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Recent developments of Ocean Energy in India – An Overview

Hitesh J. Yadav
Mechanical Engineering Department
R. C. Technical Institute, Sola
Ahmedabad, India
e-mail: hjyadav06@gmail.com

Abstract — This paper presents an overview of ocean energy technology as a source of renewable energy. It investigates ocean energy resources and new technologies under development to capture that energy. Ocean energy (also referred as Marine Energy) refers to the energy carried by ocean waves, Tides, temperature difference & salinity. Ocean energy has the potential to play a significant role in the future energy system, whilst contributing to the reduction of carbon emissions and stimulating economic growth in coastal and remote areas where there is a scarce of electricity and cost of transmission of electricity is very high. Ocean energy has attracted increasing interest, particularly in India because India has long sea shore.

A number of policy initiatives and mechanisms have been put in place to ensure that ocean energy technologies could become cost-competitive in the short term, in order to exploit the benefits that these technologies to India.

Keywords*-Ocean energy, Marine energy, Wave energy*

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I. INTRODUCTION

The main forms of ocean energy are wave energy, thermal energy, tidal energy and ocean currents. India being a tropical country a constant difference in temperature is available between surface water and the deep ocean. This gradient can be used to generate power and fresh water simultaneously. Now a floating offshore plant of larger capacity has to be attempted to serve coastal mainland water requirements.[2]

Marine energy or ocean energy (also referred to as marine power , ocean power, or marine and hydrokinetic energy) refers to the energy carried by ocean waves, tides, salinity, and ocean temperature differences. The movement of water in the Indian oceans creates a vast store of kinetic energy, or energy in motion. This energy can be harnessed to generate electricity to power homes, transport and industries. This production of energy is from ocean, so coastal area can receive electricity at lower cost and minimum transportation cost.

The term marine energy encompasses both wave power – power from surface waves, and tidal power – obtained from the kinetic energy of large bodies of moving water. Offshore wind power is not a form of marine energy, as wind power is derived from the wind, even if the wind turbines are placed over water. The oceans have a tremendous amount of energy.[3] Ocean energy has the potential of providing a substantial amount of new renewable energy around the world. Increasing demand of renewable energy and scarce of conventional source of energy motivates all world towards renewable source of energy like Ocean energy, Wind turbines, Geothermal energy, Solar plants and so on. The acute shortage of power and water scarcity faced by the country, demands extensive studies in these areas.

India has around 150 GW or greater than 150 GW, if all the sources like tidal, wave, geothermal, solar included. Even with such a vast potential, only around 22% of renewable energy potential is developed in the country.[4] Total installed capacity in India is around 256 GW (as on October 2014) from all thermal source of energy like Oil, Coal and Natural Gas.[4] India's commitment to reduce carbon emissions and fuel related concerns in conventional sectors has increased in recent years. The Indian Government has shifted focus towards development of renewable energy sources. This step will help India in achieving energy security, reducing adverse environmental impact, lowering carbon foot print.

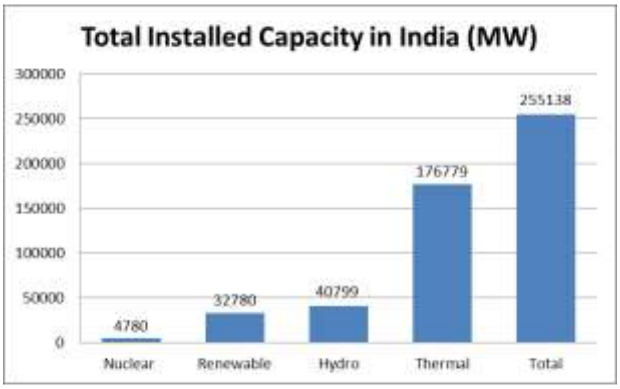

Fig. 1 Total installed capacity in India (MW) from all sources (as on October 2014) [4]

II. FORMS OF OCEAN ENERGY

Ocean can produce two types of energy: thermal energy from the sun's heat, and mechanical energy from the tides and waves. Below are the few main sources of renewable Ocean energy [12]. The forms of ocean renewable sources can be broadly categorized into,

Ocean Tidal Energy: Potential energy associated with tides can be harnessed by building barrage or other forms of turbine-equipped construction across an estuary.

