Wave power potential around East Malaysia.

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Abstract

Many countries in the world are diversifying their energy resources to utilise renewable and clean energy resources as part of their energy planning. The government of Malaysia has encouraged the development of renewable energy as a fifth source of fuel along with the existing oil, natural gas, coal and hydro in the future planning. Ocean wave is one type of renewable and clean energy resource that is available around the East Malaysian coastline. The potential of the ocean wave energy resources around the coastline of East Malaysia have been estimated and presented.

Keywords: Ocean wave energy, renewable energy, East Malaysia

INTRODUCTION

East Malaysia is a part of the Borneo island and consists of Sarawak and Sabah states. Sabah occupies the northern half of the Borneo island and Sarawak is situated in the northwest of the Borneo island between latitudes 1^0 to 6^0 north and between longitudes 109^0 to 119^0 east. East Malaysia is bordered by South China Sea along its northwest coast, by the Sulu Sea along its northeast coast of Sabah and

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Celebes Sea also known as Suluwesi Sea along the east coast of Sabah. East Malaysia covers an area of 201,320 sq km.

Population of Malaysia is around 25.1 million with most of the population concentrated in West Malaysia. In 2001, Malaysia consumed 31,515 kilo tonnes of oil equivalent (ktoe) of energy, industrial sector consumed 11,852ktoe and transportation sector 13,137ktoe [1]. The four primary energy sources of energy are natural gas, oil, coal and hydro. The power poduction in East Malaysia are operated by government agencies and Independent Power Producers (IPPs). In the state of Sarawak, the government agency involved in electricity generation and distribution is SESCo. In the Sabah state, it is carried out by SESB. The electricity demand in the East Malaysia states is lower than states in West Malaysia. Currently, the main fuel source used for generating electricity is natural gas at 45.7%, Table 1 shows the installed capacity of power plants in East Malaysia. Apart from hydro, rests of the resources are non-renewable and emit green house gases during operation. The utilization of hydro as the primary energy source is as low as 10.5MW but after the completion of the Bakun project with 2,400 MW, hydro will be the prime source of fuel for electricity generation in East Malaysia [2]. A large part of areas in East Malaysia is not connected to the grid or situated far away from existing electricity grid. Development of electricity production from renewable sources found around these two states will help provide electricity to the rural areas.

This paper aims to estimate renewable wave energy source which is available around the East Malaysia coastline. Ocean waves are form of renewable and clean energy source that has been recognized since the 1970's. Serious research has been carried out since then. The estimated worldwide wave energy potential is more than 2 TW [3]. Figure 1 gives wave power levels for some locations around the world [4].

The development of Wave Energy Conversion Devices (WECD) is mainly concentrated in European countries. Extensive review on the development of wave energy has been made by Clement, A. et al [5]. WECD based on Oscillating Water Column (OWC) principle have shown to be able to generate electricity to provide to the local electricity grid. Most notably is in the Island of Islay, Scotland, where an OWC power plant has been developed and tested since 1991. Currently this power plant can provide 500kW of electricity. Other OWC projects carried out in the world are in Pico Island in the Azores, Norway, India, Sri Lanka, China and Japan. To gain access to more powerful wave regime, WECD must be placed further out into the sea. In the offshore region, more powerful swell waves can be harvested before part of its energy dissipates due to shoaling and refraction in the surf zone. Pelamis, Archimedes Wave Swing, PowerBoüy and Wave Dragon are some of the offshore WECD that are currently under development. The Pelamis was developed by Ocean Power Delivery Ltd. The Pelamis is a semi-submerged, articulated structure composed of cylindrical sections linked by hinged joints and it is ideally moored in waters approximately 50-60m in depth that allows access to the great potential of the larger swell waves [6].

ESTIMATION OF WAVE ENERGY

The potential of wave energy around the coast of East Malaysia is estimated from the wave data provided by the Malaysia Meteorological Service (MMS). The wave records are complied and published yearly in the form of a book summarising all the available wave data available throughout the year. The wave data are derived from voluntary observing ships, oilrigs and lighthouses located around the Malaysian coastline. The wave data are available from year 1985 onwards from MMS. The wind wave and swell data are presented separately on monthly charts in squares of 2-degree latitude by 2-degree longitude.

Sea depth surrounding East Malaysia is generally less than 100 m. East Malaysia has a tropical climate and the weather pattern can be classified into four different seasons, southwest monsoon, two inter-monsoon period and northeast monsoon. The southwest monsoon starts from latter half of May and ends in September. The prevailing wind flow is generally southwesterly [7]. During this period, tropical storms occur in the pacific and passing near or over the Philippines islands and toward main Asian continent. Even though tropical storm rarely passes through East Malaysia, storm system will affect the surrounding area where East Malaysia is in close proximity to the Philippines islands. The northeast monsoon usually starts in early November and ends in March. The prevailing wind flow is easterly or northeasterly.

