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POTENTIAL OF RENEWABLE WAVE AND OFFSHORE WIND ENERGY SOURCES IN MALAYSIA

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Abstract

Malaysia is a country vastly surrounded by water. Wave power and offshore wind power has been recognised by the international community as a renewable clean energy source. Analysis was conducted for the potential of wave energy and wind energy along the coastline of Malaysia from the data obtained by the Malaysia Meteorological Service (MMS) from 1985 to 2000. The Malaysian coastline has been divided into four major zones, east peninsular Malaysia, west peninsular Malaysia, Sarawak and Sabah. The wind waves, swells and wind characteristics (maximum wind wave height / period / direction, average wind wave height / period, maximum swell height / period / direction, average swell height / period and vector resultant wind direction / speed) were analysed. Locations situated in the South China Sea has the most promising site for wave power potential, with the highest energy resource available in the months of November to February, which coincide with northeast monsoon season. The annual wave power is below 5.0 kW/m. The offshore wind energy resource for this region also shows the same trend as the wave energy. The highest potential is in the east peninsular Malaysia with annual vector resultant wind speed of 4.1 m/s.

Keywords: Wave energy, Offshore wind energy, Malaysia

Introduction

Malaysia is a country mostly surrounded by water. Geographically, Malaysia can be divided into West Malaysia and East Malaysia. West Malaysia consists of peninsular Malaysia which can further be divided into east peninsular Malaysia and west peninsular Malaysia. Peninsular Malaysia is located roughly between 1^0 and 6^0 latitude north and between 100^0 and 104^0 longitude east. It is bordered by Thailand in the north; the South China Sea on the east side, while the Straits of Malacca on the west coast separates the peninsula from Sumatra. East Malaysia is located on the north and northwest side of the island of Borneo with Sabah occupied in the northern half and Sarawak situated in the west. East Malaysia is bordered by the South China Sea along its northwest coast, by the Sulu Sea and Celebes Sea at the northeast section of Sabah, while on the south side, it has a common boundary with Kalimantan (Indonesia).

In recent times, search for alternative and renewable sources of energy has intensified all around the world. Types of alternative and renewable sources of

energy are solar energy, wind energy, ocean wave energy, geothermal energy and biogas. In view that Malaysia is mostly surrounded by water, the potential for an ocean based energy source could help supplement the present conventional energy sources for Malaysia in the future. The worldwide estimated wave energy resource is more than 2 TW. Among the ocean based energy systems that are available or in research stage are Ocean Thermal Energy Conversion (OTEC), tidal power, ocean current, wave power and offshore wind power. Offshore wind speeds are generally higher than coastal wind speeds, hence higher available energy resource. The estimated offshore wind potential in European waters alone is in excess of 2500 TWh/annum,. Offshore area also provides larger area for deploying wind energy devices. The development of offshore wind energy is concentrated in the European nations. Denmark, Sweden, Belgium, the Netherlands, Germany and the United Kingdom have already built wind turbines in marine environments, either in the sea or on harbour breakwaters.

In Malaysia, study on ocean based energy sources is still in the infant stage. Hence a study on the potential of wave and wind energy along the coastline of Malaysia has been taken up to estimate the available resource potential.

Analysis of the Data

The climatology of ocean waves and wind is based on the monthly summary of marine meteorological observations published by the Malaysian Meteorological Service (MMS), covering the period of 1985-2000 [1]. The wave and wind data collected are derived from marine surface observations reported by ships which participated in the World Meteorological Organization Voluntary Observation Ships Scheme, oilrigs and lighthouses. The data provided by the MMS is presented on monthly charts with individual values in squares of 2-degree latitude by 2-degree longitude.

For this study, 16 locations were chosen based on the nearest sea grid to Malaysian coastline. Each location is a square of $2^0 \times 2^0$. Numbers from 1 to 16 were given to label each location (Figure 1.). Grids 1, 2, 3, and 4 represent area covering the east peninsular Malaysia coastline situated in the South China Sea. Grids 5, 6 and 7 represent area covering the west peninsular coastline situated in the Straits of Melacca. Grids 8, 9, 10 and 11 cover coastline in Sarawak that faces the South China Sea. Grids 12, 13 and 14 cover coastline of Sabah that face the South China Sea and grids 15 and 16 cover coastline of Sabah that face Sulu Sea and Celebes Sea respectively.

