

Feasibility Study of Renewable Energy System for an Island in Terengganu

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Abstract. Malaysia has started encouraging renewable energy technology in 7th Malaysia Plan. However, inadequate power distribution in the island makes diesel generator important power sources which cause pollution. Some initiatives have been made by installing wind turbine and solar panel to reduce the dependency on generator. The hybrid PV/wind system is a good combination as solar radiation is high during the Southeast Monsoon, and strong wind during the Northeast Monsoon. Since the wind speed and wave height has a strong tie, during windy season, the wave height can go up to two meters. However, the feasibility of wave energy as power supply hasn't been explored. This paper focuses on the feasibility of using wave energy system to supply electricity to an island using HOMER. The obtained results show that a hybrid wave energy system has lower potential with cost of electricity (COE) is RM 1.303/kWh compared to the most optimal system, hybrid PV-battery generator, with COE is RM 1.262/kWh.

1. Introduction

The consumption of fossil fuels lead to environmental problems especially CO₂ emissions. According to International Energy Agency (IEA), nearly 68% of the worldwide electricity was generated from fossil fuels including coal (40.6%), gas (21.4%) and oil (5.1%) in 2009 [1]. The electricity production from fossil fuels is higher in the developing countries. Thus, cleaner sources of energy are required to secure the future electricity supply. The advantages of renewable energy are no global warming emission, improves public health and environmental quality. In 2009, UCS analysis found that a 25% by 2025 national renewable electricity standard would lower power plant CO₂ emission 277 million metric tons annually by 2025, equivalent of the annual output from 70 typical (600MW) new coal plants [2].

As renewable energy is greatly exploited for various technologies, Malaysia also not left behind in using these gifts by implementing Sustainable Energy Authority Development (SEDA). Malaysia is ideal for large scale solar power installations due to its location in the equatorial region. The continuous supply of sunlight, low maintenance cost, independent of fuels source, and contributions to lower carbon emissions, made solar is the best choice for future energy power generation [3]. Another potential source is wind energy. The wind speed in Malaysia is light and varies from season to season in the range of 2 m/s to 13 m/s [4]. The Northeast Monsoon which is from September to March recorded the strongest wind comes from the South China Sea to the East Coast. Despite from that,



ocean wave energy also has high power density and generating significant wealth [5]. But, the energy has not yet been explored to any significant extent in Malaysia.

Terengganu is popular with beautiful islands. A well-known island that can be found at Peninsular Malaysia on the east side is Pulau Perhentian. Due to the popularity of this place, tourists attract to go there. In Pulau Perhentian Kecil, tourist can experience more environment-friendly excursions as the island has been commissioned by Tenaga Nasional Berhad (TNB) to develop wind and solar technologies [6]. But, the power demand keeps increases in future. Mentioned in [7], 4.8 MW of power needed in future to fill the energy demand in Pulau Perhentian Kecil especially for the resorts and hotels in tourism purpose. An issue arise as the owner of the resorts and hotels are requesting continuous electricity supply from the government for their business. So far, the resorts and hotels in the islands still are depending on the diesel generator to supply electricity because TNB only supplying the power to the residential area [7]. Therefore, it became concerned to the owners. The uses of diesel generator also causing pollution especially to the underwater ecosystem and the price of diesel is unstable.

With the presence of renewable technologies in Pulau Perhentian Kecil and abovementioned potential of renewable energy, this paper is prepared to add wave energy in the power system. The disadvantages of diesel generator also presented and an off-grid simulation-based hybrid renewable energy system to supply electricity in Terengganu is developed in HOMER.

2. Pulau Perhentian System Configuration

The proposed system configuration illustrates in Figure 1. It consists of four sources of electivity which are photovoltaic (PV), wind turbine (WT), hydro power plant to represent wave generator (WG) as used in [8] and diesel generator (DG). Diesel generator is added as backup unit of the system. Meanwhile, battery (B) is needed to store the excess electricity from sources to be used later especially at night as this system is an off-grid system.

