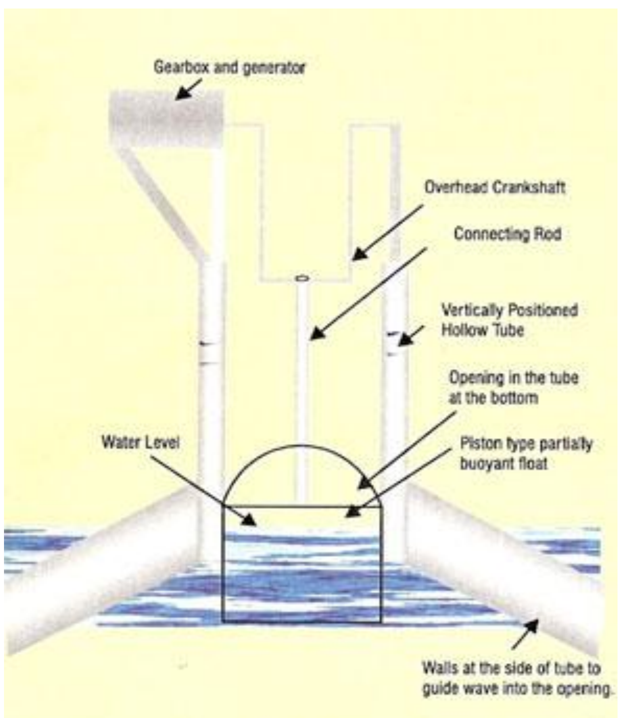

Fig. 5.1.1 Iwave WEC

5.2 ANACONDA WEC:

This device consists of a giant rubber tube. The snake like tube is closed at both ends. The fluid in the tube is squeezed due to wave movement. This squeezing motion causes a bulge wave to be formed inside the tube. The Anaconda is designed so that its bulge wave speed is close to the speed of the water waves above. In these conditions the bulges grow as they travel along the tube, gathering wave energy. The bulge wave then turns a turbine fitted at the far end of the device and the power produced is fed to shore via a cable.