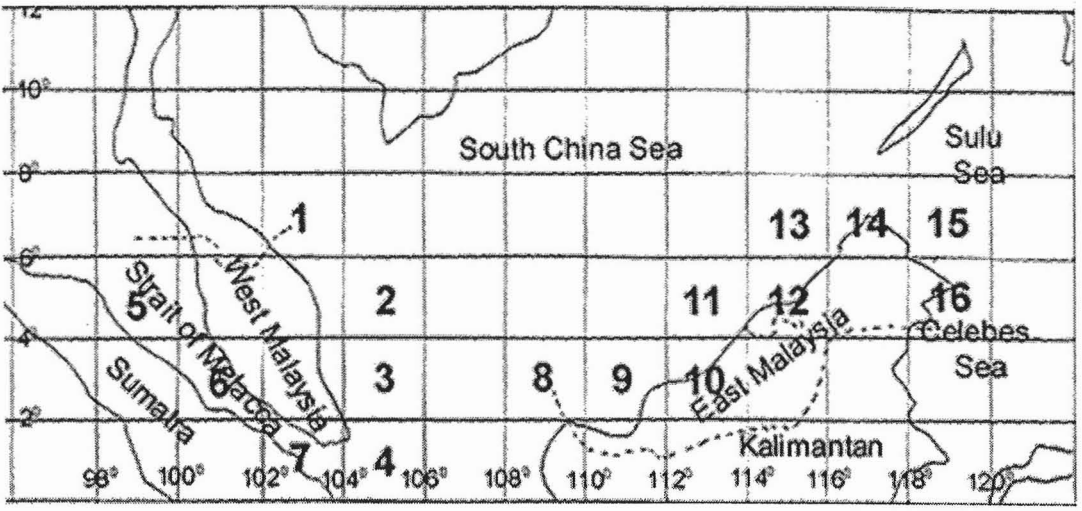

Figure 1. Map of Malaysia with study locations.

The monthly wind waves, swells and wind characteristics data from January to December for the period of 16 years (1985-2000) were keyed into the computer for analysis. The wind waves, swells and wind characteristics that were considered are, maximum wind wave height / period / direction, average wind wave height / period, maximum swell height / period / direction, average swell height / period and vector resultant wind direction / speed. From the number of observations for each grid, grids 2, 3, 4, 5, 6, 11, 12, 13 and 14 contained the most data sampling. With grids 1, 7, 8, 9, 10, 15 and 16 have fewer data sampling. It is common to find zero or less than five observation in a month reported for the latter locations. The higher sampling density is associated with the main shipping routes.

From the wind waves and swell characteristics, the average and maximum power available in the waves was calculated for each location. Power available in the waves or wave power is the rate of energy transfer per unit area per unit crest width across a plane normal to wave propagation, is calculated using the equation [2,3].

$$P = 0.55 \times H_s^2 \times T_z \text{ kW/m}$$

where H_s is the significant wave height and T_z the zero-up-crossing wave period. In this study, assumption was made that the visually observed average wave height values as compiled by the MMS are equal to H_s and average wave period equal to T_z, since the analysis of wave record data for Malaysia is not available.

