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Estimation of Electrical-Wave Power in Merang Shore, Terengganu, Malaysia

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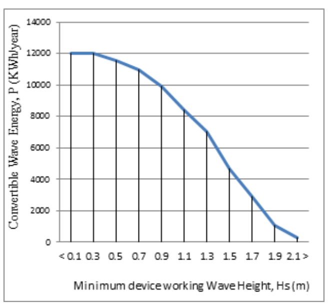
Graphical abstract



Abstract

Malaysian government introduced Small Renewable Energy Power (SREP) Program such as biomass, biogas, and municipal solid waste, solar photovoltaic and mini-hydroelectric facilities in 2001. In year 2010, the energy generated by biomass was achieved 18 MW and mini hydro also successes to generate around 23 MW. Green Technology and Water Malaysia are targeted by Ministry of Energy to achieve cumulative renewable energy capacity around 2080 MW at year 2020 and 21.4 GW at year 2050. This paper discusses the possibility to utilize ocean wave in Merang shore, Terengganu, Malaysia. The literature reviewed available technologies used to convert wave energy to electricity which are developing currently. The available technologies reviewed here are attenuator, overtopper, point absorbers, oscillating wave surge converter and oscillating water column. The work principle of the device was covered. Finally, the sea condition in Malaysia also studied to analyze the possibility to utilize the wave energy by using the available technologies. It is found that the mean wave height is 0.95 meter and the mean wave period is 3.5 second in the Merang shore, Terengganu, Malaysia. Attenuator type wave converter developed by Wave Star is considered as one of the possible devices to be installed at the location. From the calculation, it is obtained that the total rate electrical power possible to grid is 649 MWh a year if only one set of C5 Wave star device is installed on Merang shore, Terengganu.

Keywords: Wave energy; electrical power; energy source; merang shore Terengganu Malaysia

1.0 INTRODUCTION

Demand and supply in energy market can be affected by several factors. As listed in the econometric models, such factors are the gross national product (GNP), energy price, gross output, population, technological development, energy.[1] However, the energy supply must be always sufficient for country demand to ensure the economic growth can be achieved from time to time. In Malaysia, the main energy source used for electricity generation and other application is a fossil fuel.

The main energy sources consumed in power generation station in Malaysia are natural gas, coal and coke.[2] Renewable source energy become more and more important now day due to the increase of fossil fuel price. Compared to other energy source, renewable energy such as hydro power energy utilized in Malaysia is only scored a small amount compared to the other types of energy. The reasons lead to low interest of using renewable energy especially in Malaysia may causes by systemic problems. The systemic problems identified by Simona O. Negro (2011) are hard and soft institutional, market structures, demand, required worker's skill, interaction, knowledge and physical infrastructure problems.[3] On the other hand, the major issues and challenges face by Malaysia to develop the renewable energy technology typically are financial problem such as high research development cost, technical problem such as lack of technologies support and regulation problem which related to government's subsidy on conventional fuel source.[4] All the mentioned factors are leading to lower motivation in developing renewable energy technologies in Malaysia.

Compared to the conventional fossil fuel power generation system, renewable energy can be considered as a free energy source because majority of the renewable energy can obtain from natural without payment. Therefore, high initial costs of those technologies are believed can be recovered back after the plant start operates. In Malaysia, the renewable energy technologies still very new and have not matured enough to use in the country. However, if the country able to utilize five percentages of renewable energy than around 264 million USD can be saved by the country a year from better energy utilization.[5]

Several types of renewable energy were currently used in Malaysia. Malaysian government had introduced Small Renewable Energy Power (SREP) Program at 2001. Under this program, 500 MW of additional qualified biomass, biogas, and municipal solid waste, solar photovoltaic and mini-hydroelectric facilities were installed in Malaysia. The majority of electricity generated by renewable energy technology in Malaysia is biomass and mini hydro. In year 2010, the energy generated by biomass was achieved 18 MW and mini hydro also successes to generate around 23 MW.[6] Building Integrated Photovoltaic (BIPV) systems also a high potential renewable energy source in Malaysia which help to reduce the dependency of the country to fossil energy. This dominant type of Small Scale Embedded Generators (SSEG) was designed to install in the public Low Voltage (LV) distribution networks. However, the real power flow direction will cause the problem in issues related to power quality, distribution system efficiency and possible equipment overloading because currently Malaysia electricity distribution network assumes the power flow always from high voltage level to low voltage level network. By increasing the PV systems on the low voltage distribution network, the power flow may go inverse direction during low load condition and higher PV penetration levels.[7]