Fig. 5.2.1 Anaconda WEC

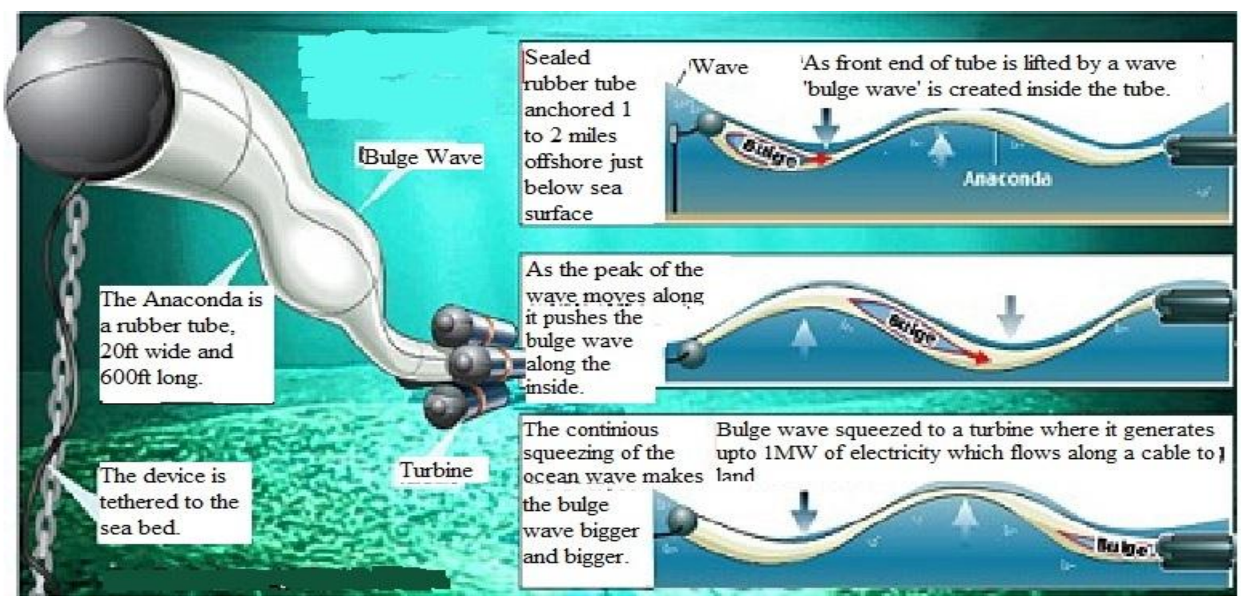

Fig. 5.2.2 Working of Anaconda WEC

5.3 Pelamis WEC:

It is a semi-submerged, articulated structure and comprised of sections linked by hinged joints. The passing waves produce a motion in the joints which is resisted by hydraulic rams. This resisted motion by rams pump high- pressure oil through hydraulic motors. The motors are connected to generators to produce electricity. Several devices can be connected together and linked to shore through a single seabed cable. This device is one of the best and successful wave energy converters. World's first commercial wave farm 'Aguçadoura Wave Park', which is located in Portugal uses Pelamis wave energy converters to produce electricity.

