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Feasibility Study of Wave Energy in Merang Shore, Malaysia

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ABSTRACT

Malaysian government introduced Small Renewable Energy Power (SREP) Program in 2001. In this paper, it discussed the possibility to utilize ocean wave in Merang shore, Terengganu, Malaysia. Besides, this paper also discusses the current technologies have been used to convert wave energy to electricity. The work principle of the devices also present in this paper. After that, sea condition in Malaysia was explored to study the possibility of utilization of wave energy in Malaysia. Finally, It is found Merang shore is the idea location to utilize the wave energy in Malaysia. Mean wave height and mean wave period at the location are 0.95 meter and 3.5 second. Also, attenuator type wave converter developed by Wave Star was considered as one of the possible devices to install at the location. From the calculation, the research obtained that the total rate of electrical power possible to grid is 649 MWh a year if only one set of C5 Wave star device install at Merang shore, Terengganu.

KEY WORDS: *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 countrys' demand to ensure the economic growth can be achieved from time to time. In Malaysia, the main energy source use for electricity generation and other application is a fossil fuel.

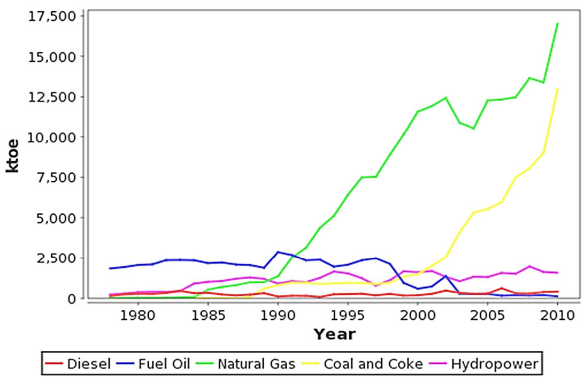

Figure 1: Record of energy source used in Malaysia from year 1978 to 2010 [2].

Figure 1 shows main energy sources consumed in power generation station in Malaysia are natural gas, coal and coke. Renewable source energy becomes more and more important now day due to increase of awareness on the side effect of fossil to environment. 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 in using renewable energy especially in Malaysia may causes by systemic problems. The systemic

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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 development of 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].

There are few types of renewable energy are currently using 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 are biomass and mini hydro. In year 2010, the energy generated by biomass achieved 18 MW and mini hydro also successes to generate around 23 MW [6]. Building Integrated Photovoltaic (BIPV) systems also considered as a high potential renewable energy source in Malaysia. This dominant type of Small Scale Embedded Generators (SSEG) is 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. This is because 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 of renewable energy in Malaysia still behind the government target where they 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 in year 2020 and 21.4 GW in year 2050. Whereas, the ratio of renewable energy capacity to peak energy demands at that moment is around 73 percent [9].

Most of the wave conversion devices developing today still lead 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 happened 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 by sea. West Peninsular Malaysia is surrounded by Stress of Melaka. However, East Peninsular Malaysia and West coast of East Malaysia is surrounded by the South China Sea. Available of long coastline of Malaysia provide 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 working principles of the devices were 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 DEVELOPMENT OF WAVE ENERGY CONVERSION TECHNOLOGIES

There are many types of wave energy converter to convert wave energy available. As an example, Attenuator, Overtopper, Point absorbers, Oscillating wave surge converter and Oscillating Water Column. The majority of the devices extract the 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 on the sea surface. For the devices utilize the wave undulating motion, the devices utilizes fluctuation motion of the ocean wave motion to power a hydraulic pump or turbine which connect 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].

2.1 Attenuator Wave Energy Converter

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. For wave star energy device, it is completed with a series of hemisphere-shaped floats and partially submerges in sea water. The floats can oscillate follow the wave elevation individually. The motion of floats is used to extract or

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retract their own hydraulic cylinder for pressurize hydraulic oil as shown in Figure 2. The pressure than is transmitting to hydraulic motor which connected to generator [13]. Wave Star Energy with ½ model scale was installed at Hanstholm on 18 September 2009. As claimed, the Wave Start Energy device able to produce maximum power around 600 kW if the wave height is 2.5m to 3m and wave period from 3sec to 7sec [14].