Coastline of East Malaysia can be divided into three different parts, coastline that faces the South China Sea, Sulu Sea and Celebes Sea. Zones Z1, Z2, Z3, Z4, Z5, Z6 and part of Z7 represent area covering coastline of Sarawak and Sabah that face northwest of South China Sea as shown in Figure 2. Part of zone Z7, Z8 and part of Z9 form area covering coastline of Sabah that face Sulu Sea. Part of zone Z9 coastline faces the Celebes Sea.

Ocean waves are random in nature and hence are described by their statistical values. Two important parameters are characteristic height and characteristic period. For height, the most commonly used is the significant wave height and is defined as the average of the highest one-third waves in the given record. The characteristic period could be the mean period or the average zero crossing period. The statistical parameters can be obtained from the wave record directly in the time domain or from the frequency domain representation. Wave power for real seas can be calculated using the equation:

$$P = 0.55 H_s^2 T_z$$

where H_s is the significant wave height and T_Z is the zero up-crossing period. The multiplying factor 0.55 in the above equation depends on the shape of the wave spectrum, which normally ranges from 0.45 to 0.64 depending upon the spectral shape [8]. Baba [9] used multiplying factor of 0.55 in estimating the wave power potential for Lakshadweep, Andaman and Nicobar group of islands is that situated in the Indian Ocean.

It is known that for Malaysian waters, there is almost no information about analysis from wave record data [10]. Visually observed wave data when subjected to stochastic simulation technique have been shown to have reasonable simulated wave conditions as measured by buoy [11]. In the absence of this information, reasonable assumptions have been made in estimating the wave power around the coastline of East Malaysia using the visually observed data. The average wave height (H_a) and the average wave period (T_a) were used to calculate the wave power (P in kW/m) according to the following equation:

$$P = 0.5 (H_a)^2 T_a$$

The value of 0.5 in this case is a conservative approximation since no details of the wave spectrum are available. The annual wave height, wave period and wave power are calculated by averaging all the available records for each locations from 1985 to

2000. The mean wave directions are calculated by vector averaging all the available records.

RESULTS AND DISCUSSION

The wave power potential estimated has been grouped into various categories for better representing the wave power potential around the coastline of East Malaysia. Wave power contributions from wind waves and swell have been calculated separately. Figure 3 gives the wave power potential and mean wave direction from wind waves and have been categorized into seven divisions with 0.5kW/m interval. Wave power potential for each location is represented by the size of the circle. Larger circle indicates higher wave power potential. The mean wave direction is given by the straight line extended from the circle. Table 2 summarizes the annual wind wave height and period and also the mean wind wave height and period during the northeast and southwest monsoon periods. The wind wave conditions in East Malaysia are normally around 1.0m with wave period of 2.5 to 4.0s. During the northeast monsoon, the mean wind wave direction for all locations except for zones Z8 and Z9 is northeasterly. Mean wind wave direction for zones Z8 and Z9 is northwesterly. In the southwest monsoon, the wind wave direction is southwesterly for all locations. Figure 4 represents the wave power potential and mean wave direction from swell, which have been categorized into four divisions with interval of 2.0kW/m. Table 3 summarizes the annual swell height and period and also the mean swell height during northeast monsoon and southwest monsoon periods. The swell around the East Malaysia is normally around 1.0 to 1.5m and swell period of 4.5s. In South China Sea, waves of 9.0m have been recorded in the period of 1985-2000. The mean swell direction during the northeast monsoon period is northeasterly except for zones Z8 and Z9, which are northwesterly and southeasterly respectively. During the southwest monsoon, the mean swell direction is around southwest to west direction.

From the 16 years of data analysed, the wave power level did not show any significant trend of increase or decrease in wave power around the East Malaysia coastline. In zone Z1, the average wind wave power is around 1.0kW/m to 2.0kw/m. But in year 1995 wind wave power is of the order of 13.8kW/m and in year 1998 the wind wave power is of the order of 4.0kW/m. The swell wave power level in Z1 is around 3.0kW/m to 7.0kW/m. In zone Z2, the wind wave power is around 1.0kW/m except for the year 1993, 1998, 1999 and 2000 where the wind wave power is 2.0kW/m, 2.3kW/m, 4.6kW/m and 2.5kW/m respectively. As for the swell wave power level, it is around 3.0kW/m to 10.0kW/m. The highest was in the year 2000, with swell wave power of 21.8kW/m. In zone Z3, the wind wave power level is around 1.5kW/m. The swell wave power level is around 3.0kW/m to 6.0 kW/m and the highest is in the year 1993 of the order of 18.8kW/m. In zone Z4, the wind wave power level is around 2.0kW/m and the swell wave power level around 4.0kW/m. In zone Z5, the wind wave power level is around 1.5kW/m and the swell wave power level around 5.0kW/m. In 1993, the wave power level is at it highest for this zone at 11.6 kW/m. In zone Z6, the wind wave power level is around 1.5kW/m and the swell wave power is around 4.0kW/m. In zone Z7, the wind wave power level is around 1.5kW/m and the swell wave power level is around 5.0kW/m. In zone Z8, the wind wave power level is around 1.0kW/m and swell wave power level of around 5.0kW/m. In zone Z9, the wind wave power level is around 0.5kW/m and swell wave power level around 3.0kW/m.