Results and Discussion

Wave characteristics

Wave condition in Malaysia is influenced by the northeast monsoon and the southwest monsoon wind. Higher average wind waves of 1.0 to 1.5 m occur during the northeast monsoon season from the months of November to March. The corresponding average period is around 2.5 to 5.0 s. Higher wind waves of 2.5 to 3.0 m are more likely to occur in the middle of the northeast monsoon

period (December and January). It is to be noted that MMS data are largely derived from VOS which would avoid rough sea conditions. In the southwest monsoon season from June to September, the average wind waves between 0.7 to 1.1 m in height with the corresponding period averaging around 2.0 to 4.0 s. The maximum height of wind wave during this period is around 2.0 m. In the months in between the two monsoon periods (April, May and October), the height of the wind waves are around 0.7 m and with the corresponding period of 2.0 to 4.0 s. The maximum height of wind wave in this period is around 2.0 m. This shows that the wind waves heights in Malaysian waters especially in the areas facing South China Sea has peak (northeast monsoon season) and valley (period in-between the two monsoon seasons). But for areas in the west peninsular Malaysia (grids 5, 6 and 7), wind waves average less than 1.0 m in height throughout the year because of it location situated between the Sumatra island and the mountain ranges of Peninsular Malaysia. The corresponding period varies between 2.0 to 3.0 s throughout the year. The maximum wind waves of 1.5 to 2.0 m usually occur during the months in between the two monsoon seasons.

Similar behaviour occurs for the swell conditions in Malaysian waters. Swell of 1.5 to 2.0 m occur during the northeast monsoon season. The corresponding period average around 4.0 to 5.0 s, with maximum swell of 2.5 to 3.0 m likely to occur in the middle of the northeast monsoon period. In the southwest monsoon season, swell averages between 1.0 to 1.5 m in height with the corresponding period averaging around 4.0 to 5.0 s occurring during this period. The maximum height of swell during this period is around 2.0 to 2.5 m. In the months in-between the two monsoon periods, the swell height is around 1.0 to1.5 m and with the corresponding period of 4.0 to 5.0 s. The maximum height of swell in this period is around 2.0 to 2.5 m. But for areas in the west peninsular Malaysia (grids 5, 6 and 7) swell average around 1.0 m in height throughout the year, with maximum swell of around 2.0 m in height. The corresponding period is 3.5 to 4.5 s.

The directions of wave in Malaysia are influenced by the monsoon wind. In the northeast monsoon period, the predominant wave direction is from the east quadrant for locations in the east peninsular Malaysia, Sarawak and Sabah except for west peninsular Malaysia which is from the south quadrant. In the months of April to May, the wave direction gradually changes from east to southwest quadrant. In the southwest monsoon period, the wave direction is from the southwest quadrant for all locations. In October, predominant wave direction is from the southwest quadrant.

Wave power

From the data obtained, wave power for each location was calculated. Table 1 shows the average wave power calculated from wind wave for each month from year 1985 to 2000. Table 2 shows the average wave power calculated from swell from year 1985 to 2000. In the months of November to February, wave power of around 2.0 kW/m (wind wave) and 6.0 to 12.0 kW/m (swell) is observed in the east peninsular Malaysia. For regions in Sarawak and Sabah, the available wave power is lower than in the east peninsular Malaysia. But in the months of July to October, the available wave power in Sabah and Sarawak is higher when

compared to other regions in Malaysia, which have a potential of 3.0 to 5.0 kW/m (swell). In west peninsular Malaysia, the wave power available is in the region of 0.5 kW/m (wind wave) and 2.0 kW/m (swell) throughout the year.

