Wave energy potential around West Malaysia

E.P.Chiang [a], P.A. Aswatha Narayana [b,**] and Z. A. Zainal [b]

[a] Post graduate research student, University Science Malaysia, School of Mechanical Engineering, Nibong Tebal, Penang, 114300, Malaysia

** Associate Professor. University Science Malaysia, School of Mechanical Engineering, Nibong Tebal, Penang, 114300, Malaysia

Abstract

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. Major development of renewable energy in Malaysia is concentrated in biomass and solar energy. This paper introduces ocean wave as another type of renewable and clean energy source that is available around the West Malaysian coastline. The potential of the ocean wave energy resource have been estimated and presented.

Keywords: West Malaysia, Alternative energy, Ocean wave energy.

1 INTRODUCTION

West Malaysia is situated in the southern portion of the Malay Peninsula between latitudes 1^0 to 6^0 north and between longitudes 100^0 to 104^0 east and is surrounded by water on three sides, South China Sea to the east. Strait of Melacca to

* Corresponding author. Tel.: 60-04-5937788, ext 6319; fax: 60-04-5941025. E-mail addresses: [illegible] (P.A. Aswatha Narayana)

the west and Strait of Johore separating West Malaysia with Singapore. It is connected to the rest of Asia through South Thailand in the north. It covers an area of 131,587 sq km. The population of Malaysia is around 25.1 million with 80% 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 electricity utilities in West Malaysia are operated mainly by Tenaga Nasional Berhad (TNB) and Independent Power Producers (IPP). TNB undertakes the responsibility of transmission and distribution of electric supply. Table 1 gives the total installed capacity of power plants in West Malaysia. At the end of year 2001, the total installed capacity in West Malaysia is 13,158.9MW. The generation capacity development up to year 2005 will be of installed capacity of 20,320 MW. The IPP generation constitutes about 40 % of the total installed capacity by year 2005. Projected power production forecast that the electricity consumption would grow at an average annual growth rate of 8.87% from year 2000 till2010. It is forecasted the peak demand will increase from 9,712 MW in 2000 to 14,547 MW in 2005 and 21,668 in 2010 [2]. With the exception of hydro. the rest are non-renewable and emit green house gases during operation. The government has encouraged the development of renewable energy as a fifth source of fuel along with the current four in the future planning. The target for the renewable energy is to contribute 5% of generation capacity by 2005 and 10% by 2010.

This paper aims to estimate a form of renewable energy source which is easily available around the West Malaysia coastline. Ocean waves are a 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 2TW [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, PowerBouy 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].

2 ESTIMATION OF WAVE ENERGY

The potential of wave energy around the coast of West Malaysia was 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 summarizing all the available wave data 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 the 1985 onwards. 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 West Malaysia is generally less than 100 m. West Malaysia has a tropical climate and the weather pattern can be classified into four different seasons, southwest monsoon, two inter-monsoon periods and northeast monsoon. The southwest monsoon starts from latter half of May and ends in September. The prevailing wind flow is generally southwesterly. The northeast monsoon usually starts in early November and ends in March. The prevailing wind flow is easterly or northeasterly [7]. The east coast of West Malaysia is separated from the west coast by mountain ranges in the middle of the Malay Peninsula. Seven zones are identified based on the data available from the MMS as seen in Figure 2. Zones Z1, Z2 and Z3 represent areas covering coastline that face the Strait of Melacca from the north to the south respectively. Zones Z4, Z5, Z6, and Z7 represent areas covering the coastline that face east of South China Sea with zone Z4 situated furthest to the north.

Ocean waves are random in nature and hence are described by their statistical properties. 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 is calculated using the equation below:

$$P = 0.55 H_s^2 T_z$$

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 that is situated in the Indian Ocean.

It is known that for Malaysian waters, there is almost no information about analysis from wave record data (Omar. Y., 2003, personal communication). Visually observed wave data when subjected to stochastic simulation technique have been shown to have reasonable simulated wave conditions as measured by buoy [10]. In the absence of this information, reasonable assumptions have been made in estimating the wave power around the coastline of West Malaysia. 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:

$$P = 0.5 \text{ X } (H_a)^2 \text{ X } T_a$$

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 location from the year 1985 to 2000. The mean wave directions are calculated by vector averaging all the available records