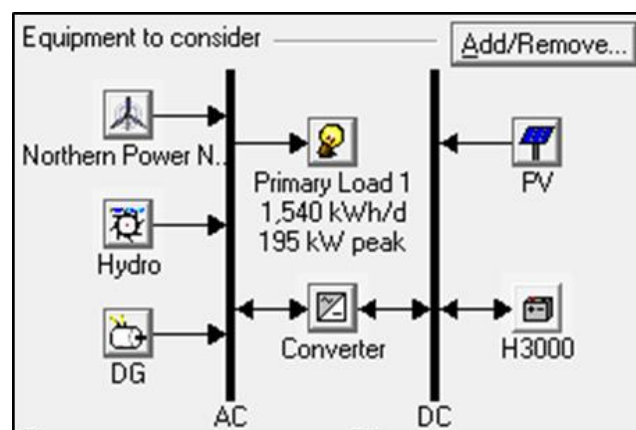


Figure 1. System configuration of proposed system.

2.1. Load Profile

Load in the system is the electrical appliance used in Pulau Perhentian Kecil. The hourly average load profiles in the island for two seasons are shown in Figure 2 and Figure 3, respectively. Only one residential area located in Kampung Pasir Hantu, Pulau Perhentian Kecil with population approximately 2023 people [7]. Most of the residents involved in tourism activities and build their own resorts/homestays/chalets. The rest are doing fisheries activities. In the fishing village, some facilities are provided such as police stations, health centre, jetty and shops. The load profile of Pulau Perhentian Kecil increases approximately twice in peak seasons which from Feb to October compared to low season happens from November until January.

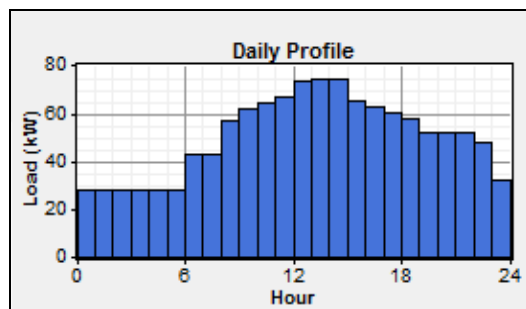


Figure 2. Load profile on low season.
(Nov – Jan)

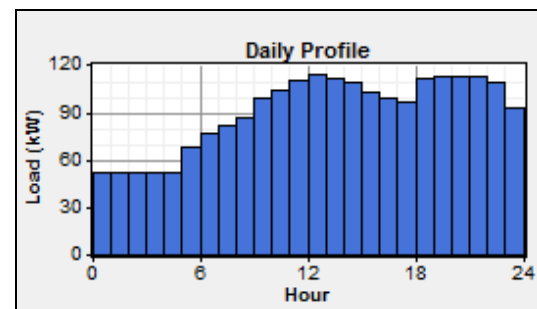


Figure 3. Load profile on peak season.
(Feb – Oct)

2.2 Renewable energy resources and specifications

Solar radiation and wind speed data were collected at Universiti Sultan Zainal Abidin (UniSZA) weather station and the monthly average of solar radiation shown in Figure 4. According to the figure, the highest radiation is in March with radiation of $5.532 \text{ kWh/m}^2/\text{day}$ and lowest on November with $3.069 \text{ kWh/m}^2/\text{day}$. The decreasing of solar radiation from October to January is due to monsoon season as Terengganu is located at East of Peninsular Malaysia facing to South China Ocean.

Otherwise, the wind speed data can be seen in Figure 5, shows the highest reading during January at 3.213 m/s . The significant wave height and wave period were obtained from Institute of Oceanography and Environment (INOS), Universiti Malaysia Terengganu (UMT). From the data, flow rate can be calculated using equation (6) of [8] and the annual wave flow rate is depicted in Figure 6. For the cost of components in this research were referred to the previous research. Specification of PV panel, wind turbine, converter, diesel generator, battery are obtained from [9] while wave generator from [8] as shown in Table 1.

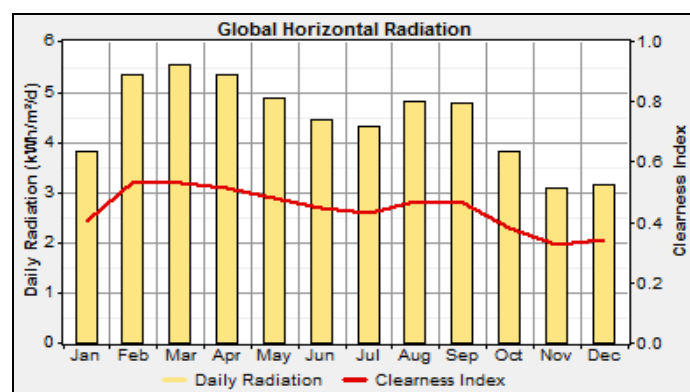


Figure 4. The annual solar radiation data.