Month	East Peninsular Malaysia				West Peninsular Malaysia			Sarawak				Sabah				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Jan	2.0	3.1	2.0	1.8	0.5	0.5	0.7	1.9	1.6	3.1	4.6	2.0	2.8	2.0	1.7	1.1
Feb	1.8	2.2	1.3	1.1	0.5	0.4	0.5	1.2	1.6	2.1	2.7	1.4	2.0	1.4	1.8	1.1
Mar	1.1	1.3	0.7	0.8	0.6	0.4	0.4	0.9	1.5	1.6	1.8	1.3	1.5	1.1	0.9	1.1
Apr	0.4	0.7	0.3	0.5	0.4	0.5	0.4	0.4	0.7	0.7	0.8	0.8	0.9	0.8	0.4	0.4
May	0.4	0.9	0.6	0.5	0.4	0.5	0.5	0.6	0.4	0.7	0.6	0.6	0.9	0.9	0.6	0.5
Jun	0.5	1.2	0.6	0.7	0.4	0.5	0.5	0.6	0.9	0.8	0.9	1.1	1.2	1.4	0.7	0.2
Jul	0.5	1.6	1.0	0.7	0.4	0.6	0.5	1.0	0.8	0.8	1.0	1.1	1.5	1.6	0.8	0.5
Aug	0.9	1.7	1.0	0.8	0.6	0.7	0.7	0.8	0.6	0.9	1.1	1.2	1.2	1.6	0.8	0.6
Sep	1.5	1.2	0.6	0.8	0.4	0.6	0.4	1.3	0.6	0.9	1.0	1.0	1.1	1.3	0.7	0.7
Oct	0.7	1.1	0.6	0.5	0.5	0.6	0.6	0.6	0.7	1.2	1.7	1.4	1.6	1.6	0.8	0.3
Nov	2.3	2.2	0.9	0.7	0.5	0.6	0.9	1.6	1.0	2.7	3.1	1.7	1.8	2.0	0.8	0.7
Dec	1.9	5.1	2.6	1.9	0.5	0.5	0.6	1.6	2.3	3.0	5.0	2.8	3.3	2.5	1.2	0.5
Mean	1.1	1.9	1.0	0.9	0.5	0.5	0.5	1.0	1.0	1.5	2.0	1.4	1.6	1.5	0.9	0.6

Table 1. Monthly mean wind wave power in kW/m.

Month	East Peninsular Malaysia				West Peninsular Malaysia			Sarawak				Sabah				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Jan	11.8	7.9	8.6	5.7	2.2	1.9	0.7	7.6	7.5	3.2	5.8	5.4	5.7	5.4	11.9	3.1
Feb	10.8	5.8	6.7	3.5	1.9	1.0	0.8	4.5	5.1	5.5	3.8	4.6	4.9	3.5	5.0	2.5
Mar	5.4	3.8	3.9	2.9	1.4	1.3	1.8	3.5	3.0	3.9	3.5	2.7	3.8	4.2	4.2	3.6
Apr	2.9	2.8	1.9	1.2	1.7	1.0	1.4	1.3	1.6	0.8	1.5	2.5	2.3	1.8	1.5	1.0
May	1.1	1.9	1.9	1.1	2.1	1.3	1.2	1.6	0.8	1.1	2.0	1.1	1.9	3.5	2.4	1.1
Jun	1.6	2.1	2.1	2.3	2.4	1.8	0.9	1.4	2.8	2.4	2.2	3.6	3.1	4.4	2.4	0.6
Jul	1.8	3.9	3.3	2.3	2.7	2.2	1.6	3.0	5.3	3.3	4.0	4.7	5.1	5.4	3.3	2.5
Aug	2.0	2.9	3.8	2.8	2.6	2.3	1.9	2.5	2.5	2.9	3.0	4.7	4.6	4.1	2.0	4.3
Sep	1.8	2.3	2.1	2.5	1.5	2.2	0.8	1.5	2.2	1.2	2.3	3.5	3.3	3.6	1.2	1.2
Oct	1.9	2.5	2.8	1.9	2.1	1.7	2.7	4.0	4.1	2.3	2.9	3.6	4.5	3.8	2.5	1.5
Nov	6.0	5.0	5.0	2.3	2.5	2.3	0.8	6.3	5.2	5.9	4.2	4.8	5.0	5.3	2.6	2.0
Dec	6.6	11.2	9.5	6.9	2.6	2.0	2.6	9.4	13.3	5.1	8.2	8.6	8.1	5.8	5.3	1.8
Mean	4.5	4.3	4.3	3.0	2.1	1.8	1.4	3.9	4.5	3.1	3.6	4.2	4.4	4.2	3.7	2.1

Table 2. Monthly mean swell wave power in kW/m.