3 RESULTS AND DISCUSSION

The wave power potential calculated has been grouped into various categories for better representation of the wave power potential around the coastline of Malaysia. Wave power contribution from wind waves and swell were calculated separately. Figure 3 gives the wave power potential and mean wave direction from wind waves and was categorized into six divisions with 0.5kW/m interval. Wave power potential for each location are represented by the size of the circle. larger circle indicates higher 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 the mean wind wave height and period during the northeasterly and southwesterly monsoon period. The wind wave condition in West Malaysia is normally around 1.0m with wave period of 2.0 to 3.0s. During the northeasterly monsoon period, the wind wave direction is northeasterly for zones Z1. Z3, Z4, Z5, Z6 and Z7. Mean wind wave direction for Z2 during the northeasterly monsoon is northwesterly. In the southwest monsoon period, the mean wind wave direction is southwesterly for all the zones except for zone Z7. Mean wind wave direction for Z7 is southerly. Figure 4 gives the wave power potential and mean wave direction from swell, which have been categorized into five 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 period. The swell around the West Malaysia is normally around 1.0m.Annual swell conditions for the east coast is around 1.3m. During the northeast monsoon period. swell around the east coast is higher compared to other months with values around 1.3 to 1.8m. Swells of 6.0m have been recorded in the sea around the east coast during the northeast monsoon period. During the northeast monsoon period, the swell direction for zones Z1, Z4, Z5, Z6 and Z7 is northeasterly. Meanwhile, zones Z2 and Z3 are northwesterly. In the southwest monsoon period, the mean swell direction for zones Z1, Z3 and Z4 is northwesterly. Mean swell direction for zones Z2, Z5 and Z6 is southwesterly, while mean swell direction for Z7 is southeasterly.

From the 16 years of data analyzed, the wave power levels do not show any significant trend of increase or decrease in wave power around the West Malaysia coastline. In zone Z1, wave power level is around 0.5kW/m for wind wave and 2.0kW/m for swell. In zone Z2 wave power level is around 0.5kW/m for wind wave and 2.0kW/m for swell except for the years 1999 and 2000, wave power level increases to 1.8kW/m for wind wave and 3.4kW/m for swell. In zone Z3, wave power level is also around 0.5kW/m for wind wave and 2.0kW/m for swell. However, in the year 1998, wave power level increased to 2.9kW/m for wind wave and 6.1kW/m for swell. In the year 1996, wave power level for swell has almost reached 10.0kW/m. In zone Z4, wave power level is around 1.0kW/m to 2.0kW/m for wind wave and 3.0kW/m to 8.0kW/m for swell. The highest wind wave power level is 7.3kW/m which has recorded for the year 1995. In the same year, the highest swell wave power level of 13.7kW/m was recorded for this zone. In zone Z5, wind wave power level is around 1.0kW/m to 3.0kW/m. The swell wave power level at Z5 is around 3.0kW/m to 8.0kW/m. In zone Z6, wind wave power level is around 1.0 kW/m. Meanwhile, the swell wave power level is around 3.0kW/m to 6.0kW/m. In zone Z7, wind wave power level is around 1.0kW/m and the swell wave power level is around 2.0kW/m to 5.0kW/m.

The general annual wave power level is around 0.5 to 2.0kW/m from wind waves and 2.0 to 6.0kW/m from swell. The east coast has higher wave power potential when compared to the west coast. Zones 4 and 5 have higher potential than the other zones especially during the northeast monsoon period. Zones 4 and 5 cover the coastline of Kelantan and Terengganu states. The annual wave power potential for Z4 and Z5 are 1.7 and 2.0kW/m for wind waves and 6.3 and 5.3kW/m for swell respectively. During the northeast monsoon, the wave power level for Z4 and Z5 are 2.8 and 2.9kW/m for wind waves and 10.2 to 7.6kW/m for swell. During the southwest monsoon, the wave power level for Z4 and Z5 are 0.9 and 1.5kW/m for wind waves and 2.2 and 3.7kW/m for swell respectively. The east coast receives higher wave energy during the northeast monsoon because it is situated in the southern end of the South China Sea. During this period, the predominant wind is the northeasterly wind that passes over the South China Sea first before hitting the coastline of east coast. This allows the wind to transfer more energy to the sea surface and create larger waves before passing over landmass. But during the southwest monsoon, the sheltering effect of the Malay Peninsula and also the Sumatra Island limit the energy received during this period of time. The west coast has lower wave energy potential because of it location situated in the middle of the Sumatra Island and the Malay Peninsula. These two landmasses shelter the west coast from wind moving over open sea that creates sea waves. In general, the wave power level for the west coast is 0.5kW/m for wind waves and 2.0kW/m for swell.

4 CONCLUSION

The highest wave power potential in the West Malaysia is off the coast of Kelantan and Terengganu (zones Z4 and Z5). The annual wave power that is available

REFERENCES

1 Annual Report. National Energy Balance Malaysia 2001. Selangor, Malaysia: Pusat Tenaga Malaysia, 2001.

2 ASEANenergy.org. Malaysia Electricity Sector: Tenaga National Bhd. ASEAN Centre for Energy, 2004. See also: http://www.aseanenergy.org/energy_sector/electricity/malaysia/tnb/introduction.htm

3 WEC. 1993. Renewable energy resources: opportunities and constraints 1990-2020". World Energy Council, London, June 1993

4 Thorpe, T.W. An Overview of Wave Energy Technologies: Status, Performance and Costs. Wave power: Moving towards Commercial Viability, 30 November 1999, Broadway House, Westminster, London.

5 Clement, A.. McCullen, P.. Falcao. A., Fiorentino, A..Gardner, F., Hammarlund, K., Lemonis. G., Lewis, T.. Nielsen, K., Petroncini, S.. Pentes, M. T., Schild, P., Sjostrom, B.O.. Sorensen. H. C., Thorpe, T. Wave energy in Europe: current status and perspectives. Renewable and Sustainable Energy Reviews, 6 (2002) 4005-431.

