OCEAN WAVE ENERGY POTENTIAL AND EXTRACTION TECHNOLOGIES

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ABSTRACT

To cope with the energy crisis, many countries are struggling to develop the new and renewable energy resources. Wave and wave current energy are promising energy resources because they can be developed at a very large scale. In order to develop techniques for harnessing wave energy, field measurements have been performed and numerical modeling as well as estimation of potential energy are under progress in Kuala Terengganu coastline. The main wave characteristics are commonly given in terms wave height, period, direction of propagation and power. The power in wave can be expressed by the formula $P = (\rho g^2 /64\pi)H^2_sT,$ kW per meter of crest length. However, it is rarely possible to measure data in a proposed sea area over a long period of time, and to use the data in setting the environmental condition parameters within which such devices will be expected to function. As a result, short-term data and water-related data supplied by weather stations concerning the proposed sea area are often used when designing WEC devices. This paper aims to describe the importance of data and collection methods, parameters to estimate the potential wave energy and explain wave energy conversion methods.

Keywords: Conversion, Energy, Environmental, Renewable, Wave

1.0 INTRODUCTION

The need for energy resources for future is recognized by all countries as their economic growth and self-reliance will depend mainly on vital field of energy. The increase in oil prices, the depletion of coal resources, the possible threat to the environment due to effluents from fossil fuels and nuclear power plants has prompted the technological developments in the utilization of renewable sources of energy such as solar, wind, biological and ocean energy programs. The sources of energy from the seas are waves, tides, currents and salinity gradients and natural thermal differences in the oceanic water. The wave energy is suited for countries with vast coast line and high waves approaching the shore. It is free from environmental pollution and continuous as waves are never going to cease. The extraction of energy from the waves can be a viable solution to the enormous power requirements of a country like Malaysia having a vast coastline. The present technology of wave energy conversion may be economically not encouraging when compared to the conventional energy sources like fossil, hydro power.

Research on renewable energy has lagged in part because it is difficult for any new technology to compete economically with cheap and established fossil fuel plants. However, proper accounting for externalized costs of energy production puts renewable energy in a more favorable light, while advances in technology and economies of scale can cause the costs of such technologies to drop considerably over time. While wave energy development necessarily presents some challenges, much of the infrastructure and knowledge necessary to generate energy from the ocean already exists.

Wave energy has long been considered one of the most promising renewable technologies. Not only is the energy resource vast, but it is more dependable than most renewable energy resources wave power at a given site is available up to 90 % of the time, while solar and wind availability tend to be available just 20–30 % of the time [10]. There are a more than 1000 different patented proposals for wave energy devices, and several have demonstrated the potential for commercially viable electricity generation.

Worldwide, wave energy could potentially provide up to 2TW of electricity, according to the World Energy Council, approximately 1/5 of current global energy demand [10]. The economics of wave energy power, though not yet competitive with fossil fuels, are promising, and the situation is improving with more advanced technology.

Several methods and technologies to capture the energy from waves are being developed around the world. The selection and assessments of wave energy conversion devices is depend on the sea condition. University Malaysia Terengganu (UMT) has initiated research work in renewable energy including wave to find a suitable renewable energy form from Malaysian sources. In order to develop techniques for harnessing wave energy, field measurements have been performed and numerical modeling as well as estimation of potential energy is under progress in Kuala Terengganu coastline.

2.0 DATA MEASUREMENT

Currently there are four methods being used to gather wave data such as discussed in the following paragraphs:

2.1 Instrumentals Measurement

Wave instrumentals measurement or direct observation was the most accurate way to measure the wave height concerning the area of each particular study. But this method needs a highest cost, expose to the vandalism and unfortunately scarce limitary point data in the fields of wide areas. This measured wave data can only be used to calibrate the others measurement. There are four main categories of instruments to measuring the wave, which are known as wave staff, sub-surface sensor, buoys and ship borne systems.

