

A Study on Electricity Generation in India from Wave Energy and its Future Scope

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Abstract: *Renewable energy is an important drive for low carbon growth and is a sustainable solution to the problem of electrification in remote locations. India has around 150GW of renewable energy potential. The total installed capacity in India is 256GW primarily dominated by thermal sources of energy and it contributes around 69% of total installed capacity. Ocean produces two types of energies: Thermal energy due to sun's heat and Mechanical energy from the Tides & Waves. Ocean mechanical energy is quite different as it consists of Tides and waves. Waves driven are primarily by the winds. Wind is the cause of sun's heat. So oceans can be called as heat engines which will convert the solar energy into the kinetic energy of waves, winds and currents. The N-dimensional analysis of constraints involved in wave energy trapping is not yet finalized up to the mark. Several technologies are proposed to classify the wave energy conversion systems. The ocean depth and waves distance from the shore will decide the capacity of waves to trap energy from them. It is well known that India has a very long coastline -7500km and 336 islands in the Bay of Bengal and Arabian Sea. This paper introduces the major projects and activities taken place in India to trap electrical energy from the ocean waves across and around the coastline. It focuses on the importance given for the new researches on the wave energy conversion technologies. Finally we conclude that by using this renewable energy source as one of the advanced technology, we can reduce the risk of fossil fuel import and we can save it for future utilization in combination with the renewable energy source to meet the Indian Power requirement up to certain extent.*

Keywords: Ocean, waves, fossil fuel, power-load, realistic study and stochastic technology.

1. INTRODUCTION

Energy is a basic input to the national economy. The primary commercial energy inputs to the Indian economy are from coal, oils, and hydroelectricity and to a limited extent nuclear energy. We know that in Indian perspective there is tremendous scope for the energy from the ocean as India has a long coastline of about 7500 km and about 336 islands in Bay of Bengal and Arabian Sea. Oceans cover about 71% of the earth's surface, making them the world's largest solar collectors. They receive, store and dissipate energy through various physical processes. As per present technological status, recoverable energy in oceans exists mainly in the form of waves, tides and temperature difference (between surface and deep layers). Hence the ocean can produce two types of energy, tides and waves produce mechanical energy whereas temperature difference produces thermal energy. Tidal energy technology is relative

more developed compared to the other two, which are still undergoing evaluation and initial development stages. It is becoming challenge for the technical Research and Development Authorities that the extraction of energy from the ocean waves is highly difficult and skill full techniques are required to do the same. In oceans tides will be created by the gravitational pull of the moon and waves are created by the winds which flow on the surface of the ocean. The average solar power flux onto the surface of the ocean at 15⁰ North latitude is about 0.2 kW/m², but this is typically converted to trade winds of about 20 knots, which have a power flux of 0.6 kW/m². Recent reviews have identified more than 50 wave energy devices at various stages of development. The dimensional scale constraints of wave devices have not been fully investigated in practice. The dimension of wave devices in the direction of wave propagation is generally limited to lengths below the scale of the dominant wavelengths that

characterize the wave power density spectrum at a particular site.

2. WAVE ENERGY

Waves are caused by the transfer of energy from surface winds to the sea. The rate of energy transfer depends upon the wind speed and the distance over which it interacts with water. In other words Wave power is the transport of energy by ocean surface waves, and the capture of that energy to do useful work – for example, electricity generation, water desalination, or the pumping of water (into reservoirs). A machine able to exploit wave power is generally known as a wave energy converter (WEC).

The energy flux in waves is more than that available from solar, wind and other renewable sources. The power in the waves is directly proportional to the square of its amplitude and to the period of motion. Wave power is usually expressed in kilowatts per m, representing the rate at which energy is transferred across a line of 1-m length parallel to the wave front. Waves created by the oceans are more complicated to analyze. Till now there is no one particular solution to identify the waves generated in the mid-point of the oceans and to trap energy from them, even though the waves are existing continuously in the ocean without long time-gap. Coastal structures which can also serve as a lifesaving tool during cyclones and storms. Wave energy potential of the ocean can be calculated using numerical models, which can give guidelines to further detailed researches on renewable energy. Numerical wave models are the representation of reality which can be improved further for better accuracy and results. Research is going on to improve the existing wave models. Another major development in the numerical wave modeling is the coupling of different type of models together to get improved results.

The main advantages of wave power are i) the availability of large energy fluxes and ii) predictability of wave conditions over periods of days.