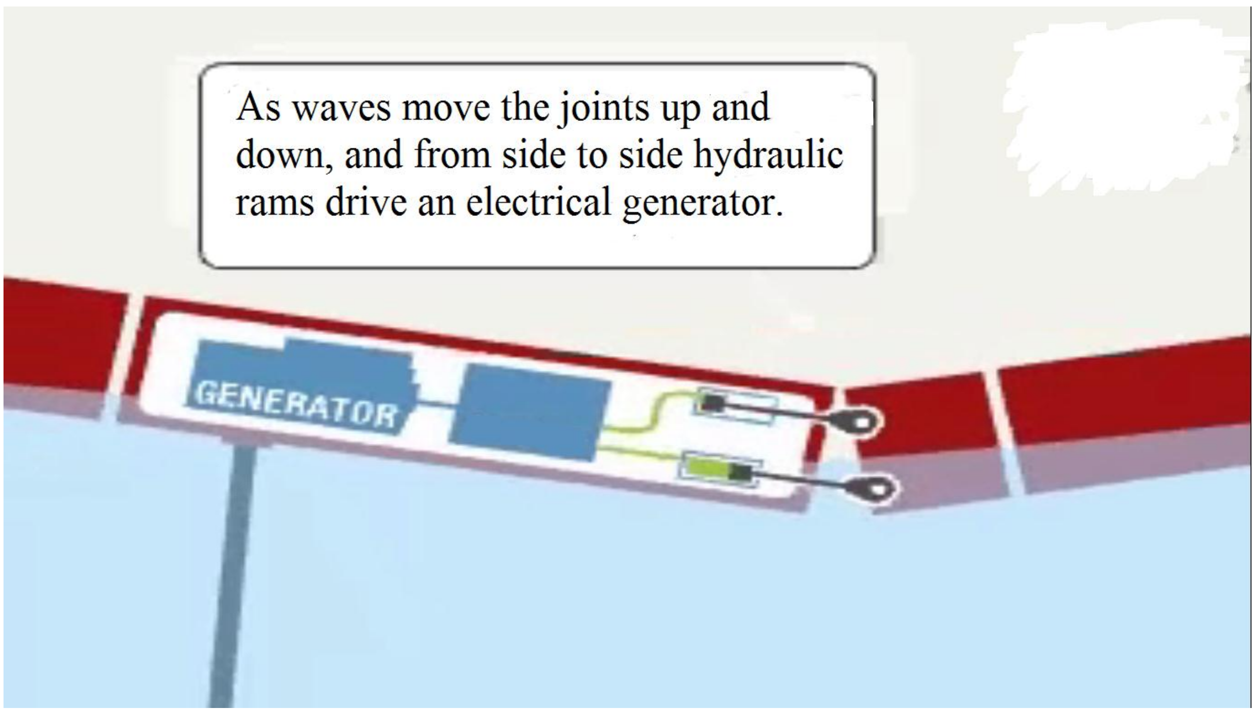

Fig. 5.3.1 Working of Pelamis WEC

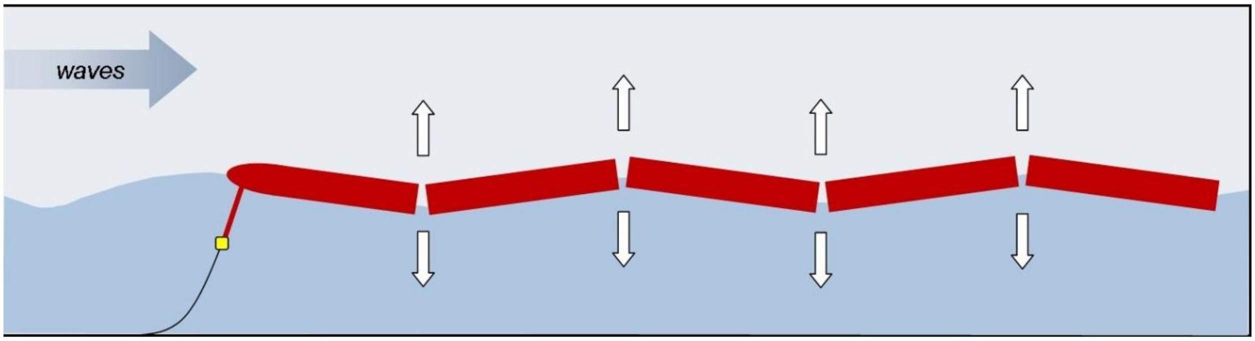

Fig. 5.3.2 Movement of Pelamis WEC

Fig. 5.3.3 Pelamis WEC

5.4 NASA Hydrokinetic Energy Transfer System:

In the proposed hydrokinetic energy transfer system, the flow of water current causes turbine blades to rotate. The rotor's rotational speed is increased through a gearbox, which drives a high-pressure fluid pump. The high-pressure fluid would be transported though flexible tubes to a larger pipe and then to an efficient, onshore hydroelectric power plant. This design can provide a stable electric output.