By series of effort from Malaysia government, finally 61.7 MW of power capacity had achieved in year 2011.[8] However, the capacity renewable energy in Malaysia still behind the government target where aim to achieve 73 MW in the year 2010. In addition, capacity of Green Technology and Water Malaysia are still targeting by Ministry of Energy to achieve cumulative renewable energy capacity around 2080 MW at year 2020 and 21.4 GW at year 2050 where the ratio of renewable energy capacity to peak energy demand is around 73 percent that time.[9]

Most of the wave conversion devices develop today still leads by European countries. In the South East Asian Countries, the development of Marine Renewable Energy such as wave, current, tidal energy are still far behind the European countries. The previous study stated that the factors lead to this situation occurred in the South East Asian Countries such as Malaysia included lack of sound policy environment, low level technology development, unsustainable Research and Development (R&D) activities, conflicting between other marine users, marketing development or strategic.[10]

From the view of geography, Malaysia is a country surrounding with the sea. East Peninsular Malaysia is surrounded by Stress of Melaka. However, West Peninsular Malaysia and East coast of West Malaysia is surrounded by the South China Sea. Available on the long coastline of Malaysia was provided initial requirement to utilize ocean wave energy. This paper discusses the possibility to utilize ocean wave in Merang shore, Terengganu, Malaysia. The literature reviewed included the available technologies used to convert wave energy to electricity which are developing currently. The available technologies reviewed here are Attenuator, Overtopper, Point absorbers, Oscillating wave surge converter and Oscillating Water Column. The work principle of the device was covered. Finally, the sea condition in Malaysia also studied to analyze the possibility to utilize the wave energy by using the available technologies.

2.0 LITERATURE REVIEWED

There are many types of wave energy converter available such as Attenuator, Overtopper, Point absorbers, Oscillating wave surge converter and Oscillating Water Column to convert wave energy. The majority of the devices are extracting wave energy from wave surface or fluctuation of pressure below the wave surface. Typically, the devices obtain kinetic energy from the movement of wave surface or the wave potential from the change of wave elevation when the wave propagates in the sea. For the devices utilize the wave undulating motion, the device utilizes fluctuation motion of the ocean wave motion to power a hydraulic pump or turbine which connecting to an electric generator. While, other types of devices are using hoses connected to floats which can ride the waves. The oscillation motion of the float and then stretches and relaxes the hose to pressurizing the fluid. By repeating the process, turbine blades are rotating to generate electric.[11]

The attenuator is a floating device design to move parallel with the wave movement direction. Movement of attenuator device rides the crests and troughs of gravity waves along the device can be controlled to generate electric power.[12] The attenuator wave energy converters currently use are Pelamis, Wave star energy and McCabe wave pump. Among the attenuator wave energy converter machine, Pelamis type is the most successful device.[14]

Oscillating Water Column is a device used to convert wave energy and can be separated to near shore type device where install at location with water deep up to 10m or offshore device for the location with water deep from 40 to 80m.[15] The device is constructed by a bottomless air chamber and the chambers are partly immersed in sea water. The design allows the change of wave elevation outside the chamber oscillate the free surface of the water inside the chamber. The oscillation of free surface inside the chamber change the air pressure inside the chamber and then force the air trapped inside the chamber to move out from the chamber or move into the chamber through a nozzle. The Motion of air through the nozzle can be utilized to rotate an air turbine and then use the energy to drive other machine.[16] Currently, Oscillating Water Column device is developed by several companies and some of the devices still under testing. Among of them, Voith Hydro Wavegen Limited is the market leader in developing this type of wave energy converter device.[14]