Ocean Wave Energy: Energy associated with ocean waves can be harnessed using modular types of technologies.

Marine Current: Kinetic energy associated with tidal/marine currents can be harnessed using modular systems.

Temperature Gradient or OTEC: Thermal energy due to temperature gradient between sea surface and deep-water can be harnessed using different ocean thermal energy conversion (OTEC) processes.

Salinity Gradient: At the mouths of rivers where fresh water mixes with saltwater, energy associated with the salinity gradient can be harnessed using a pressure-retarded reverse osmosis process and associated conversion technologies.

2.1. Tidal Energy

Tidal energy, sometimes called tidal power, is the power achieved by capturing the energy contained in moving water in tides and open ocean currents. Tidal energy is divided into two techniques. Tidal barrage technique & tidal current technique.[12]

Tidal barrage technique:-

Tidal barrages consist of a large, dam-like structure built across the mouth of a bay or estuary in an area with a large tidal range. As the level of the water changes with the tides, a difference in height develops across the barrage. Water is allowed to flow through the barrage via turbines, which can provide power during the ebb tide (receding), flood tide (allowing water to fill the reservoir via sluice gates during flood tide), or during both tides. This generation cycle means that, depending on the site, power can be delivered twice or four times per day on a highly predictable basis. Tidal barrages represent the oldest and most mature of all the ocean power technologies. There are several commercial plants up to 240 MW in size in operation in the world. Some new construction and feasibility studies for this type of plant are underway in different parts of the world. The substantial capital costs associated with construction and concerns over adverse environmental impacts make the technology somewhat unappealing in contrast to tidal current technologies. [12]

Tidal Current technique:-

Tidal current energy represents a different approach to extracting energy from tides (or other marine currents). Rather than using a dam structure, the devices are placed directly "in-stream" and generate energy from the flow of water [16]. There are a number of different technologies for extracting energy from marine currents, including horizontal and vertical-axis turbines, as well as others such as venturis and oscillating foils. Additionally, there is a variety of methods for fixing tidal current devices in place, including seabed anchoring via a gravity base or driven piles, as well as floating or semi floating platforms fixed in place via mooring lines. [12]

Tides are generated through a combination of forces exerted by the gravitational pull of the sun and the moon and the rotation of the earth. The relative motion of the three bodies produces different tidal cycles which affect the range of the tides. In addition, the tidal range is increased substantially by local effects such as shelving, funneling, reflection and resonance. Energy can be extracted from tides by creating a reservoir or basin behind a barrage and then passing tidal waters through turbines in the barrage to generate electricity. Since India is surrounded by sea on three sides, its potential to harness tidal energy has been recognized by the Government of India.[1] There are two types of energy systems that can be used to extract energy: kinetic energy, the moving water of rivers, tides and open ocean currents; and potential energy from the difference in height (or head) between high and low tides. The first method - generating energy from tidal currents – is becoming more and more popular because people believe that it does not harm the environment as much as barrages or dams.[5]

2.1.1 Advantages of Tidal Power:-

- It is non-polluting and almost silent when running
- Low term operation lifetime of plant
- The system is easy to operate & maintain
- Protects vulnerable coastline from strong waves and floods
- Does not emit greenhouse gases
- Provides a non-polluting and inexhaustible supply of energy

2.1.2 Tidal Power Energy conversion

Ocean current energy conversion devices are submerged in sea water and capture energy from the ocean similar to the way wind turbines capture energy from the wind. Ocean water is more than 800 times denser than wind. Energy available from ocean currents is estimated at 5,000 GW worldwide with energy densities as high as 15 kW/m^2. Turbines are oriented cross flow or axial flow. Axial-flow turbines feature open or shrouded rotors. Figure below shows examples of each type of turbine. Ocean current and tidal current technologies are in the early stages of development and only prototypes have been tested to date.