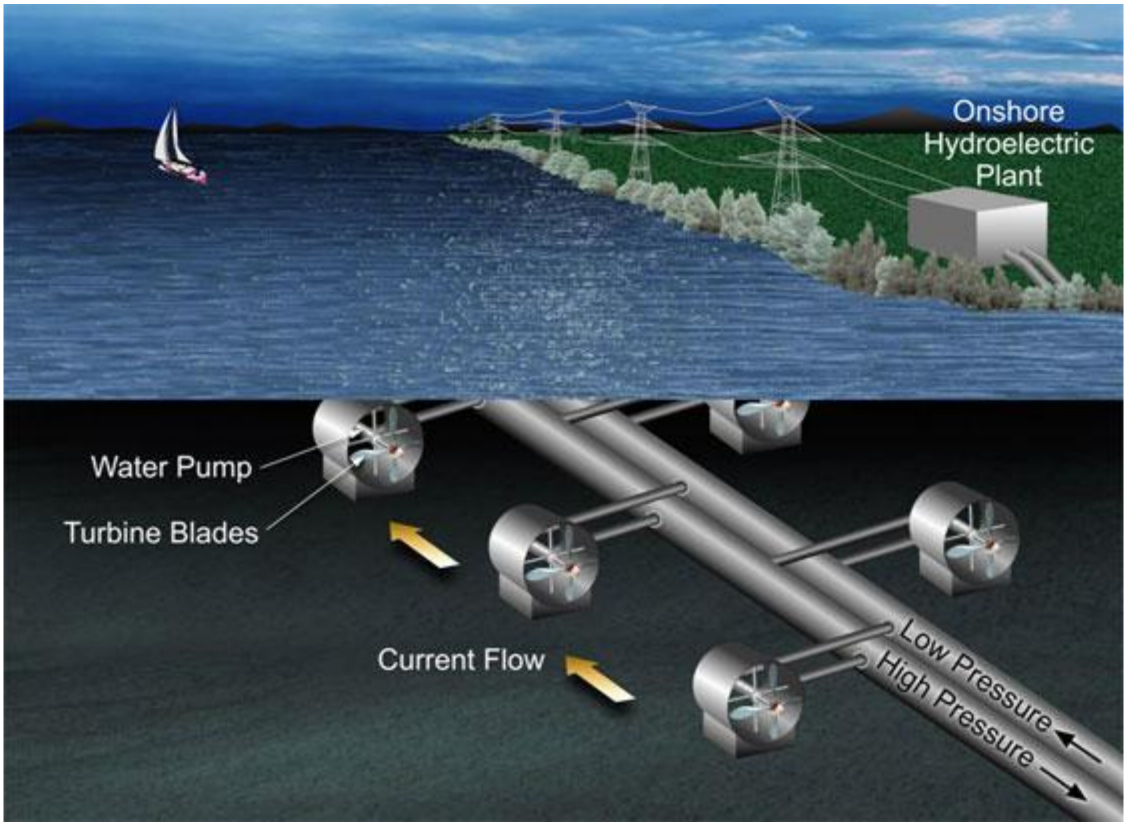

Fig. 5.4.1 Diagram of NASA Hydrokinetic Energy Transfer System

6. WAVE ENERGY CONVERTER INDIA:

The annual wave energy potential along the southern Indian coast is between 5 to 15 MW per meter. But the variation of sea-bed topography can lead to the focusing of wave energy in concentrated regions near the shoreline called 'hot spots". The "hot spots" on south West Indian coasts are identified by computation. The best spots for wave energy are at Vizhinjam, off Tuticorin and off Andaman islands. A mean monthly wave power of 4 - 25 kW/m was estimated and a Wave Energy Converter device of 150 MW capacity was installed at Valiathura. This power plant delivered 75 kW during April - November and 25 kW from December – March. During June - September, it has peaks of 150 kW. The monsoon month's average power production was 120 kW. The cost of construction of this power plant was 99 lakhs Indian rupees and it produced 4.45 lakhs units of electricity per year. The unit cost stands 0.73 rupees, while the power from hydroelectric generators cost around 1.5 rupee per unit.

India has a coast line of 6000km which estimates a potential of 60,000MW power. In India the Department of Ocean Development (DoD) Government of India has sponsored wave energy research at the Ocean Engineering Centre of the Indian Institute of Technology, Madras.

Fig. 6.1 The Wave Energy Converter Prototype Developed at the IIT

7. WAVE ENERGY CONVERTER UTILIZING THE WAVE SHOALING PHENOMENON

7.1 What Is Wave Shoaling Phenomenon?

Wave shoaling is the effect by which surface waves entering shallower water increase in wave height. The wave velocity and kinetic energy decreases. Under stationary conditions, the wave length is reduced while frequency remains constant. The energy flux must remain constant and the reduction in kinetic energy is compensated by an increase in wave height (and thus potential Energy).