6 OPD. The Pelamis Wave Energy Converter. Endinburgh, UK: Ocean Power Delivery Limited, 2004. See also: http://www.oceanpd.com/Pelamis/default.html

7 MMS. General Climate of Malaysia. Selangor, Malaysia: Malaysian Meteorological Service, 2004. See also: http://ww.kjc.my/english/education/climate/climate01.html

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

	TNB	IPPs	Total	%
Steam				
Coal	1,600.0	0.0	1.600.0	12.2
Gas	1,200.0	0.0	1,200.0	9.1
Oil	360.0	0.0	360.0	2.7
Hydro	1,898.0	20.0	1,918.0	14.6
Mini Hydro	11.9	15.0	26.9	0.2
Diesel/LFO	0.0	0.0	0.0	0.0
Rural Diesel	0.0	0.0	0.0	0.0
Combined-cycle	1,721.0	3,580.0	5,301.0	40.3
Gas Turbine				
Diesel/Oil	68.0	0.0	68.0	0.5
Gas	1,805.0	880.0	2.685.0	20.4
Total	8,663.9	4,495.0	13158.9	100.0
Percentage	65.8	34.2	100.0	

Table 2: Average wind wave height and period 1985-2000.

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	0.7	1.9	0.7	2.0	0.7	1.9
Z2	0.7	2.0	0.7	1.9	0.7	2.0
Z3	0.7	2.2	0.8	2.2	0.7	2.2
Z4	0.9	2.7	1.1	2.9	0.7	2.4
Z5	1.1	2.7	1.3	3.0	1.0	2.5
Z6	0.9	2.3	1.0	2.6	0.8	2.2
Z7	0.8	2.4	0.9	2.6	0.8	2.3

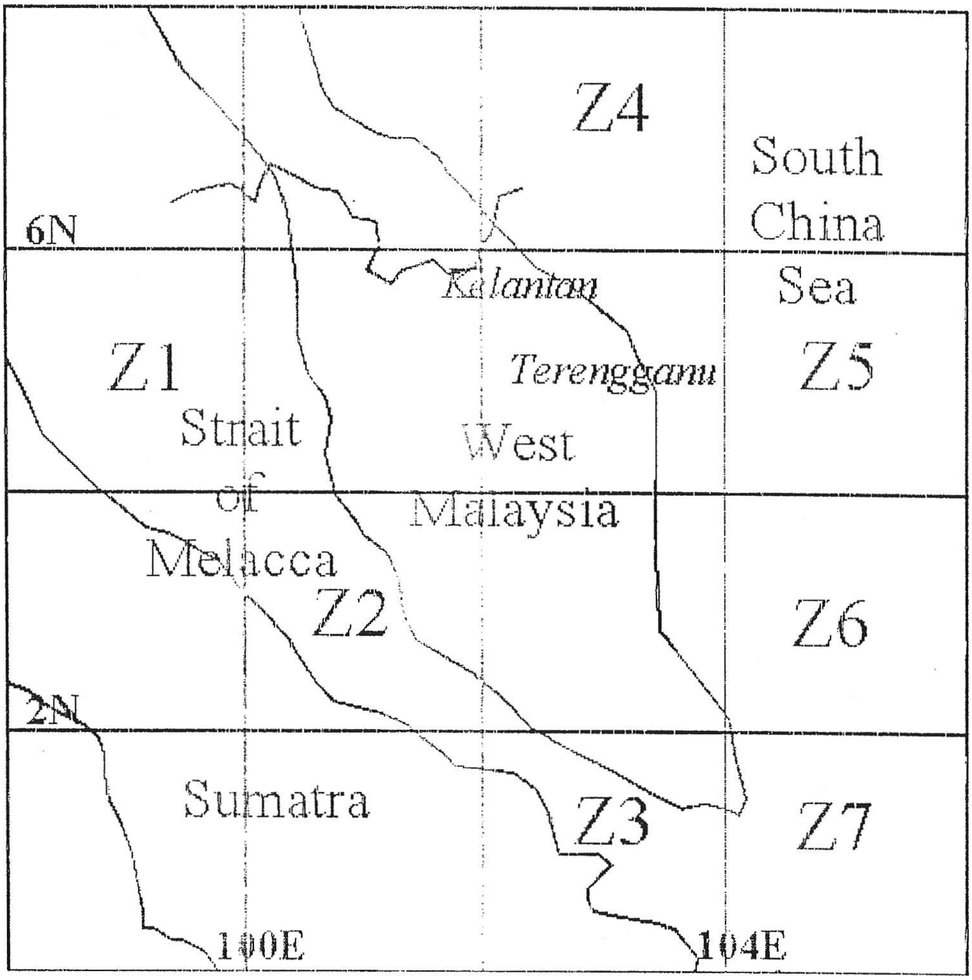

Figure 2: Map of West Malaysia.