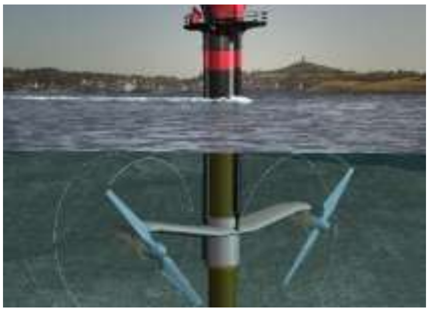

Fig. 2 Sea gen [8]

Fig. 3 Tidal power plant [8]

This type of turbine works similar to wind turbines. It is submerged in sea water, the turbines are driven by marine current or tidal current if velocities are high (in excess of 4 knots). SeaGen type turbines consist of two axial rotors 15 to 20 meters across that rotate to drive a generator. The pair of rotors can be pitched to a neutral position to stop or limit the turbines when velocities are too high. The turbines are designed to operate in bi-directional flows by allowing the blades to be pitched 180°. The power trains are mounted on a cross beam that is raised up the supporting structure when maintenance is required.[6]

Figure below shows another type of tidal turbine for electricity generation or tidal power development. These types of turbine are axial flow type, Bi-directional & housed in a single unit. The blades are easily removable, so that maintenance & repair work can be easily done.

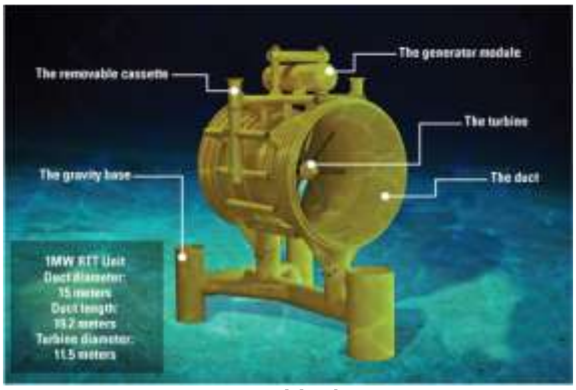

Fig. 4 Tidal turbine

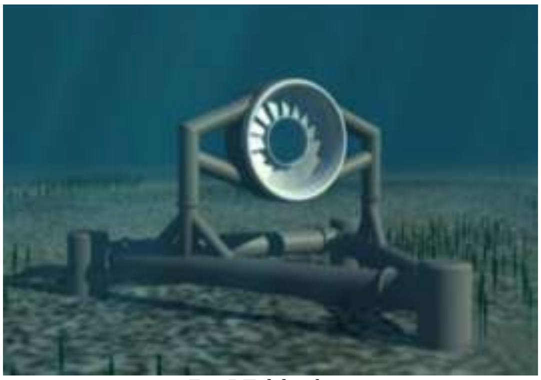

Fig. 5 Tidal turbine

2.2 Ocean Wave Energy or Wave Power

To convert wave energy into useful work, there are many wave energy conversion technologies were adopted. Some of the technologies are very costly. There are many variables need to be consider while conversion of ocean wave energy into useful work or electricity. Major variables include the method of wave interaction with respective motions (heaving, surging, pitching) as well as water depth (deep, intermediate, shallow) and distance from shore (shoreline, near shore, offshore). Efficient operation of floating devices requires large motions, which can be achieved by resonance or by latching, that is, with hold/release of moving parts until potential energy has accumulated. [9]

The types of wave energy conversion systems may be categorised in different ways. Figure 2.5 shows some examples of the primary types of WEC devices. The point absorber, attenuator, and inverted pendulum (or ‘oscillating surge’) systems in the figure are all examples of oscillating body WECs.[8]

Oscillating body WECs involve the transfer of power from the waves to the motion of a structure or structures. A PTO arrangement is then connected between structures (self-referenced) or between a structure and the seabed (seabed referenced). This type of WEC sometimes operates on the surface (floating) or is completely submerged.