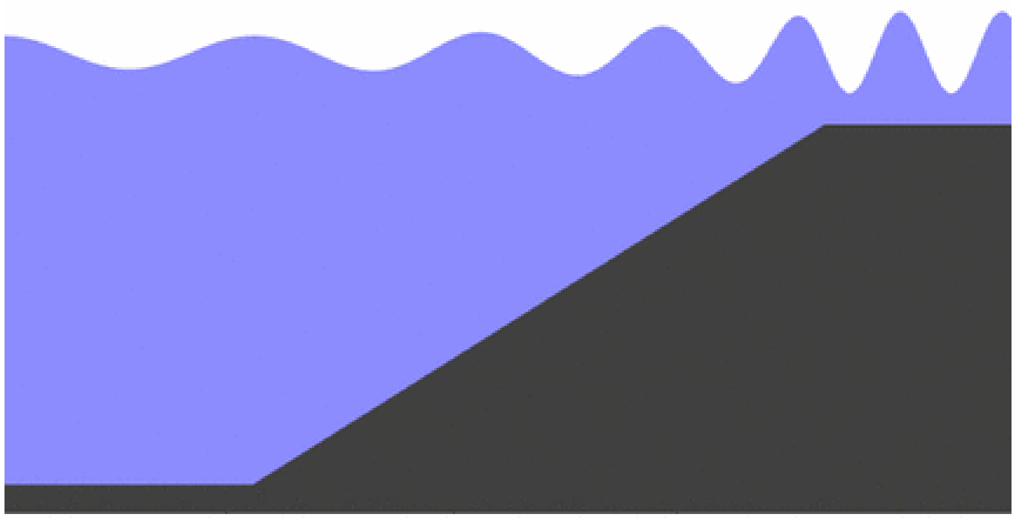

Fig. 7.1.1 Wave Shoaling Effect

7.2 A New Concept:

Most of the previously proposed method involves heavy metal structure, which make it difficult to sustain the extreme sea conditions. Furthermore, installation of such converter also faces serious cost to power ratio barrier. Sea waves produced in the sea surface also do not follow a particular wave form. Ocean waves carry both the kinetic and potential energy. Wave height in fact is a measure of the potential energy and velocity of the wave gives a measure of its kinetic energy. Most of the converter mainly utilizes the potential energy as vertical movement of the converter harness the energy. Energy carried in the form of wave velocity is not much extracted.

In this type of Wave Energy Converter energy either in the form of pressure or mechanical head is used to produce useful power output. The design description is similar to a floating bed, which consist of a large rubber float. Float internally consists of a number of large diameter tubes placed parallel to each other. Ends of all these tubes are connected to a combine manifold (Pressure manifold). Float is placed in sea such that in coming manifold face the incoming waves.

This converter is a flexible float which consists of water fluid passages separated from each other and resembles to an array of flexible hoses placed parallel to each other. This converter is designed for near shore application and energy from the waves approaching the shore will be driving this converter. The Shoaling waves hitting the converter will pass through the converter, which will produce a zig zag motion in the float. This zig-zag motion will run through the whole converter and will perform a squeezing action in the passages. Since converter is floating, the external pressure applied by the waves on both sides of the converter, which will transfer the potential and kinetic energy of waves to the converter. This transfer of energy will produce a squeezing action which will result in increased velocities of the fluid in the passages.