The general annual wave power level is 0.5 to 2.0kW/m from wind waves and 2.0 to 6.0kW/m from swell. The lowest annual wave power potential is in zone Z9, which has 0.8kW/m for wind waves and 2.9kW/m for swell. Zone Z9 is situated in the Celebes Sea. It is surrounded by islands, namely the Borneo island and the Suluwesi island and the Philippines islands. These islands diminish the wave energy received around the Celebes Sea. Coastlines that face the South China Sea has higher wave power level when compared to other places in East Malaysia. For example, for zone Z1, the annual wave power level is 2.0kW/m for wind waves and 4.7kW/m for swell that is two times higher than zone Z9. In zone Z4, the annual wave power level is 2.1kW/m from wind waves and 4.1kW/m for swell. The coastline that faces South China Sea are situated in the southern end of the South China Sea. This also explains that during the northeast monsoon period, higher wave energy is received in this period than other periods of the year. During the northeast monsoon period, zone Z4 receives a mean wave power of 3.6kW/m from wind waves and 5.8 kW/m from swell. However, during the southwest monsoon period, the mean wave power received is 1.0kW/m from wind waves and 3.0kW/m from swell. Annual wave power level for coastlines that face the Sulu Sea are 1.4kW/m for wind wave and 5.1kW/m for swell. Coastline bordering the Sulu Sea also receives higher wave energy during the northwest monsoon period where mean wave power of 2.0kW/m for wind wave and 7.1kW/m for swell. During the southwest monsoon, the mean wave power is 1.0kW/m for wind wave and 3.2kW/m for swell.

CONCLUSION

The highest wave power potential in the East Malaysia is along coastline facing the South China Sea, especially coastline of Sarawak near Miri (zone Z4). In Z4 the annual wave power is of an order of 2.1kW/m for wind wave and 4.1kW/m for swell. The amount of wave energy received by the East Malaysia varies with the

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Table 1: Installed capacity of power plants in East Malaysia (MW) as of 31-12-2001. (Annual Report, 2001)

	SESCo	SESB	IPPs Sarawak	IPPs Sabah	Total	%
Steam						
Coal	0.0	0.0	100.0	0.0	100	6.0
Gas	0.0	60.0	0.0	0.0	60	3.6
Oil	0.0	106.0	0.0	0.0	106	6.4
Hydro	94.0	66.0	0.0	0.0	160	9.7
Mini Hydro	7.3	6.3	0.0	0.0	13.6	0.8
Diesel/LFO	75.0	74.2	0.0	170.0	319.2	19.3
Rural Diesel	27.6	3.9	0.0	0.0	31.5	1.9
Combined-cycle	0.0	44.0	0.0	0.0	44	2.7
Gas Turbine						
Diesel/Oil	64.0	0.0	0.0	0.0	64	3.9
Gas	290.9	127.0	218.0	120.0	755.9	45.7
Total	558.9	487.4	318.0	290.0	1654.3	100.0
Percentage	33.8	29.5	19.2	17.5	100.0	

Table 2: Average wind wave height and period.

Location	Annual wave height (m)	Annual wave period (s)	Mean wave height during NE monsoon (m)	Mean wave period during NE monsoon (s)	Mean wave height during SW monsoon (m)	Mean wave period during SW monsoon (s)
Z1	0.9	2.6	1.0	2.9	0.8	2.5
Z2	0.9	2.6	1.0	2.8	0.7	2.3
Z3	0.8	3.8	1.1	4.3	0.7	3.5
Z4	0.9	4.2	1.2	4.7	0.7	3.7
Z5	0.8	3.7	1.0	4.0	0.8	3.5
Z6	0.9	3.7	1.1	3.9	0.8	3.5
Z7	0.8	4.3	0.9	4.5	0.8	4.2
Z8	0.8	2.6	1.0	2.7	0.7	2.5
Z9	0.7	2.4	0.8	2.6	0.7	2.3