The overtopping wave energy converter uses the change of water potential energy to generate energy. The wave energy capture by this device can be achieved by allowing waves overtopping into the water reservoir where the level is higher than average free surface level and then draining the seawater through a low head turbine. The turbine blade will rotate once the water drain passes through the turbine. From the hydrodynamics point of view, the device cannot be presented by using linear wave theory due to strong non-linear phenomena of wave motion during overtopping.[17]

A point absorber wave energy converter converts wave energy by utilizing the heave motion of the device causes by wave.[18] The device normally has a large submerged, axisymmetric and anchored to the seabed.[12] The point absorber device can be either a single-body device or multi-bodies device where the single body device generates energy by reacting against a fixes seabed frame while multi-bodies device generates energy from relative motion between the two bodies.[18] Some of the success point absorber devices currently use to convert wave energy are PowerBuoy (Ocean Power Technologies), Wavebob and IPS buoy.

Oscillating wave surge converter device is designed to extract wave energy from wave surge motion and the movement of water particular within them. The earliest form of this device consists of a paddle suspended from a hinge located above the water surface so that it can rotate about an axis approximately parallel to the wave crests, together with an angled back-wall behind this paddle.[19] To detect the wave surge motion, normally a pendulum is connected to the oscillation arm so that the device able to respond to the water movement in the progressive wave. Some of the examples of this type of wave converter are CETO (Carnegie Wave Energy Limited), bioWAVE and WaveRoller.

3.0 ESTIMATION OF ELECTRICAL POWER GENERATED FROM WAVE

Geographically, Merang shore is facing the South China Sea and the ocean wave condition in that region is predicted relatively harsh compared to another region in Malaysia. The exact coordinates of sampling wave data collected by the Malaysian Meteorological Department, MMD is longitude 1020 55.5'E and latitude 50 35' N as shown in Figure 1. The location of the device is around three nautical miles from Merang Jetty. Although this wave condition is not conducive to the safety issue but higher wave energy is possible to obtain from that region. As shown in Figure 1, Merang, Terengganu is one of the region attached by the highest wave height compared to others. The maximum and average wave height recorded in December 1985 at the location is 5.0 meters and 1.7 meters respectively. Therefore, Merang shore, Terengganu is selected as the possible location in Malaysia to utilize wave energy.

3.1 Wave Data Collection

A full scale experiment was conducted to evaluate the available wave energy in the Merang shore, Terengganu. A wave buoy was installed at the location to measure the wave height during the low wave season as shown in Figure 2. Perspective view of the wave buoy used is shown in Figure 3. As presented in Table 1, the diameter, height and total displacement for the wave buoy are 0.6 m, 1.24 m and 52.02 m^3, respectively. In addition, the rolling natural period for the wave buoy is 0.72 Sec and heave natural period is 1.14 Sec. The wave buoys used an accelerometer to measure the wave height. The wave amplitude measured by the wave buoys during sea trial is showed in Figure 4 while the wave spectra is showed in Figure 5.

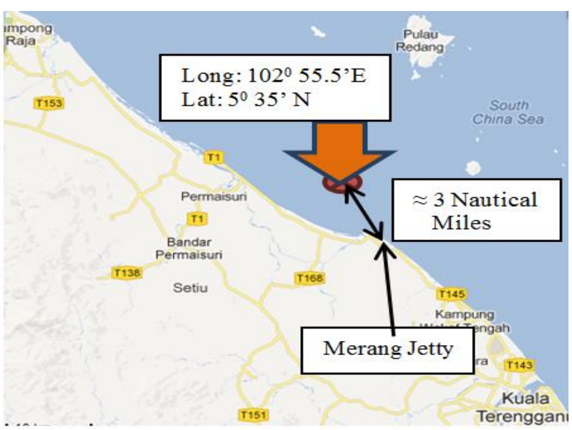


Figure 1 Location of the device to wave sampling data

Figure 2 Wave buoy installed to measure weight height in the Merang Shore, Terengganu, Malaysia