2.2 Visual Observations

There is a huge volume of observations of waves from ships in normal service all over the world, and these are held in data banks of various meteorological offices. A major source of visual wave data is the compilation made by Hogben and Lumb [4], which cover most of the ship routes to and from Europe. The Pacific Ocean is not so well documented but this can be supplemented with the data from Yamanouchi and Ogawa [16], which covers that ocean in detail. Another important compilation is due to Walden [13], containing visual observations performed in the North Atlantic Ocean Weather Stations, during a period of 10 years. The observations are divided into subsets for each combination of area, season, and wave direction classification used. In particular, the distribution of the wave periods conditional on the wave height was corrected by an analytical modeling of the joint probability distribution of heights and periods, avoiding use of visual observations. Afterwards, this distribution, together with the marginal distribution of visually observed wave heights, was used to reconstruct the scatter diagram of wave heights and periods by a computer analysis program.

3.0 MALAYSIAN WAVE DATA

At present, sources for wave data especially on wave height and wave period available in Malaysia for engineering purposes are limited [7]. Researchers rely on the visual observation data and the wave spectrum, which are based on western sea conditions and parameters for engineering applications.

British Maritime Technology (BMT) provides the data that contains statistics of ocean wave climate for whole globe generally known as Global Wave Statistics atlas. The data are presented in terms of probability distributions of wave heights, periods and directions for global selection of sea areas. The data have been derived by a quality enhancing analysis of a massive number of visual observations of both waves and winds reported from ships in normal service all over the world, using computer program called NMIMET [7].

Malaysian Meteorological Service (MMS) provides monthly statistics of marine meteorological observation information such as wind waves and swells. The wave and wind data collected are derived from marine surface observations reported by ships operating in the Malaysian waters which participated in the World Meteorological Organization Voluntary Observation Ships Scheme, oilrigs and lighthouses. MMS also provides the forecasting wave data and buoy data. MMS also uses a wave-forecasting model called WAM. The data provided by the MMS is presented on monthly charts with individual values in squares of 2^o latitude by 2^o longitude and with forcing by MMS 6-hourly wind field [7].

4.0 WAVE ENERGY CHARACTERIZATION

Performance assessment the of a Wave Energy Converter that is, predicting the effective amount of energy converted from the incident wave field over certain period of time in nominal operation conditions necessarily requires a precise knowledge of the local wave climate. The developers, indeed, need to optimize their devices in order to fit them to actual wave conditions at the envisioned zone of deployment. The main wave characteristics are commonly given in terms wave height, period, direction of propagation and power.

The variability of wave conditions in coastal waters is, generally, very large compared to offshore waters. Near-shore variation in the wave climate is compounded by shallow-water physical processes such as wave refraction, which may cause local ‘‘hot spots’’ of high energy due to wave focusing particularly at headlands and areas of low energy in bays due to defocusing. In addition, other coastal wave processes such as wave reflection, diffraction, bottom friction and depth-induced breaking effects may have some influence. As averaged over years, offshore wave-power levels in the range of 30–100kW/m are found at latitudes 40^0–50^0, and less power levels further south and north. In most tropical waters, the average wave-power level is below 20 kW/m. The average wave energy for a winter month can be 5–10 times the mean value for a summer month. The wave energy can vary 10 times from one week to the next. The wave energy during one storm can be 5 times higher than the mean value for the week the storm occurs. Wave energy in wave groups can be up to 50 times the wave energy between wave groups. Extreme storm seas contain very much wave energy and contribute significantly to yearly mean values of wave-power level [5].

Since the last few decades, the hydrodynamics of ocean waves have been thoroughly studied and now it is possible to determine the energy content of the sea with the help of large amount of wave data collected. The power in wave can be expressed by the formula [9],

$$P = (\rho g^2 /64\pi)H^2_s T,\ \text{kW / meter crest length.} \quad (1)$$

And per unit area of sea surface a stored energy (E) amounting to an average of

$$E = \rho g H^2_s / 16 \quad (2)$$

is associated with the wave, where ρ is the mass density of sea water, g is the acceleration of gravity, H_s is the significant wave height in meter and T, is wave energy period in seconds for the actual sea state [5].

The wave climate and energy resource can be presented by the long-term statistics presented in Table 1, which were mostly proposed in WERATLAS [11].