3. WAVE ENERGY CONVERTING DEVICES

Sea waves are the result of the concentration of energy from various natural sources like sun, wind,

tides, ocean currents, moon, and earth rotation. Waves near land tend to be parallel to the coast. Wave energy contains roughly 1000 times the kinetic energy of wind. Hence it allows smaller and less conspicuous devices to produce power. Wave energy varies as the square of wave height whereas wind power varies with the cube of air speed. Water being 850 times as dense as air results in much higher power produced from wave averaged over time. Theoretically you can extract 40 MW of power per km of coast where there are gentle waves (say 1 M height) and 1000 MW per km of coast where the wave height is 5 M. Unlike wind and solar, power from sea waves continues to be produced round the clock whereas wind velocity tends to die in the morning and at night. Solar power depends on sun and cloud cover. The problem with sea waves is that they have very high force at low speeds whereas for electricity generation you need higher speeds.

Energy in the waves is harnessed basically in the form of mechanical energy using wave energy converters, also known as wave devices or wave machines. A wave device may be placed in the ocean in various possible situations and locations i.e device either floating on the surface of the ocean or moored to the ocean floor. The fluctuating mechanical energy is modified/smoothed out to drive a generator. The design of the device to do this conversion is most crucial to the economics.

Wave conversion devices float on the surface have joints hinged together that bend with waves. The kinetic energy pumps fluid through turbines and creates electric power. Stationary wave energy conversion devices use pressure fluctuations produced in long tubes from the waves swelling up and down. This bobbing motion drives a turbine when critical pressure is reached. Other stationary platforms capture water from waves on their platforms. This water is allowed to runoff through narrow pipes that flow through a typical hydraulic turbine.

Wave energy devices may be classified in various ways. Depending upon the location of these devices, they can be classified as (i) off-shore or deep water devices, and (ii) shoreline devices. Depending upon the position with respect to sea level they are classified as (i) floating, (ii) submerged, and (iii) partly submerged devices.

Depending on the actuating motion used in capturing the wave power, these devices are classified as (i) heaving float type, (ii) pitching type, (iii) heaving and pitching float type (iv) Oscillating water column type, and (v) surge devices.

The wave energy conversion device structure is as given below in Figure 3.1. The propagation of sea waves is shown in figure .3.2

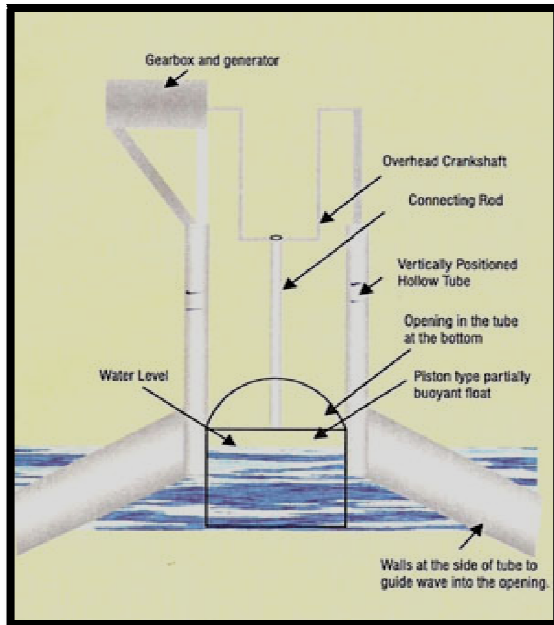


Fig. 3.1 Indian Wave Energy Converting Device

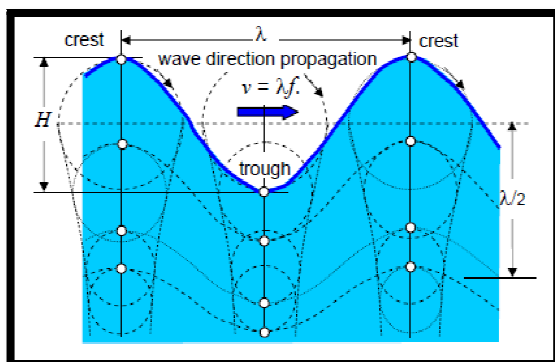


Fig. 3.2 Propagation of sea waves

The working principle of wave energy converting device in INDIA can be viewed in the URL provided^[4].

3 WAVE ENERGY CONVERSION TECHNOLOGIES

Wave energy technology is rapidly growing and varies widely in application of conversion devices. Energy conversion devices can be situated on or off shore.