The McCabe wave pump also a new device developed to convert wave energy by using attenuator method. The McCabe Wave Pump constructed by three narrow rectangular steel pontoons and all pontoons are hinged together across a beam. The device is required to alight in head sea condition to ensure it can work efficiently. The forward and afterward pontoon is allowed to pitch relative to the center pontoons so that hydraulic rams hinge between the pontoons can be operated to extract wave energy. The high pressure hydraulic oil and then is transmitted to hydraulic motor for energizing the generator or water pump [16].

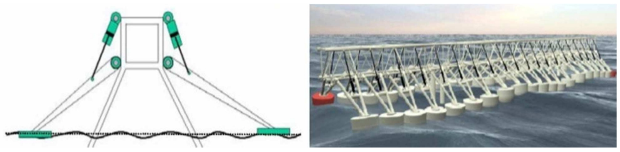

Figure 2: Model design for Wave Star Energy Device [15].

Among the attenuator wave energy converter machine, Pelamis type is the most successful device [17]. This device is developed by Pelamis Wave Power, PWP in Scotland. The device is completed with five tube sections and jointed with universal joints to allow two directions of motion. This device floats semi-submerged on the sea surface and typically heading the wave. The progress of ocean wave along the device will bend the device then flow the hydraulic oil by using hydraulic system which joint the device's tubes. All the power takes off system installed inside the joint of tubes are able to work independently in this design. Generators inside the tubes use the hydraulic power to generate electricity and then transmit to land by subsea cable [18]. At the current state, each P2 Pelamis unit able to produce power capacity up to 750 MW and the size for this machine is 180 m long and 4 m wide with total weight 1350 tonnes [19].

This technology was used to convert wave energy in first time at year 2008 at Aguçadoura, Portugal and able to produce total 2.25 MW electricity [19]. In addition, Pelamis Wave Power Ltd were received several projects to construct wave farm with latest P2 Pelamis from capacity 10 to 50MW. However, the market for the company still inside European Countries and most of the new projects received are from Scotland, UK [20].

2.2 Oscillating Water Column

Oscillating Water Column is a device used to convert wave energy. The device 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 [21]. The device was constructed by a bottomless air chamber and the chamber is 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 is utilized to rotate an air turbine and then use the energy to drive other machine [22].

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 [17]. The company installed the first oscillating water column device in Scotland west coast at year 2000 [17]. Besides, Oceanlinx also apply the same concept to develop the energy converter device in Australia. This company successes to connect the device to the electrical grid and produce electricity in Australia by the device name MK3PC in the year 2010 [23].

In addition, this concept also further develops by other countries to convert wave energy. In Ireland, the company name Ocean Energy constructed ¾ scale model name Ocean Energy buoy and launched for sea trials before moving to production phase [24]. Besides, this concept also tested in Korea from year 1993 to 2001 with the plant capacity up to 60 kW [25]. In china, the shoreline Oscillating Water Column also one of the major devices used to convert wave energy to electricity and the capacity for this type of device in China is up to 100 kW [26]. From the series of example, it is showing that the Oscillating Water Column wave converter device was well developed by many researchers. Hence, it is believed that the device has a good capability to convert wave energy effectively due to the maturity of the concept after the series of year of development.

2.3 Overtopping Wave Energy Converter

The overtopping wave energy converter uses the change of water potential energy to generate energy. The wave energy can be capture by this device by allowing waves overtopping into the water reservoir located at the level higher than average free surface level. And then, the sea water is draining 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 [27]. As shown in figure 6, design factor will determine the capability of this device to successfully convert the wave energy are high of freeboard, amount of water can be stored in reservoirs, location of the turbine and speed of the water drain out of the reservoir.

From the study, there are two main types of overtopping wave energy converter available, there are Coast based devices and floating device [28]. The first coast based devices were developed in Norway in the year 1985 and called Tapered Channel wave energy device (Tapchan) [17]. This device is designed to capture overtopping water in different basins which located above the mean water level. The amount of energy can be extracted is proportional to the turbine head [29]. The same types

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of device also currently use to construct a new wave farm in Norway and the plant called Seawave Slot-cone Generator. The new wave farm is designed with multi-floor reservoir for storing the water temporary before drain out from the reservoir to rotate the turbine. This new wave farm is predicted to generate energy up to 320 MWh for a 10 meter wide section [28].

On the other hand, there are two major developers are currently developing the floating type overtopping device. The overtopping device name Wave Dragon is the most successful device by applying this concept to convert wave energy [17]. The real sea trial for the Wave Dragon product was carried out in the year 2003 in Nissum Bredning, Denmark [30]. From the experience obtained from the sea trial, the new version of the Wave Dragon device towards a full size production plant in 2006 have three main components there are two patented wave reflectors to increase the amount of energy capture, main structure which consist water reservoir and a set of low head propeller turbines [28].