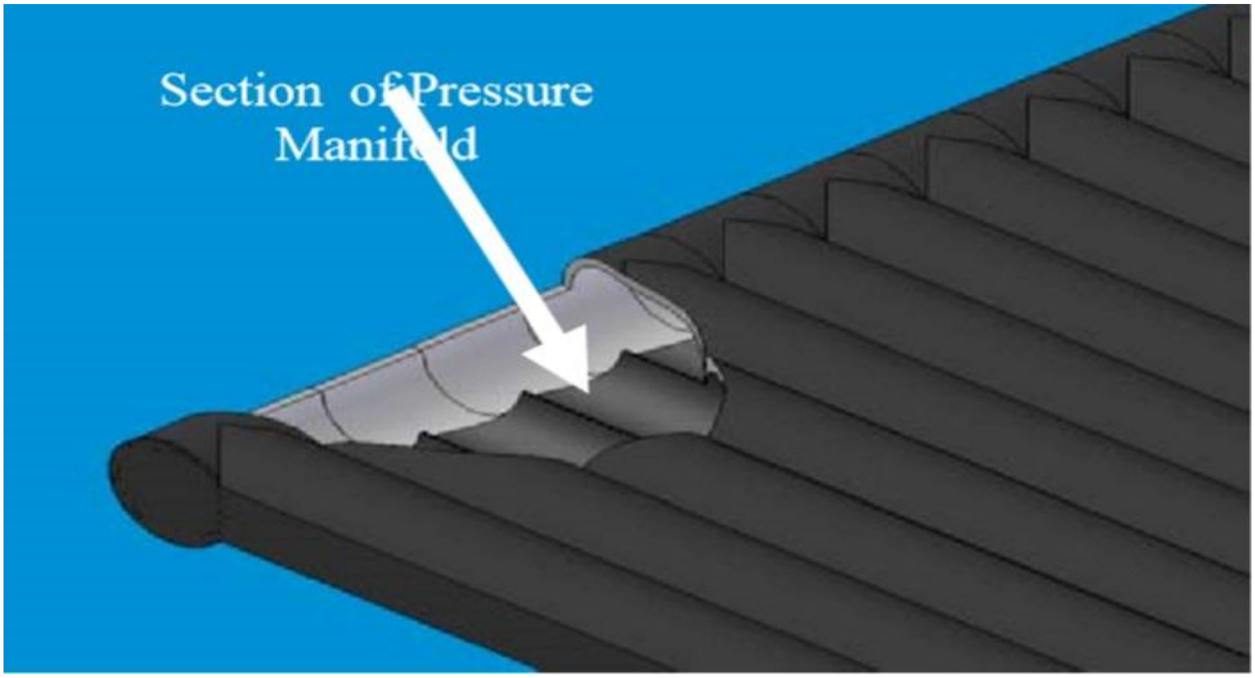

Fig. 7.2.1 A Section View of Pressure Manifold

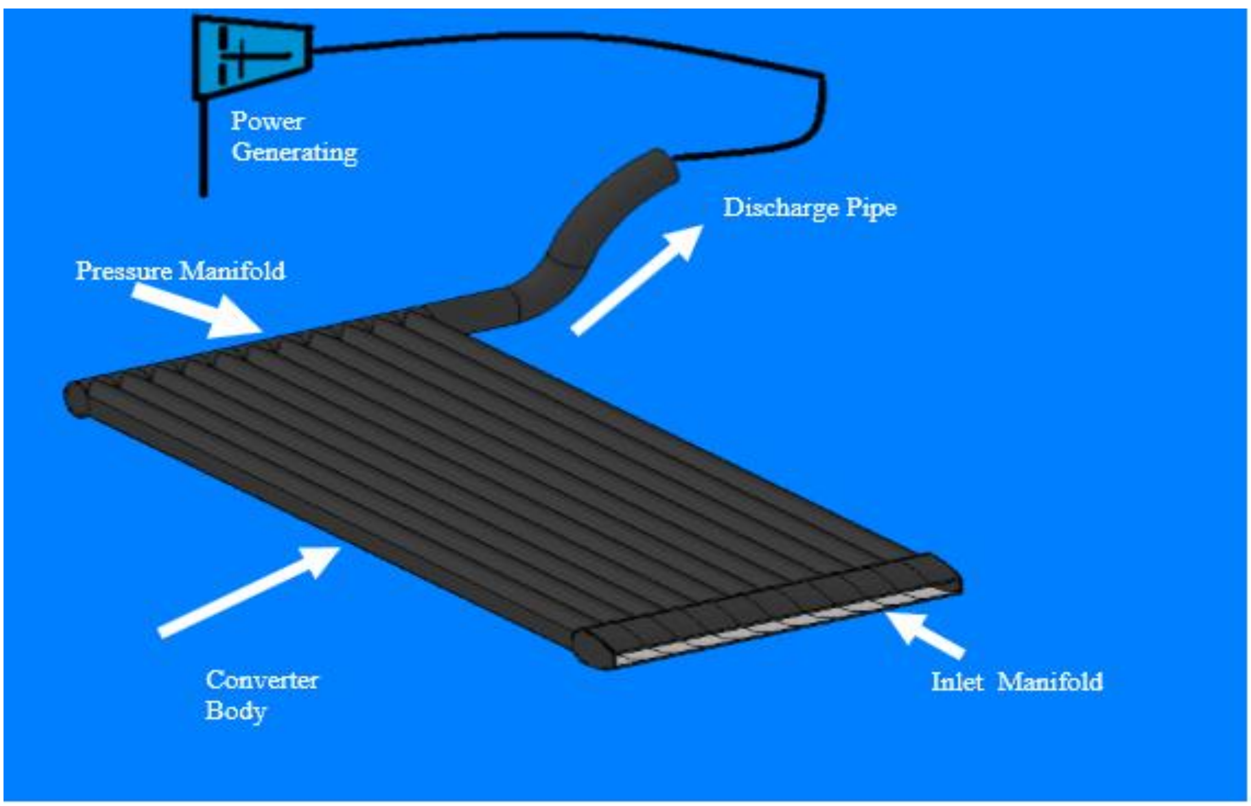

Fig. 7.2.2 The New Wave Energy Converter Design

Length L of the float is designed such that it is at least more than three times the average wave length λ of the waves. This ratio (L / λ) of more than 3 will ensure a regular squeezing action to maintain continuity in energy transfer. Converter is designed to have its neutral buoyancy such that it is fully or ¾ submerged. Converter will be moored from atleast 6-8 points with sufficient flexibility to assist in producing a bulge wave in the passages. Pressure manifold is at farthest end where all passages will discharge giving a high pressure and flow rate (combine effect of all passages). This high pressure fluid will be transported to power generating unit through flexible hose. The proposed converter can be used as an open or close cycle. In a close