The first, top-level, category of WEC – oscillating water column devices – consist of an air chamber with its lower end open to the ocean and its top connected to the surrounding atmosphere via an air turbine. As the waves oscillate within the chamber, air is pushed through the turbine forcing it to spin and drive an electric generator. This arrangement may be fixed (to the seabed or shore) or floating (in which case it is the oscillations in sea surface). [8]

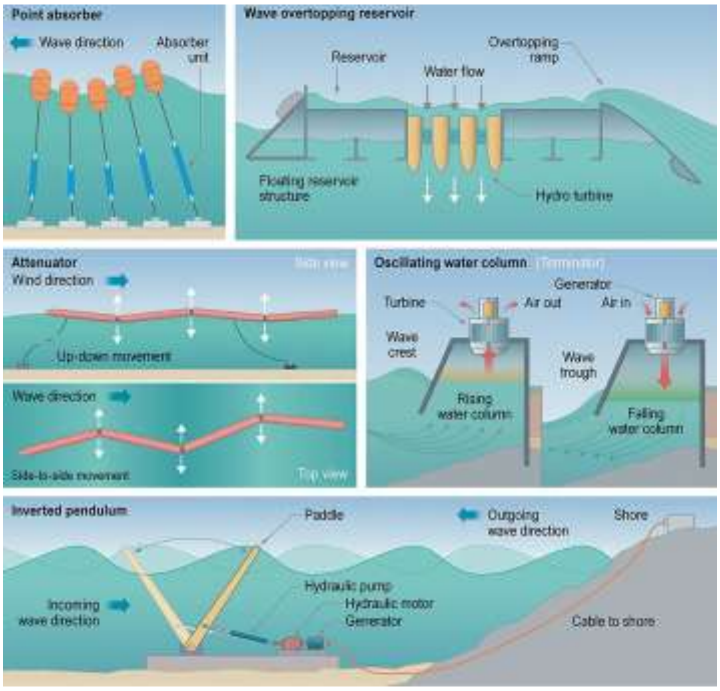

Fig. 6 Examples of major types of wave energy devices [8]

WECs are sometimes also categorised based on their dimensions and orientation as point absorbers, attenuators or terminators. Attenuators extend more in the down-wave direction than parallel to the wave front and progressively absorb energy as the wave travels down the length of the WEC. Terminator WECs, on the other hand, are those in which the converter predominantly extends in the cross-wave direction. Point absorbers are small in both cross-wave and down-wave horizontal dimensions in comparison to dominant incident wave lengths [8]. Recent reviews have identified that there are more than 50 wave energy conversion devices & techniques at various stages of development, some are patented and some are under research.

India has experimented with a 150-kW wave energy system at Thiruvananthapuram (Kerala) in 1983. The system average output was 25 kW during December–March and 75 kW during April– November in 1983 [10] and Vizhingam wave energy pilot project in Kerala. The wave energy pilot project at Vizhingam, an undertaking of the National Institute of Ocean Technology (NIOT) at IIT-Madras, aims to gather technical data on the oscillating-water column (OWC) concept. However though prototypes have been built and some operating experience obtained, this is not yet a commercially available technology. A wave energy plant installed by NIOT currently yields 6–7 kW to produce 7000–8000 litres of desalinated water per day [11]. The obstacles to wave power production are mainly technical: a design which will withstand the battering of waves, cost of special materials and techniques for construction and maintenance of equipment and infrastructure in corrosive environment as well as the problems related to efficiency and source variability. [9], [10]

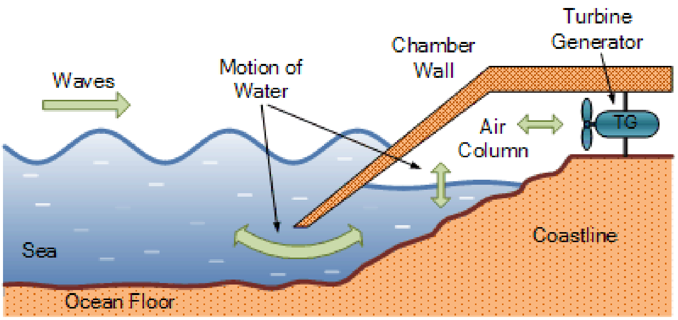

Fig 7 :- Oscillating Wave Column

Fig. 7 shows Oscillating wave column type wave energy converter. Figure is self-explanatory that Sea water will rise inside chamber wall. As the incident waves outside enter and exit the chamber, changes in wave movement on the opening cause the water level within the enclosure to oscillate up and down acting like a big giant piston on the air above the surface of the water, pushing it back and forth. This air is compressed and decompressed by this movement in every cycle. The air is channelled through a wind turbine generator to produce electricity as shown. The air inside the chamber is constantly reversing direction with every up-and-down movement of the sea water producing a sucking and blowing effect through the turbine. [15]