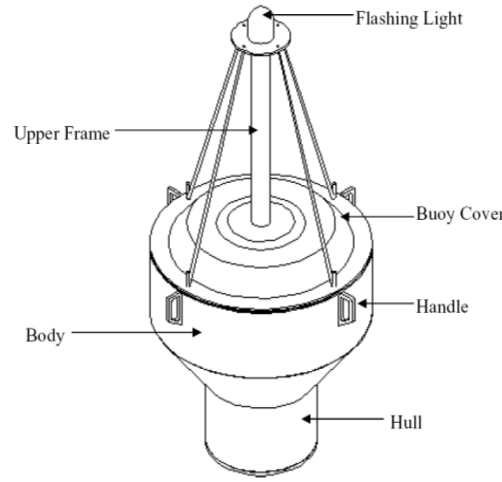


Figure 3 Perspective view of a wave buoy

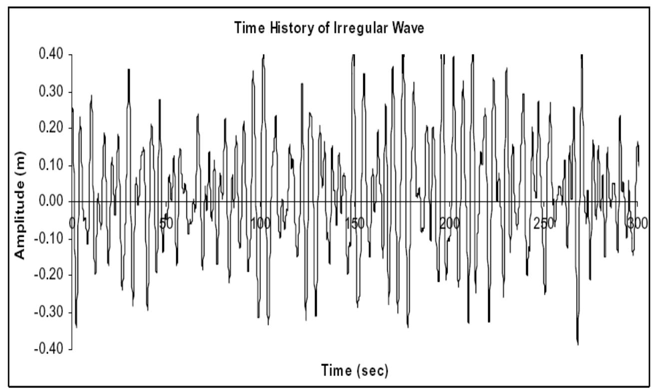


Figure 4 Recorded wave amplitude during the sea trial

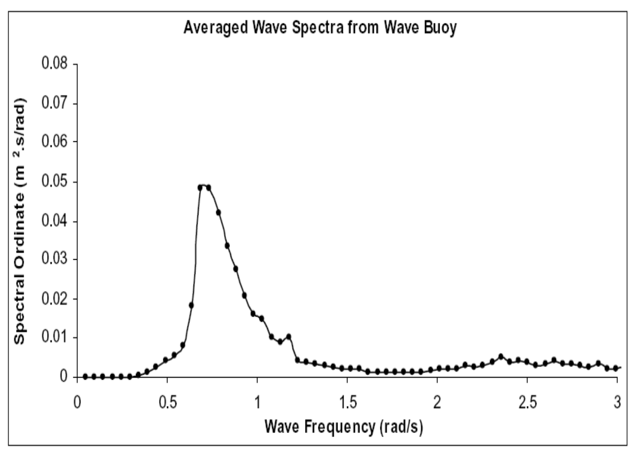


Figure 5 Averaged wave spectra of the whole duration

Table 1 Main particulars of the wave buoy

Diameter (Max)	**0.6 m**
Height	1.241 m
Displacement	52.02 kg
Heave Natural Period	1.140 sec
Roll Natural Period	0.718 sec

3.2 Estimation of Wave Energy

Figure 6 shows mean and maximum wave heights from January to December in Merang Shore, Terengganu, Malaysia. It showed that the maximum wave height at the location is lower from May to July and higher from January to April, August and December. The reason for this phenomenon is the effect of the northeast and southwest monsoon. During monsoon season, more energy can deliver to the location due to more storms and winds will arrive to the coast. The monthly average wave height obtained is varied from 0.5 meter to 1.7 meter and the recorded data showed that most of the wave height occurs within the range from 0.5 meter to 1.0 meter.