Four categories of wave energy technology exist: attenuators, point absorbers, overtopping terminators, and oscillating wave column (OWC) terminators. Point absorbers and attenuators capture wave energy as they are placed in the path of the wave. Attenuators are situated parallel to the waves and energy is captured over the surface area. Point absorbers are moored to the sea bed or float near the surface, collecting wave energy from all directions. Terminators restrain wave motion and capture energy through long arms. OWC terminators capture water from an opening into a partially submerged platform and let that water rise in an air column. The air is compressed, which drives a turbine to generate electricity.

The following table 3.1 gives the summary of the different techniques used to get energy from the ocean waves which are used worldwide now a day.

	Onshore	North Sea	Atlantic
OWC	Suitable, Concepts exist	Concepts exist	Suitable, several concepts exist
Attenuator		Concepts exist	Suitable, concepts exist
Point Absorber		Suitable, Concepts exist	Suitable, Concepts exist
Submerged Pressure Differential			Possible, Concepts exist
Oscillating Surge Converter		Possible, concept exists	Suitable, Concepts exist
Overtopping Devices	Suitable, Concepts exist	Suitable, Concepts exist	Suitable

Table 3.1 Six Basic Principles Used To Convert the Wave Energy in to Electrical Energy

There are several ways to categorize the development stages of new technologies e.g. NASA uses a measure called TRL, Technology Readiness Levels, that consists of nine different development levels with defined technical milestones. Another measure developed specifically for the marine energy sector is the Irish

Ocean Energy development and evaluation protocol with five levels including indicative costs for each step. The wave energy sector is often compared to the wind energy sector, and especially the offshore wind energy sector. It is often heard that wave energy, in terms of technological maturity, is some ten to fifteen years behind the wind sector. Indeed there are many similarities between offshore wind and wave energy, but there are also some fundamental differences. Whilst wind energy converters have been developed as an onshore technology that has been applied to the offshore, most wave energy converters are developed for offshore operations from the start. Being offshore increases the obstacles that must be overcome (e.g. survivability) and the wind energy sector could prove the technology onshore before taking the step offshore whereas the wave energy sector must face all challenges associated with being at sea with the first prototypes. A simplified description of the development process for wave energy converters is given in figure 3.2.

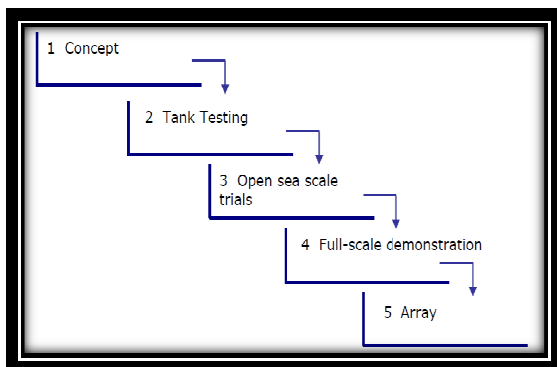


Fig. 3.2 The different stages in the development process of wave energy technology simplified

The procedure is as follows: **1. Concept:** A drawing table phase where the initial design is established. This phase usually includes numerical modeling for early validation of the wave energy concept. **2. Tank testing:** Experiment in ocean wave basins is a cost effective way to do tests on a design. Testing in this protected environment has many other advantages compared to real sea testing, e.g. accessibility to workshops, safety, and most importantly the sea states can be chosen. The

freedom to choose the sea state is essential for comparative tests since different designs can be tested in identical conditions and also for survivability tests. Suitable scale versions are typically around 1:15th to 1:20th scale for power tests and possibly smaller for survival tests. Tank testing campaigns can also be performed in later stages of the development process to give guidance results in case of e.g. a design change is called for. Many Wave Energy Converting (WEC) developers rely much on simulation tools, which often are produced in-house, and tank-testing results are important to validate numerically derived results. Hence are tank experiments important in order to develop not only the device itself, but also numerical tools. **3. Open sea scale trials:** At one point it is necessary to bring the design out in the real sea. Although modern wave basins can create very realistic environments they cannot fully capture the complexity of the real sea. In this step a scaled device is used in order to give information about e.g. deployment strategy and real sea performance that ultimately will baseline the decision to go to full scale. **4. Full-scale demonstration:** The focus in this stage is set on verifying the concept in full scale in real operational conditions. One of the main constraints for a successful full-scale demonstration is the economical resources required. This is further discussed later in this section. **5. Array:** Once the wave energy converter is demonstrated array operation is the last and ultimate step to take in order to show that the wave concept is a viable technology for commercial energy production. Today there are several wave energy converter developers somewhere around stages 3 and 4, but no developer has really showed continuous array operation i.e. stage 5. Obviously the further the developers reach in the development process, the higher the cost get for taking another step, and this is often a restricting factor. In the fore coming section let us see the wave energy conversion and its implementation in India.