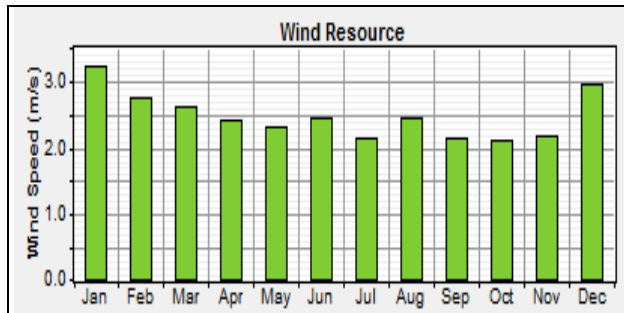


Figure 5. The annual wind speed data.

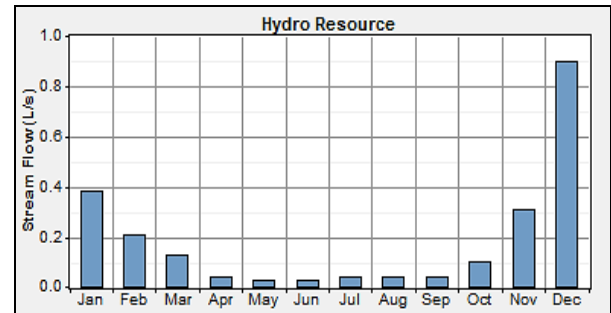


Figure 6. The annual wave flow rate data.

Table 1. List of components specification.

Component	Sizing (kW)	Lifetime (years)	Capital cost (MYR)	Replacement cost (MYR)	Size to consider
PV panel [9]	0.055	20	2030	1544	0 – 198 kW
Wind turbine [9]	100	20	1,763,840	1,664,000	0 – 5 unit
Wave generator [8]	9.81	12.5	210,300	168,240	-
Diesel generator [9]	80.0	~1.14	85, 118	78 694	0 – 80 kW
Battery [9]	120V ^a	10	6071	5460	0 – 5 strings
Converter [9]	1.0	15	2573	2, 412	0 – 130 kW

^a batteries per string

3. Results and Discussions

The simulation results generated by HOMER which rank all possible configurations for the proposed system from the least to highest net present cost (NPC) shown in Figure 7. PV/DG/B system is the most optimal system with configuration of 143 kW PV panel, 80 kW diesel generator, two strings (240 V) of battery and 120 kW converter. The total NPC is RM 8,855,308.00 with cost of electricity (COE) RM 1.262/kWh which is the lowest than other configurations.

Sensitivity Results Optimization Results													
Sensitivity variables													
Interest Rate (%) 0.194													
Double click on a system below for simulation results.													
	PV (kW)	VW100	Hydro (kW)	DG (kW)	H3000	Conv. (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kWh)	Ren. Frac.	Diesel (L)	DG (hrs)
	143.000			80	240	120	\$ 7,128,841	170,810	\$ 8,855,308	1.262	0.28	181,558	7,321
	143.000		9.81	80	240	120	\$ 7,339,141	177,931	\$ 9,137,580	1.303	0.28	181,558	7,321
	132.000	1		80	240	120	\$ 8,486,681	99,692	\$ 9,494,320	1.353	0.28	180,430	7,285
	132.000	1	9.81	80	240	120	\$ 8,696,981	106,813	\$ 9,776,592	1.394	0.28	180,430	7,285

Figure 7. Optimization results of hybrid-RE system.

From the result, PV is the most potential renewable energy component to be developed as the initial cost to install the PV is cheaper compared to wind turbine [10] and wave generator. In addition, the solar radiation in Terengganu is high while the wind speed is still considered low. Still, diesel generator is needed to supply electricity for the power system. For the use of wave generator in generating electricity, Figure 7 shows that the second best combination is PV/WG/DG/B with the total

NPC is RM 9,137,580.00 and COE RM 1.303/kWh followed by PV/WT/DG/B and PV/WT/WG/DG/B.

The production of electricity for different configurations is shown in Figure 8. In PV/DG/B system, DG produces most electricity for the system which is 538,804 kWh/yr, while the consumption of electricity is 694,025 kWh/yr. Similar trend in the rest of configuration which shows high electricity production by DG at 416, 441 kWh/yr, 420,800 kWh/yr and 424,652 kWh/yr, respectively. WT only contributes 17,401 kWh/yr of electricity. WG produces smallest amount of energy compared to the other renewable energy resources which at 6,148 kWh/yr.