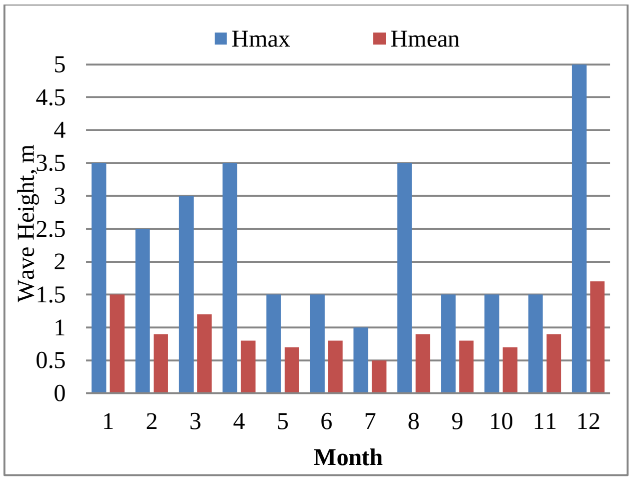


Figure 6 Wave height record at South China Sea, Merang shore in a year and H_{mean} is mean Wave Height and H_{max} is maximum wave height

As shown in the Figure 6, the maximum wave height recorded in Merang shore, Terengganu, Malaysia is 5 meter. The data were indicated that wave height in the region is relatively low compared to the wave height in the locations which were identified as the best place to install wave energy converter device such as North Sea, Atlantic Ocean and Australian shores. The mean wave height is 0.95 meter and the mean wave period is 3.5 second in the Merang shore, Terengganu, Malaysia.

Wave energy per meter length can be calculated by using the equation

$$P = (500\, Wm^{-3}s^{-1})H_s^2 T \quad (1)$$

Where;
H_s is significant wave height and T is wave period.

Using the above equation, the estimation wave energy per meter length in Merang shore, Terengganu, Malaysia is shown in Table 2. From the calculation, most of the available wave energy can be obtained at the location has fallen within the range of wave height from 0.6 m to 1.8 m while the maximum wave energy can be obtained is in the range of wave height 1.2 m to 1.4 m. Finally, this analysis also obtained that the total yearly wave energy can be utilized is around 12 MWh if the wave energy device able to work ideally at the location.

In general, all available wave energy converter devices can only work efficiently if ocean environment is achieved the device working requirement. Typically, the main working requirement for the device is the minimum and maximum wave height of the wave. However, this parameter is very depending on device design such as the size and weight. Figure 7 shows the amount of convertible wave energy versus the minimum required a working wave height of the wave energy converter device.

Table 2 Available wave energy per meter per year for different significant wave heights

Significant Wave Height, Hs (m)	Available Wave Energy per year per meter, P (KWh/m a year)
< = 0.2	14.90
0.2–0.4	425.38
0.4–0.6	604.55
0.6–0.8	1061.30
0.8–1.0	1491.85
1.0–1.2	1408.69
1.2–1.4	2317.63
1.4–1.6	1755.18
1.6–1.8	1868.35
1.8–2.0	774.78
> 2.0	289.74
Total Wave Energy, P (KWh/m/year)	**12012.33**

From the Figure 7, if the minimum device working wave height is settled for 0.5 m, the wave energy can be utilized in Merang shore, Terengganu up to 11572 of kWh/m per a year. If the minimum wave height of the device to work increases, the amount of wave energy available will reduce in almost linear function from wave height 0.5 m to around 2 m. Also, it is almost no wave energy can be utilized if the device only can work for the wave height larger than 2 m in Merang.

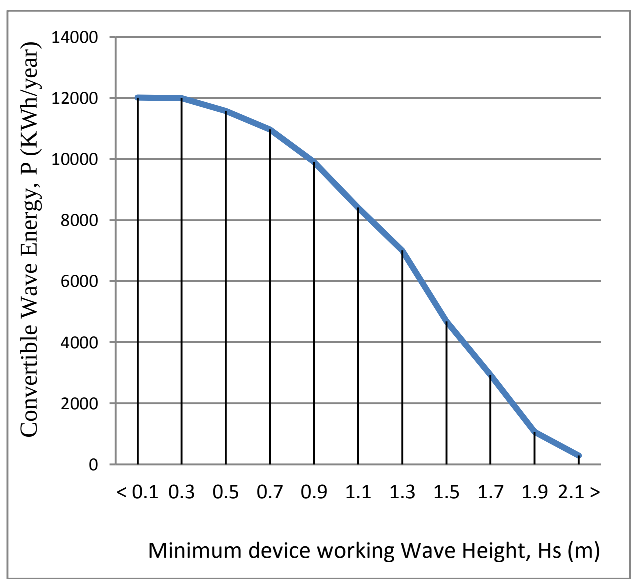


Figure 7 The amount of convertible wave energy at minimum required working wave height of wave energy converter device.