Besides, Wave Plane A/S also a developer currently developing float overtopping device to convert wave energy. The difference between the Wave Plane A/S devices to a Wave dragon device is the Wave Plana device do not have water reservoir and overtopping water is directly drained to turbine [17]. In comparison, Wave Plane A/S claimed that the design has less moving parts, better wave energy conversion per unit weight compared to other wave energy converter, multiple generator and flex grid which creates a multi-plane of multiple units [31].

2.4 Point absorbers Wave Energy Converter

A point absorber wave energy converter converts wave energy by utilizing the heave motion of the device induce by wave [32]. The device normally has 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 [32]. Some of the success point absorber devices currently use to convert wave energy are PowerBuoy (Ocean Power Technologies), Wavebob and IPS buoy.

The PowerBuoy wave energy converter allows a floating buoy to move up and down freely follow the wave's elevation and then the motion of buoy convert to electricity by drive an electrical generator [33]. The PowerBuoy model currently available in the market was named as PB 150. Each of the device is estimated able to generate average energy 150 kW [34]. Also, first PB 150 PowerBuoy model was completed it sea trial at a site approximately 33 nautical miles from Invergordon, off Scotland's North East coast. During the sea trial, the PB 150 was successful to generate 400 kW electricity at storm wave condition and 45 kilowatts at wave heights as low as 2 meters [35].

IPS Buoy is a wave converter device developed by Swedish company Inter Project Services (IPS) AB. This device consists of vertical heaving buoy completed with a power take-off mechanism. That mechanism carries its own internal reaction mass in the form of a body of water contained within a large vertical tube which is open to the sea. The tube is connected to the buoy rigidly and blocked by a piston to slide along its axis. Due to large added inertia of the water above and below the piston, the piston will tend to stay relatively static in its position. However, the buoy and the tube will oscillate by the force induces by wave. Finally, the relative motion between piston and buoy is utilized to drive a hydraulic ram [36]. During sea trial, the prototype of the IPS Buoy name AquaBuOY was deployed and tested in 2007 in the Pacific Ocean off the coast of Oregon [37].

Wavebob is a two bodies self-reacting point absorber and heaving motion wave converter device under development in Ireland [38]. It consists of two concentric bodies with different natural heave frequencies. The shallower body is called Torus and the deeper body is named Float. Due to the different inertia between Torus and Float, both parts are oscillating with different speed after the motion induced by wave. The relative motion of the Torus as it slides along the Float is used to drive the hydraulic power take-off (PTO) system for convert the wave energy to electricity [39]. Compared to the OPT Power Buoy, Wavebob require water depths at least 50 to 100 m or deeper while OPT Power Buoy only require water depths of 25 to 50 m to install the device [40]. Therefore, the Wavebob device is more suitable to apply as an offshore device in depth water zone.

2.5 Oscillating wave surge converter

This type of wave energy 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 [41]. 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 progressive wave. The examples of this type of wave converter are CETO (Carnegie Wave Energy Limited), bioWAVE and WaveRoller.

CETO is the surge wave energy converter which is fully-submerged in the sea and produce high pressure water from the power of waves. This design allows the device to produce electricity or fresh water by utilizing standard reverse osmosis desalination technology with zero-emission. In addition, the CETO device can also to co-produce the electricity and fresh water with zero-emission. Another advantage of this design is the device does not require undersea grids or high voltage transmission or costly marine qualified plants to deliver the electricity or fresh water from site to shore [42]. For this device, the diameter of the buoyant actuator has the most significant influence on power output. In previous record, a single commercial scale 7m diameter CETO 3 device developed by the company was tested on Garden Island in 2011. The rated power achieved is 80kW. To increase the power output, the new CETO commercial device which name CETO 5 has increased the diameter of the buoyant actuator to 11 meters [43].