5.0 DESIGN APPROACH

The most critical issues in WEC technology are the design and construction of the structure, and the most influential on the economics of energy produced from the waves. In the present situation, the construction dominates the cost of the WEC plant. So, in the preliminary studies of a WEC plant, the first step usually consists in defining the sitting and basic geometry of the plant’s structure. This is established, taking into account geo-morphological constraints and local wave climate, from the wave energy absorption hydrodynamics, with the aid of numerical modeling and of wave basin model testing. Such modeling provides the information required for the specification of the power take-off equipment. The standard approach to appraising WEC output and economics is described by Thorpe [12] and this approach a simplified version is shown in Figure: 1 to easy understanding.

6.0 WAVE ENERGY CONVERTERS

So far, many different concepts of devices have been proposed. Of these, some have achieved the prototype state, already having faced real sea conditions, and in fact it might be more than one converter type that reaches the stage of large-scale implementation. Generally, the existing devices are classified according to the distance between the location of the installation and the shore. Shoreline devices do not require long underwater electrical cables or deep-water moorings. However, they have limitations regarding the potential sites to be installed because they are fixed or embedded in the shoreline, typically water depths do not exceed 10m, therefore subject to a much less powerful wave regime. The near shore devices, typical depth range 10-25m, enjoy a more energetic wave climate than the shoreline devices. However, they require suitable seabed conditions for installation. There are many types of offshore devices, typical depth around 50m. This class of devices explores the more powerful wave regimes available in deep water before energy dissipation mechanisms have had a significant effect on wave power levels. At present the following devices are used to convert this wave energy.

6.1 Terminators

Terminator devices extend perpendicular to the direction of wave travel and capture or reflect the power of the wave. These devices are typically installed onshore or near shore; however, floating versions have been designed for offshore applications. The oscillating water column (OWC) is a form of terminator. Oscillating water column based Wave Energy Power Plants convert wave energy into low-pressure pneumatic power in the form of bi-directional airflow. Self-rectifying air turbines, capable of operating uni-directionally in bi-directional airflows, are used to extract mechanical shaft power, which is further converted into electrical power by a generator (Figure 2 and 3).

6.2 Overtopping Devices

Overtopping devices have reservoirs that are filled by impinging waves to levels above the average surrounding ocean. The released reservoir water is used to drive hydro turbines or other conversion devices. Overtopping devices have been designed and tested for both onshore and floating offshore applications. The offshore devices include the Wave Dragon (Figure: 4) [14], whose design includes wave reflectors that concentrate the waves toward it and thus raises the effective wave height.

7.0 ECONOMIC CONSIDERATIONS

Cost estimates of energy produced by WECs are dependent on many physical factors, such as system design, wave energy power, water depth, distance from shore, and ocean floor characteristics. Economic factors, such as assumptions on discount rate, cost reductions from a maturing technology, and tax incentives, are also critical. These facilities are very capital intensive, and these costs currently have a high degree of uncertainty.

Unless special conditions arise, wave power will be assessed on the same basis as other candidate generating plant, coal, oil, nuclear, gas turbine, etc. The preferred plant will always be that which will enable the generating system to continue to meet a changing demand at the minimum overall cost. Each new plant is therefore assessed for the balance between the cost of installation, operation and maintenance and the overall savings, primarily of expensive fuels, which it would be expected to make in normal operation over its life.

Two important design objectives can be identified based on economical consideration. Firstly, for each site it will be necessary to optimize the scale of the device, which will be determined by the wave climate, and its rating. These will be chosen to balance the improvements in net availability against the increasing specific cost which reducing the device rating will achieve. Secondly, in order that the overall availability can even approach this potential optimum, the system must be as simple, maintainable and reliable as possible.

8.0 ENVIRONMENTAL CONSIDERATIONS

Wave energy is a virtually non-polluting source and devices produce no gaseous, liquid or solid emissions. However, the deployment of wave power schemes could have certain impact on the environment. Some of the effects may be beneficial and some potentially adverse. The most commonly cited potential environmental impacts of wave energy technologies are noise, hydraulic fluid spill, visual effects, hydrodynamics, mammal perturbations, etc. however these have not been studied in detail. It is also worth to look at the similar positive environmental impacts. i.e. wave energy devices could enhance marine life by providing structure, acting in much the same way as artificial reefs. Common and different aspects of the devices should be identified. On one hand, regarding their influence on the marine environment, wave energy devices have several features in common like the construction phase and their size or effects in wave attenuation.