3.3 Wave as an Energy Source for Electrical Power

The possibility to utilize the wave energy in Merang shore, Terengganu is depended to availability of wave converter device available currently. As discussed in the previous chapter, some of the wave energy converter devices were successfully installed and in operating and some of the devices were finishing sea trial. In this study, attenuator type wave converter develops by Wave Star is considered as one of the possible devices to install as the location. The amount of electrical power possible to connect to the grid can be calculated based on the data recorded from the sea trial of the device from another location.

Table 3 Average electrical power to grid in different progressive wave height and wave period for C5 Wavestar device.[20]

Wave height Hm0 (m)	Wave period T0, 2 (s)										
	2 - 3	3 - 4	4 – 5	5 - 6	6 - 7	7 - 8	8 – 9	9 - 10	10 - 11	11 - 12	12 - 13
0.0 - 0.5	0	0	0	0	0	0	0	0	0	0	0
0.5 - 1.0	0	49	73	85	86	83	78	72	67	63	59
1.0 - 1.5	54	136	193	205	196	182	167	153	142	132	123
1.5 - 2.0	106	265	347	347	322	294	265	244	224	207	193
2.0 - 2.5	175	429	522	499	457	412	372	337	312	288	267
2.5 - 3.0	262	600	600	600	600	540	484	442	399	367	340
3.0 -	Storm protection										

To calculate the average electrical power possible to deliver to the grid, the C5 Wavestar wave converter device is assumed possible to be installed in the location. The C5 Wave Start converter is selected in this study because the device is able to convert the wave energy for wave height as low as 0.5 meters. This working requirement is achieved by the sea condition at the selected location since the most wave energy available at Merang, Terengganu is between the range for wave height around 0.5m to 1.0 m. Besides, capability of the C5 Wave Star to absorb the wave energy from any wave direction is also consider in this study. Both the consider factors in this study is targeted to maximize amount of energy can be extracted by the relative low wave height environment at Merang, Terengganu. Finally, the C5 Wave Star is consider here and further to estimate the amount of energy can be generated by the device.

For the selected C5 Wave Star device, it was designed with overall length of 70 meters and consists of 20 hemispheres-shaped floats and the diameter of float and arm length is 5 m, 10 m respectively. As claimed by the company, this device able to produce 600 KW electricity power in significant wave height 2.5m.[13] In addition, the result of electricity power able to produce by this device was provided by the company as shown in the Table 3.

From the calculation, it is obtained that the total electrical power possible to grid is 649 MWh a year if only one set of C5 Wavestar device is installed in Merang shore, Terengganu. However, the amount of electrical power possible to connect to grid with this device in the location is far smaller compared to the amount of electrical power success deliver to the grid by the device after it installed in Hanstholm, Denmark where the total power to grid reported is 1.41 GWh a year.[20]

Besides, the C5 Wavestar device also is expected cannot fully utilize if installed in Merang, Terengganu. By referring to the Table 2, around 46.54% of the wave height occurs at Merang which is lower than 0.5m where it is lower than the minimum wave height required for the device to work.Therefore the C5Wavestar typically has been in rest mode when it wave height is below the working requirement. In this case, another source of energy is required to provide electrical power for the region.

■4.0 CONCLUSION

At the conclusion, the study was reviewed the possibility to utilize wave energy in Peninsular Malaysia with the case study in Merang, Terengganu. Several types of wave energy converter device currently developed by the manufacturer were reviewed before select the suitable type of the device. The selected wave converter device is used to estimate the possible amount of the electrical power can be obtained from the selected location. In this study, the electrical power may be connected to the grid if the C5 Wavestar is installed in Merang shore, Terengganu is 649 MWh a year, however, almost half of a year the device is in rest mode since the available wave height is below the working requirement of the device. Although the energy available is considered small and the device cannot fully utilize, but special device may be developed using in relative smaller wave height in Malaysia in order to convert wave energy more effectively.

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