Next, bioWave is a bottom-mounted pitching device, which spans the full depth device designed to absorb wave energy from

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the sea surface and below sea surface. To absorb wave energy, this device is mounted on the seafloor, with a pivot near the bottom. The buoyant floats or "blades" is designed to interact with the oscillating sea surface and the sub-surface back-and-forth water movement to pivot structure sways back-and-forth in tune with the waves. The energy from the motion is converted to mechanical energy by a hydraulic system and then the converted energy is used to spin a generator to generate electricity. The generated electricity can be delivered to shore by a subsea cable. The bioWAVETM prototype currently under development will able to operate at a depth of 30m, while the plant 1MW commercial model will operate at the water depth of 40-45m [44]. The bioWave systems Ltd had developed a pilot demonstration project at a coastal site near Port Fairy, Australia. The company was scheduled to install a 250 kW grid-connected bioWAVE in 2013 [45].

Same as bioWave, WaveRolleris is another fully submerged bottom-hinged pitching plate WEC which has been subjected to intensive development by AW-Energy Oy. This device uses a hydraulic piston pump attached to the panel for pressurizing the hydraulic fluids inside a closed hydraulic circuit. After that, the high-pressure fluids are fed into a hydraulic motor which connected to an electricity generator. The electricity generated is delivered to the electric grid via a subsea cable [46]. In year 2012, the WaveRoller company was deployed the wave energy farm which consisted of three WaveRoller units with each 100 kW in Peniche, Portugal. Currently, the company successes to hold a 1 MW grid connection license to the national electricity grid in Portugal [47].

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 102^0 55.5'E and latitude 5^0 35' N as shown in Figure 3. 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 4, Merang, Terengganu is one of the regions attached by the highest wave height compared to others in Malaysia. 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 Spectra Measurement using Buoy

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 5. Perspective view of the wave buoy used is shown in Figure 6. As presented in Table 1, the diameter, height and total displacement for the wave buoy are 0.6m, 1.24m and 52.02m3, 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.

In the experiment, the wave height for every second was recorded by the wave buoy for whole sea trial periods. The sample for the first five minutes of recorded wave height is shown in Figure 5 and the wave spectra from the wave buoy is shown in Figure 6. During the clam season, the wave period in the South China Sea near to the Merang shore, Terengganu is around 4.5 Sec and the wave amplitude is below 0.5m.

Figure 3: Location of the device to wave sampling data.

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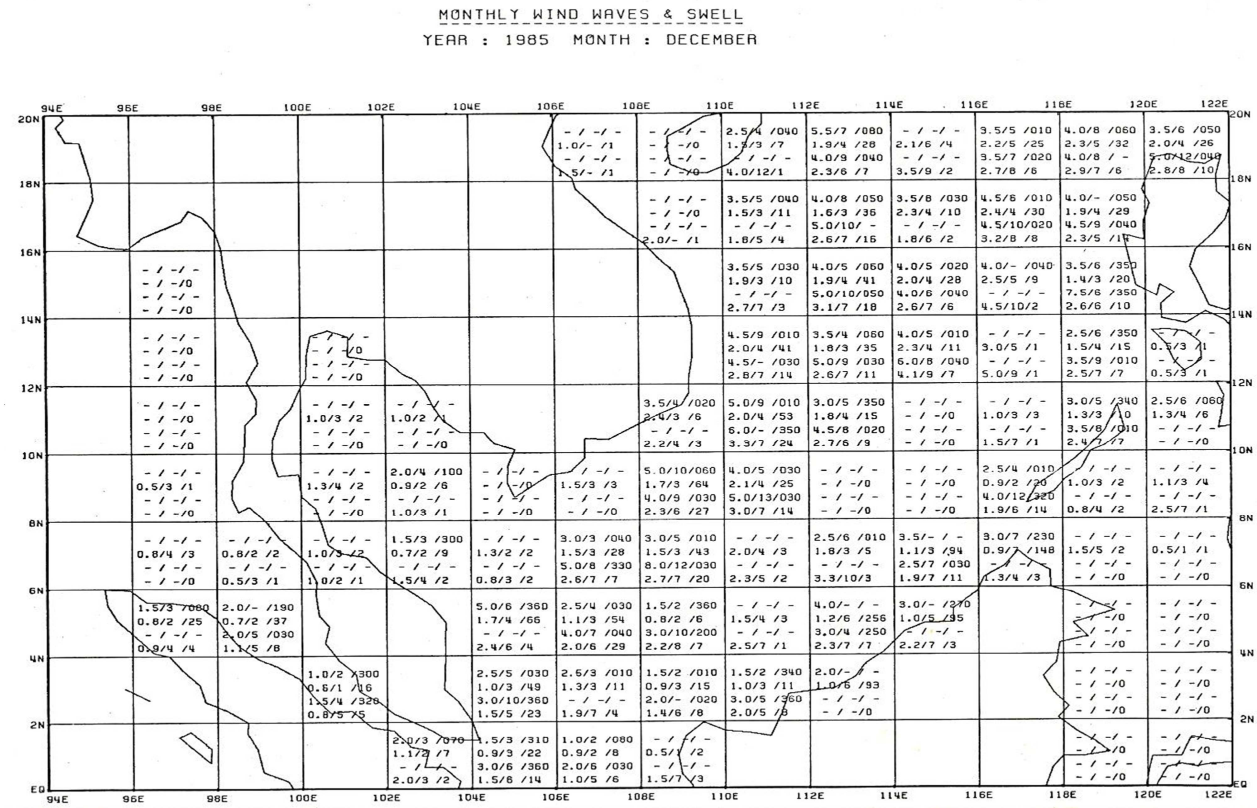