4. WAVE ENERGY CONVERSION IN INDIA

Wave data used in this article are those measured using moored Data well directional waverider buoy at the four locations as shown in Figure 4.2 and the detail is given in table 4.1. At all the locations, data are recorded for 30 min duration at 1.28 Hz interval. The waverider buoy is equipped with a

heave pitch roll sensor, a three axis fluxgate compass, x and y accelerometers and a dedicated microprocessor. The microprocessor takes information from the sensors in the waverider buoy and converts them to three acceleration values (vertical, north, west). The data are then digitally integrated to displacements, filtered, and Fourier-transformed with a Nyquist frequency of 0.64 Hz. Wave spectrum is obtained through Fast Fourier Transform (FFT) [5]. Along the Indian coast there is a large seasonal variation in wave power. For the west coast of India, most of the annual wave energy (83% at Honnavar and 85% at Ratnagiri) is during the summer monsoon period and high average wave power (15.5 kW m^{-1} at Honnavar and 19.4 kW m^{-1} at Ratnagiri) is found during the summer monsoon period.

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 [6] and Vizhingam wave energy pilot project in Kerala with 150 kW now. 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. The wave energy converting devices are located on the shore line, near the shore or offshore. The recent study reveals that along the coast of Maharashtra has shown that there are some potential sites such as Vengurla rocks, Malvan rocks, Redi, Pawas, Ratnagiri and Girye, possessing an average annual wave energy potential of 5 to 8 kW/m and monsoon potential of 15 to 20 kW/m. Considering this, the total potential along the 720 km-stretch of Maharashtra coast is approximately 500 MW for wave energy power plants. Fortunately after decades of research and development activities all over the world, some technologies are now available commercially. We need to explore the possibility of wave energy power plants at the identified sites by inviting proposals from private investors / promoters / technology providers from all over the world. They attract the private investment to the tune of Rs 3000 crores. The Govt. of Maharashtra and Govt. of India have plans to announce policies to attract private investors in this field on BOO (Build Own Operate) basis. Maharashtra Energy Development Agency (MEDA) sponsored a study, conducted by

Centre for Earth Science Studies, Thiruvananthapuram, to find the wave energy potential along the Maharashtra coast. The study completed in 1994, has shown the Maharashtra coast has an annual wave potential ranging between 4 to 8 kW per meter of the length of the wave crest. During the monsoon, i.e., between June and August, the potential is quite high, i.e. 12 to 20 kW/m. The wave energy potential of the most feasible sites in Maharashtra are given in the following table 4.2. The Vengurla and Malvan rocks and Redi are on the top among the offshore locations. In the other group, Pawas and Ratnagiri top the list followed by Girye and Miyet point. Power Generation Projects based on Wave Energy are not yet commercially established in India. MEDA has taken initiative for establishing Demonstration Power Generation Project at Budhal, Taluka: Guhagar, District: Ratnagiri. The Demonstrative Power Project is of 15 to 25 kW Capacity. The Project is being installed and commissioned with technical assistance from M/s Apar Urja Pvt. Ltd., Sangli and is being commissioned.

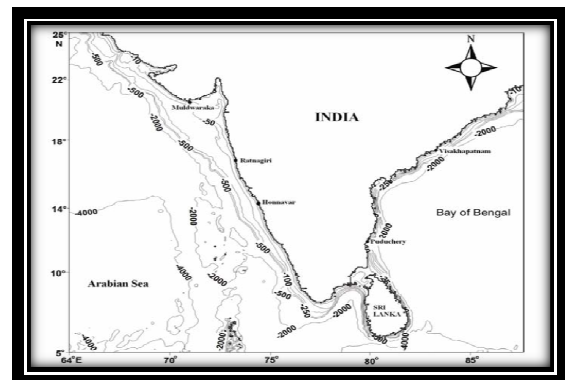


Fig. 4.2 Wave energy locations along the east coast of India

Location	Latitude; Longitude	Water depth (m)	Measurement period
Ratnagiri, west coast	16.9001°N; 73.2584°E	13	1 January 2011 to 31 December 2011
Honnavar, west coast	14.3042°N; 74.3907°E	10	1 January 2011 to 31 December 2011
Puducherry, east coast	11.9249°N; 79.6507°E	12	1 January 2010 to 31 December 2010
Visakhapatnam, east coast	17.6321°N; 83.2649°E	15	1 January 2010 to 31 December 2010