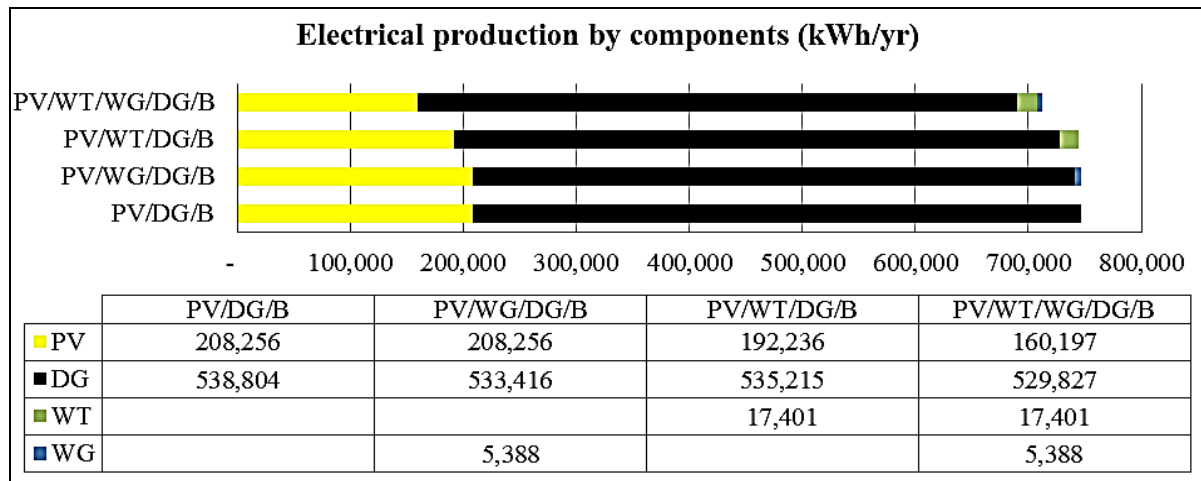


Figure 8. The electrical production by component of each system configurations.

When the system is hybrid with diesel generator, surely the system produced emission. Yet, with the presence of renewable energy components, the emission factor can be reduced. Figure 9 shows the carbon emission released by each system configurations compared to DG system. As expected, the DG system produces the highest carbon dioxide (CO₂) and RE resources helps in reducing carbon emission of the system.

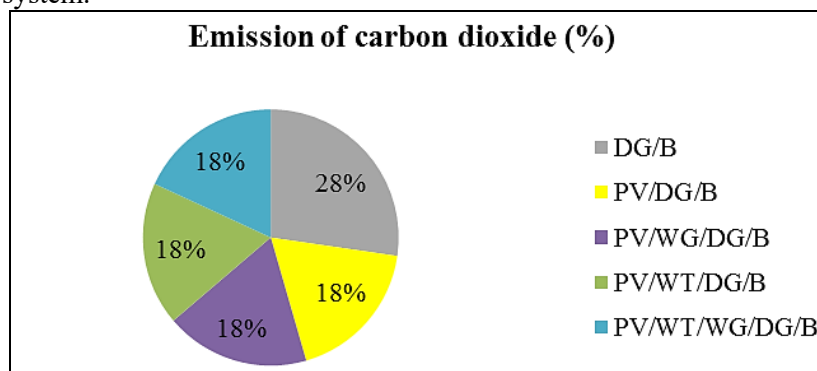


Figure 9. Percentage of carbon emission of hybrid-RE system and DG system.

4. Conclusion

HOMER optimizes hybrid-RE configuration for power system in Pulau Perhentian Kecil. This paper marked that PV is the best RE resources to be implemented in Pulau Perhentian Kecil. The other resources also possible to be developed by more advance renewable technologies because the uses of electricity is important especially in tourism spot as demand is high during peak season. In addition, the presence of RE in power system may reduce the emission of pollutants and dependency on diesel generator which is widely used on remote area. As there is no wave power plants developed on the island, this idea is presented. Even though the results for the wave potential is not convincing but,

wave generator still producing power. Improvement in terms of suitable component uses can be studied. Therefore, it is the best to find the alternative to increase the feasibility of RE power system.

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