The mean wave power for locations situated in the west peninsular Malaysia is in the region of 0.5 to 2.0 kW/m. In the east peninsular Malaysia, the mean available wave power is in the region of 1.0 to 12.0 kW/m depending upon the season, with the higher wave power occur during the northeast monsoon

season. In Sabah and Sarawak, the available mean wave power, is in the region of 1.0 to 8.0 kW/m.

Offshore wind characteristics

The mean wind speed over the sea surface around the sea surrounding Malaysia is generally below 5 m/s. From table 3, it is observed that the highest wind speed is in east peninsular Malaysia for grids 1, 2, 3 and 4, grid 8 in Sarawak and in Sabah at grid 13. Wind speed at these locations reach above 5 m/s during the northeast monsoon season and for the rest of the year wind speed is low. The direction of the wind is from the northeast and east quadrant during the northeast monsoon season and south and southwest quadrant during the southwest monsoon season.

Month	East Peninsular Malaysia				West Peninsular Malaysia			Sarawak				Sabah				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Jan	5.8	6.8	6.7	5.7	2.4	0.7	2.2	5.7	3.8	2.5	3.9	4.0	6.8	4.0	3.1	2.7
Feb	4.8	5.3	5.4	4.6	1.6	0.7	2.4	4.7	3.8	2.2	3.4	3.7	6.2	4.2	5.7	1.9
Mar	3.9	4.0	3.8	3.3	1.4	1.0	1.4	3.8	2.5	1.9	2.6	2.8	5.2	4.0	3.6	2.3
Apr	2.7	2.0	1.7	1.1	1.2	0.9	1.4	1.2	1.2	0.9	0.9	1.3	2.9	2.2	0.5	1.3
May	2.2	2.5	2.1	1.6	1.0	1.0	1.6	1.4	1.2	0.8	0.7	1.2	1.6	1.5	0.0	1.4
Jun	3.1	3.4	3.1	2.6	1.4	1.5	1.9	2.2	1.0	0.6	1.2	1.6	2.7	2.5	2.6	1.7
Jul	2.4	4.9	4.3	3.7	1.3	2.1	2.2	3.2	1.5	1.2	1.7	1.7	3.5	2.8	3.5	1.6
Aug	3.9	4.8	4.5	3.7	1.6	1.4	1.9	2.9	1.2	1.5	2.0	2.4	4.4	3.5	2.1	2.8
Sep	3.3	3.5	3.3	3.0	0.9	0.8	1.3	2.9	1.6	1.1	1.2	8.7	2.9	2.7	0.0	1.9
Oct	0.0	1.1	1.7	2.7	1.6	1.2	1.5	2.7	1.5	1.0	1.9	1.7	2.8	2.7	3.1	1.2
Nov	5.1	3.6	2.7	2.3	2.1	1.7	2.2	1.6	1.4	1.3	1.2	1.9	2.4	2.1	3.1	1.8
Dec	5.1	7.6	5.9	5.0	2.4	1.5	2.9	4.6	2.5	1.4	1.7	2.1	4.3	2.8	4.3	3.1
Mean	3.5	4.1	3.8	3.3	1.6	1.2	1.9	3.1	1.9	1.4	1.9	2.8	3.8	2.9	2.6	2.0

Table 3. Monthly vector resultant mean wind speed in m/s.

Conclusion

The available wave power around the sea surrounding Malaysia has been calculated and tabulated from data obtained from MMS derived from visual wave data from 1985 to 2000. The corresponding wind speeds have also been estimated. It can be concluded that the available annual wave power in waters surrounding Malaysia is below 5.0 kW/m with the highest annual wave power is in east peninsular Malaysia that face the South China Sea with a potential of 4.5 kW/m. The available wave power changes with season, with the highest occur during the northeast monsoon season and lowest in the months in between the two monsoon seasons. The annual offshore wind speed is around 1.2 to 4.1m/s for Malaysian waters, with higher values occurring in the east peninsular Malaysia having 3.3 to 4.1 kW/m.

The present analysis is largely based on VOS, which have been shown to have errors during taking and reporting of the observation data [4]. Data corrections based on recommendations presented in paper by Gulev et al [4], can be used in future to improve the results.

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