9.0 MORE GOVERNMENT SUPPORT NEEDED FOR WAVE ENERGY RESEARCH

The states must increase their support for wave energy research because the technologies are a crucial element in achieving a balanced global energy future, wave energy can make major contributions to the diversity and security of energy supply and to economic development. Considerable attention has been drawn to their potential for mitigating climate change. We need to use public funds as effectively as possible in achieving this. Countries must improve their market deployment strategies for wave energy technologies.

10.0 CONCLUSIONS

There are a range of wave energy concepts which could produce modest and substantial amounts of power. Shoreline devices are already viable in certain locations and could be exploited in many others. Further research is needed on wave energy data and data collection methods. The wave energy resource is extremely large and offers the possibility of environmentally benign energy at moderate cost. On the basis of currently available empirical information, the environmental impacts are expected to be small, however, efforts should be made on environmental effects by wave energy projects, and this could be essential to sustainable development of wave energy. States authorities must increase their support for wave energy research to achieve the target on renewable energy.

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Table 1: Long-term wave data statistics [11]

Distribution of wave and wave-energy parameters	
Tables	**Plots**
Frequency table of H_s	Probability density of H_s
Frequency table of T_e	Probability density of T_e
Frequency table of T_p	Probability density of T_p
Exceedance table of P	Exceedance distribution of P
Frequency table of θ	Polar distribution of θ
Bivariate frequency table of (H_s,T_e)	Bivariate probability density of (H_s,T_e)
Bivariate frequency table of (H_s,T_p)	Bivariate probability density of (H_s,T_p)
Mean power P_* for each (H_s,T_e) class	
Seasonal and Inter-annual Variability	
Plots and table of monthly mean value and confidence limits for H_s	
Plots and table of monthly mean value and confidence limits for T_e	
Plots and table of monthly mean value and confidence limits for P	
Plots and table of monthly mean value and confidence limits for θ	

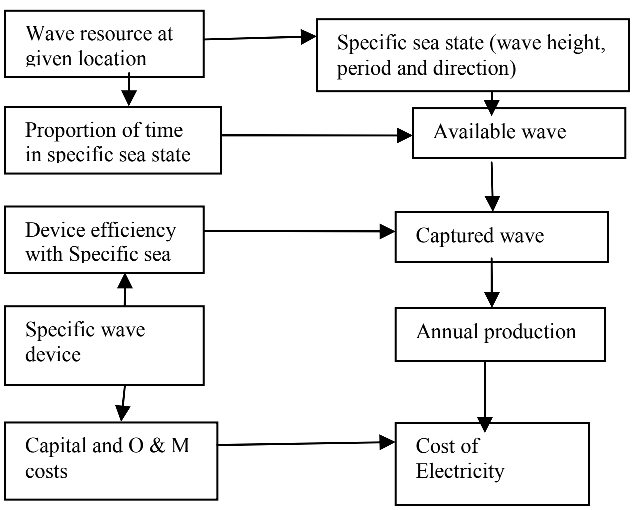

Figure 1: Methodology for appraising WECs [12]

Figure 2: Offshore Oscillating Water Column [15]

Figure 3: Shore Oscillating Water Column [3]

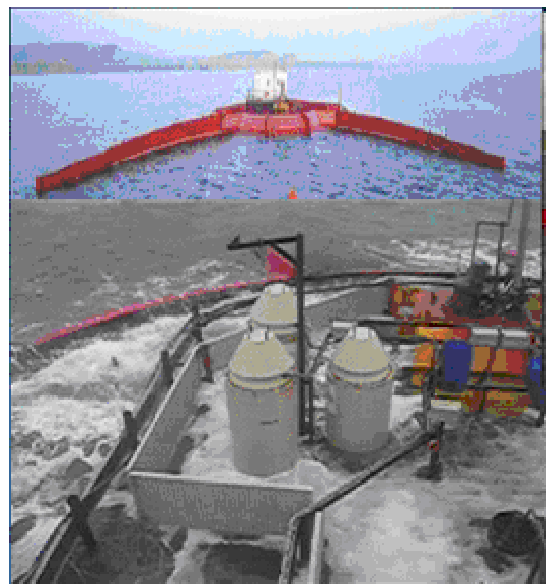

Figure 4: Wave Dragon Overtopping Device [14]