cycle feed water or any other fluid can be used. Closed loop will have increased running cost but substantial low maintenance cost for machinery, whereas open loop will utilize the sea water as a working fluid. Open loop is more recommended because it will utilize the high speed wave water. External squeezing effect by wave will convert the potential and kinetic energy of the wave. A schematic view of the converter is given. Analytical efficiency estimation has shown that significant height Hs and length of the converter L are important parameters.

This graph shows the efficiency response to length ratio N. Where N is the ratio of converter physical length (L) and Wavelength of incident sea waves as shown in equation below:

$$N=L/\lambda$$

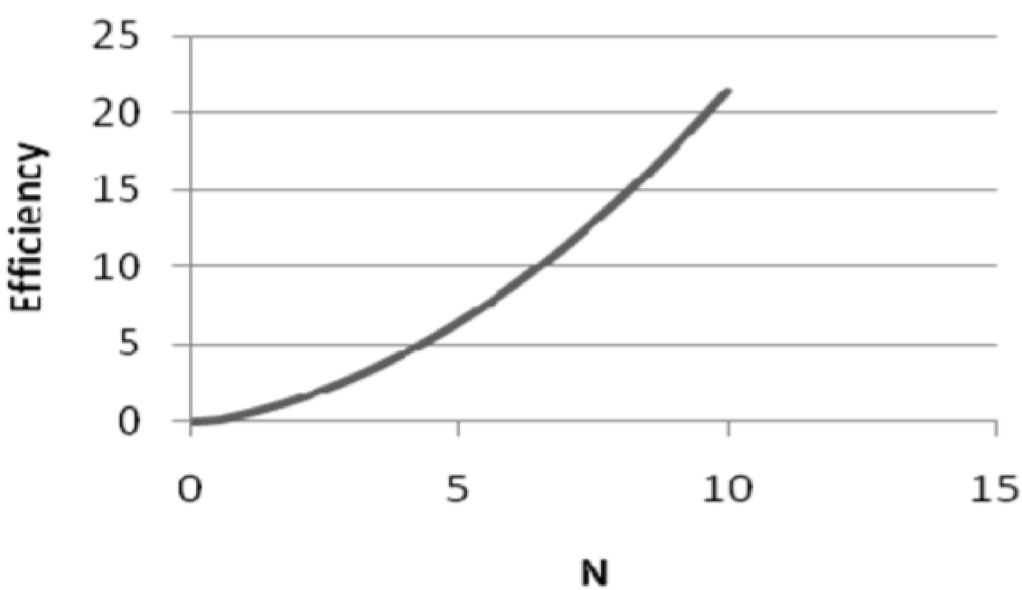

Fig. 7.2.3 Relationship between length ratios N to efficiency

Graph showing the relationship between efficiency and significant height of waves (Hs)