Table 4.1 Measurement Details

Wave power at selected sites along Maharashtra coast					
OFF SHORE Average Wave Power kW/m			COASTAL Average Wave Power kW/m		
Site	Annual	(Jun- August)	Site	Annual	(Jun- August)
Vengurla Rock	8.01	20.61	Girye	5.90	14.21
Square Rock	6.79	16.64	Vijaydurg	5.86	13.58
Redi	6.35	16.57	Ambolgarh	5.74	13.48
Malvan Rock	6.91	16.73	Kunkeshwar	5.64	13.35
Kura Inset	5.79	13.74	PawaPoint	5.36	13.10
			Wagapur	5.70	13.10

5. FUTURE SCOPE OF WAVE ENERGY IN INDIA

The motivation for national programs for wave power (or to be more precise ocean energy thus including tidal power) is a combination of need for domestic renewable power and hope of a new industrial sector creating jobs as well as exports. If The Indian Government is ready to invest and apply the advanced technologies to harness the energy from sea waves, it will become the first because 70% of the Indian coastline is covered by sea only. Therefore we can say that the coming future is waiting for the renewable energy resources with the augmentation of wave energy. But to achieve this the skill full technology is needed. The benefits to society offered by wave energy include: 1) providing a new, environmentally friendly and easily assimilated grid connected option for meeting load growth and legislated Renewable Portfolio Standard requirements, 2) avoiding the aesthetic concerns which plague many infrastructure projects, 3) reducing dependence on imported energy supplies, increasing national security and reducing the risk of future fossil fuel price volatility, 4) reducing

emissions of greenhouse gases by displacing fossil fuel-based generation, and 5) stimulating local job creation and economic development; which are very much necessary for the nations like India.

6. CONCLUSION

Wave energy is not expensive to operate and maintain, no fuel is needed and no waste is produced. However, it depends on the intensity of the waves and needs a suitable site where waves are consistently strong. The infrastructure must be able to withstand very rough weather. Wave power lies not in huge plants but in a combination of on-shore generation and near-shore generation (using a different technology) focused on meeting local or regional needs. If this system proves to be economically possible, only 0.1% of the renewable energy within the world's oceans could supply more than five times the global demand for energy. The excitement about alternative energy suggests that ocean energy oriented projects might be a similar opportunity, though perhaps on a smaller scale. The technology may take decade to mature but ocean energy is an option worth pursuing.

References

1. www.elsevier.com/locate/procedia "Aquatic Procedia 4 (2015) 443 – 448" ' Numerical wave modelling – A review' Justin Thomas and G S Dwarakish.
2. YueHong, RafaelWaters, CeciliaBoström, MikaelEriksson, JensEngström, Mats Leijon.'Review on electrical control strategies for wave energy converting systems' journal homepage: www.elsevier.com/locate/rser .
3. Wave Power Surveillance study of the development 'Elforsk rapport' http://www.iea-oceans.org/fich/6/Poster_Ocean_Energy.pdf
4. The URL for Wave Energy Converting Device: <http://ElsevierPapers/Wave%20Energy%20into%20Electrical%20Energy.htm>
5. Wave power potential at a few shallow water locations around Indian coast. 'CURRENT SCIENCE, VOL. 104, NO. 9, 10 MAY 2013 '
6. Maharashtra Energy Development Agency website:

- http://Maharashtra Energy Development Agency.htm
7. *Marine Technology Society Journal*. 'Economic and Social Benefits from Wave Energy Conversion Marine Technology' Author-Roger Bedard, Electric Power Research Institute-India.
 8. Philip, S. C., Kumar, V. S., Johnson, G., Dora, G. U. and Vinayaraj, P., Interannual and seasonal variations in nearshore wave characteristics off Honnavar, west coast of India. *Curr. Sci.*, 2012, 103, 286–292.
 9. Barstow, S., Gunnar, M., Mollison, D. and Cruz, J., The wave energy resource. In *Ocean wave energy* (ed. Cruz, J.), Springer, Berlin, 2008, pp. 93–132.
 10. Simon Lindroth, Mats Leijon. 'Offshore wave power measurements—A review' Elsevier journal, journal home page: www.elsevier.com/locate/rser