Figure 4: Wave height distribution in Malaysia for December 1985 [48].

Figure 5: Wave buoy installed to measure weight height in the Merang Shore, Terengganu, Malaysia.

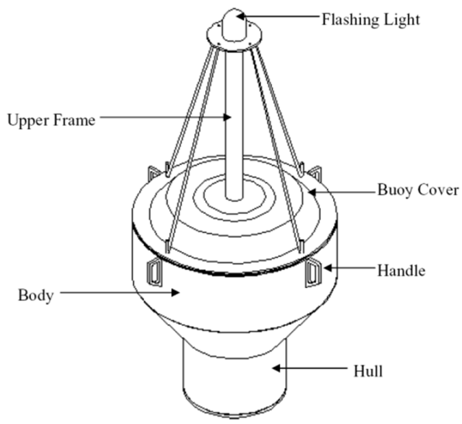

Figure 6: Perspective view of a wave bouy

Table 1: Main Particulars of the wave buoy

Diameter (Max)	0.6 m
Height	1.241 m
Displacement	52.02 kg

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International Journal of Environmental Research & Clean Energy
30 July 2016. Vol.3 No.1

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Heave Natural Period	1.140 sec
Roll Natural Period	0.718 sec

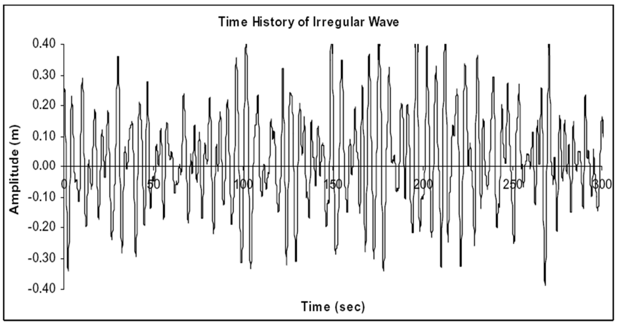

Figure 5: Recorded wave amplitude during the sea trial.

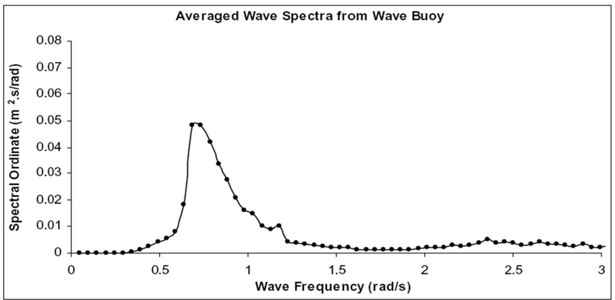

Figure 6: Averaged wave spectra of the whole duration.

3.2 Estimation of Wave Energy

Figure 7 shows mean and maximum wave heights from January to December for year 1985 in Merang Shore, Terengganu, Malaysia. It shows 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. Besides, the monthly average wave height obtained is varied from 0.5 meter to 1.7 meter and the recorded data were showed that most of the time the wave height occurs is within the range from 0.5 meter to 1.0 meter.

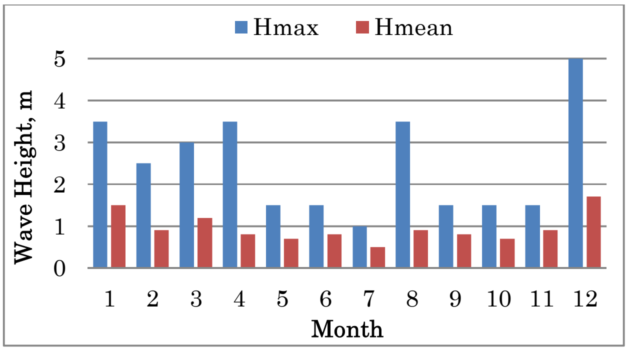

Figure 7: Wave height record at South China Sea, Merang shore in a year and Hmean is mean Wave Height and Hmax is maximum wave height.