2.3 Ocean Temperature Gradient or OTEC

Ocean thermal energy conversion (OTEC) makes use of the temperature difference between the warm surface of the ocean and the colder layers underneath. Due to solar heating, the amount of energy available in the temperature gradient between hot and cold seawater can be substantially larger than the energy required pumping the cold seawater up from the lower layers of the ocean. The warm water from the surface is used to boil a working fluid (or, in open cycle systems, the seawater itself under low pressure), which is then run through a turbine and condensed using cold seawater pumped up from the depths. Fig. 2.5 shows the fluid cycle of a closed system. OTEC is best suited to areas near the equator, where the intense solar radiation warms the surface significantly. [11]

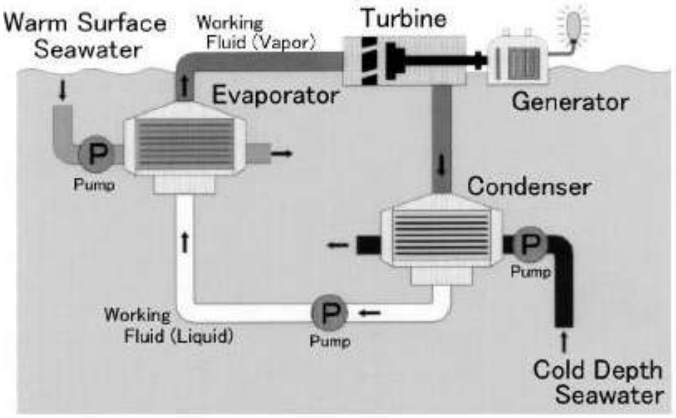

Fig. 8 OTEC Rankine Cycle [11]

The India OTEC program started in 1980 to install a 20 MW plant off the Tamil Nadu coast and in 1982, an OTEC cell was formed in National Institute of Ocean Technology (NIOT). A preliminary design was also completed in 1984 for a 1 MW closed Rankine cycle floating plant with ammonia as working fluid. In 1997, Government of India proposed to establish a 1 MW gross OTEC plant. To develop this project, India researchers have been exploring the participation of international expertise for a joint research and development. Based on the temperature and bathymetric profiles, the optimization of the closed loop system was done with the help of Saga University in 1998. [9]

2.4 Salinity Gradient

Salinity gradient energy or blue energy is an of the high potential energy sources that placed in renewable energy's list. The salinity gradient energy can be one of the important sources of the renewable energy to electricity generation for global electrical demand in future. When saline and fresh water mixes the Gibbs free energy is released. This energy could be used for generation of electrical power. [16] Salinity gradient power makes use of the potential energy available when saltwater and fresh water mix.

III. BARRIERS TO OCEAN ENERGY DEVELOPMENT

Ocean energy technologies face four main bottlenecks: technology development, finance and markets, environmental and administrative issues, and grid availability. [14]

i. Detailed resource mapping is typically lacking & this remains a significant barrier to development.

ii. Improvement required in device design.

iii. In today's time these technologies are costly.

iv. The long-term pathway to cost reduction is difficult to predict.

v. Environmental monitoring requirements are high.

vi. Environmental & social issues are prime concern.

IV. CONCLUSION

Ocean energy plays significant role in renewable source of power. The ocean energy resource is vast – with an estimated theoretical potential that can meet more than current and projected India's demand for electricity. Ocean energy technologies offer CO_2 emission-free power and enable energy independence. Number of wave power generators and ocean energy converters has been developed in India. But this source of energy conversion is on primary stage and too costly as concern to the developing country like India. A number of barriers have to be overcome to unlock the potential of ocean energy related to technology development, socio-environmental issues, economic competitiveness & infrastructure availability.

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