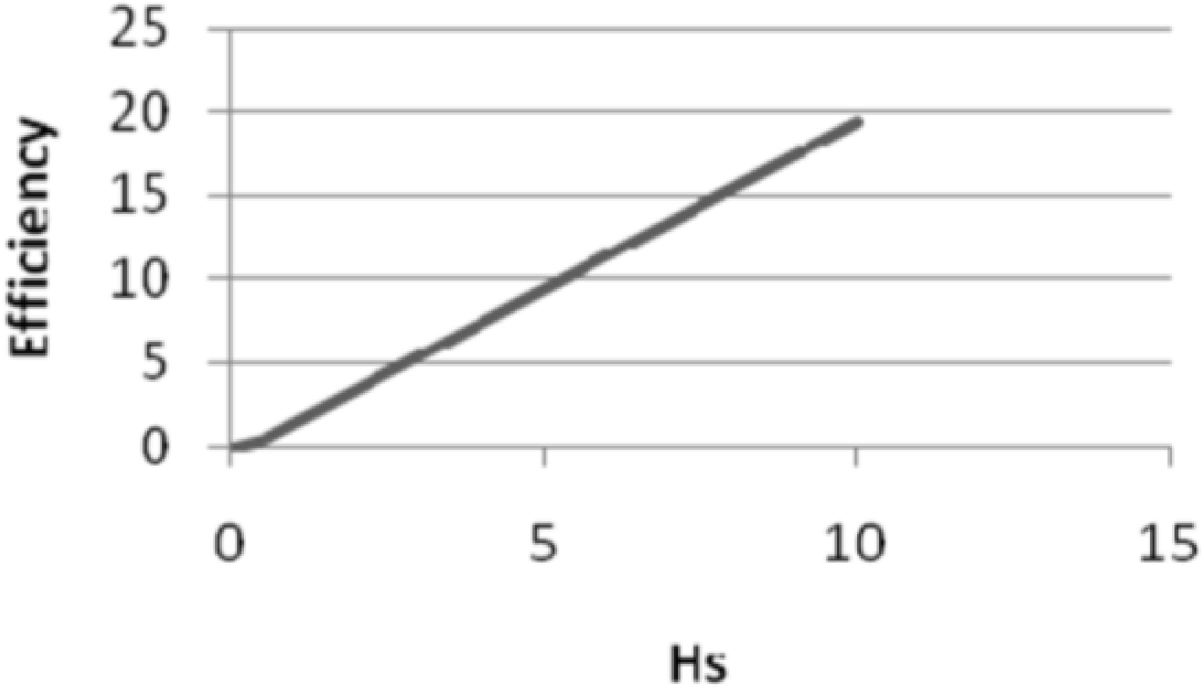

Fig. 7.2.4 Relation between Significant wave heights (Hs) to Efficiency

7.3 Advantages

Does not involve heavy metal Structure in sea

Highly Economical

Simple Design

Utilizes both kinetic and potential energy of waves

Renewable source of energy

Low environmental impact

8. CONCLUSION

In this seminar a review on wave energy and a few wave energy converters is presented. A new method of extracting wave energy utilizing wave shoaling effect is also presented. Wave energy is becoming a viable source of green energy. More focus on its research will bring its cost further down to be compared with wind and solar energy.

- Wave Energy represents one of the largest renewable resources available on the planet. Wave Energy is an emerging industry that has a potential to satisfy worldwide demand for electricity.
- Renewable energy technologies provide alternatives to fossil-fueled power plants for the generation of electricity, an essential step towards reducing our nation's dependence on fossil fuels.
- New technologies need to be developed for the sustenance of the future.

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