As shown in the Figure 7, 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

$$P = 500\ (\frac{W}{m^3 s^1}) {H_s}^2 T \qquad (1)$$

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 0.6m to 1.8m while the maximum wave energy can be obtained is in the range of wave height 1.2m to 1.4m. 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.

Table 2: Available wave energy per meter per year for different significant wave height.

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

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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

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 8 shows the amount of convertible wave energy versus the minimum device's working wave height of the wave energy converter.

From the Figure 8, if the minimum device working wave height is settled for 0.5m, the wave energy can be utilized in Merang shore, Terengganu is found around 11572 kWh/m 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 0.5m to around 2m. Also, it is almost no wave energy can be utilized if the device only can work for the wave height larger than 2m in Merang.

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. As discussed, some of the wave energy converter devices were successfully installed and in operating and some of the devices were just 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.

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 1.0m. Besides, the capability of the C5 Wave Star to absorb the wave energy from any wave direction is also consider in this study. Both the considered factors in this study is targeted to maximize amount of energy can be extracted by the relative low wave height environment at Merang, Terengganu. Therefore, the C5 Wave Star is considered 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. The diameter of float and arm length are 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 [14]. 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 connect 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 [49].

Besides, the C5 Wavestar device also is expected cannot fully utilize if installed in Merang, Terengganu. By referring to Table 2, around 46.54% the wave height occurs at Merang is lowere than 0.5m. But, the wave height available most of time is lower than the minimum wave height required for the device to work. Therefore, the C5 Wavestar has typically been in rest mode during the periods. In this case, another source of energy is required to provide electrical power for the region.

12012.33

4.0 CONCLUSION

In the conclusion, this study 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 as an example to estimate the possible amount of the electrical power can be obtained from the selected location. In this study, around 649 MWh electrical powers a year is predicted able to generate by using wave energy if one C5 Wavestar is installed in Merang shore, Terengganu, 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. Hence, to utilize the wave energy with cost effectiveness, a new special device must be developed so it can be operating in relative smaller wave height in Malaysia.

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30 July 2016. Vol.3 No.1

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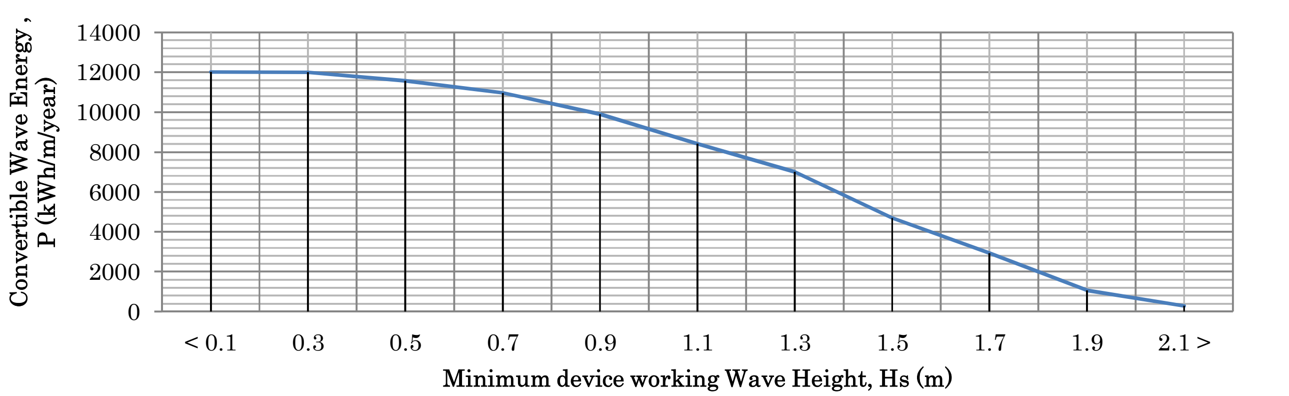

Figure 8: The amount of convertible wave energy at minimum

Table 3: Average electrical power to grid in different progressive wave height and wave period for C5 Wavestar device [49].

Wave height Hm0 (m)	Wave period T_0, 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										

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