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Potential Analysis of Grid Connected Wind Turbine System in Peninsular Malaysia

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Abstract— Wind energy is alternative energy which helps to promote cleaner environment, free, and contributes to reduce greenhouse gases (GHG) emission. The carbon dioxide (CO_2) emission of greenhouse gases causes global warming and climate change. Efforts have been taken on renewable sources to meet the energy demand as well as for sustainable life. This study identifies the potential of grid connected wind turbine (GCWT) system for domestic use in Kuala Besut, Peninsular Malaysia. This is done through designing and analyzing the system using HOMER software. The system configuration consists of wind turbine, grid model, load data and wind speed data. Domestic load and wind speeds as primary data are required to estimate the system designed. The simulation result shows that the GCWT system reduces the electricity bill to RM0.759/KWh instead of RM0.924/KWh by grid connected only. The lowest net present cost (NPC) of RM697,240 was found for the GCWT system compared to the grid system. It is concluded that GCWT system has a potential to be implemented in this area. Although the wind speed is low, but with proper design of wind turbine system the extraction of wind can be generated to cope with Peninsular Malaysia condition.

Index Terms— Grid connected, Wind turbine system, Performance and economic analysis, HOMER software.

1 INTRODUCTION

Moving towards cleaner power is important to support the green technology for sustainable greener environment and contribute to reduce carbon dioxide (CO_2) emissions. In line with this, efforts have been made on the exploitation of renewable energy (RE) to minimize the usage of fossil fuel as a source of electricity [1, 2].

Among RE sources, wind energy has an extremely large potential due to its free, clean, and inexhaustible. In Malaysia, studies have been conducted to promote the use of wind power in replacement of conventional energy supplier [3, 4, 5, 6]. Studies done indicated that only a few places in the East Coast of Peninsular Malaysia have sufficient wind energy for utilization. According to Malaysian Meteorological Department, Malaysia faces fourseasons monsoon, namely the southwest monsoon, northeast monsoon and two shorter periods of intermonsoon seasons with generally light wind speed. However, the wind flow patterns still have homogenous periodic changes. Usually the southwest monsoon started to establish in the middle of May or early June until in the end of September with the speed less than 15 knots [7]. Although, the average of wind speed is lower, but one of the place known as Pengkalan Nyireh in Kuala Besut, Terengganu has a potential to generate electricity using wind turbine with grid connected. As shown in Fig. 1, this location is directly facing the South China Sea and affected by northeast monsoon wind. The latitude and longitude of Pengkalan Nyireh, Kuala Besut are 5°48′N 102°34′E [8].

This study identifies the potential of grid connected wind turbine (GCWT) system for domestic use in Kuala Besut, Peninsular Malaysia. The system was designed based on the purpose to implement the wind turbine connected to grid in order to meet the user load. This is done through analyzing using HOMER software which can perform analysis for both grid-connected and off-grid power system for remote, stand-alone and distributed generation applications [9]. The optimization and sensitivity analysis performs by HOMER simulation software helps to evaluate the system for GCWT. The domestic operations load data and wind speed are required before start the designing [7]. Therefore, the fisherman village at Pengkalan Nyireh in Kuala Besut, which is the gateway to the Perhentian Islands, was selected according to the available wind speed.

Fig. 1. The case study location at Pengkalan Nyireh, Kuala Besut, Terengganu, Peninsular Malaysia.

At the end of this study, an assessment of the optimal system configuration includes grid system and grid connected wind turbine system is ranks according to net present cost (NPC). Simulation is carried out using the HOMER software to determine either it is economical or not to install GCWT in this place. A sensitivity analysis performs multiple optimizations under a range of inputs to account for uncertainty in the system inputs. Finally, the performance and optimum economic cost is compared to shows the effectiveness of the system designed.

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2 Background Information

2.1 User Load

A fishermen village was selected to test the performance of the GCWT system. It was assumed that this residential area has the total population about 3167 peoples with 14 villages and comprises of 650 households. Each village was estimated to have 46 households. The power consumption that estimated for each house is 135.94kWh per month. Therefore, the total power consumption is assumed 6253.124kWh per month, approximately. It was assumed that the load typically comprises of lighting, air conditioner, washing machine, iron and television.The daily and montly load profile as shown in Fig. 2(a) and 2(b) describes the load requirement varies throughout the day and different for each month. Fig. 2(a) shows that the peak demand occurs at night where most of the users stay at home during this time. Load requirements for the twelve month as in Fig. 2(b) displays the seasonal load profiles demonstrating the peak loads in November.

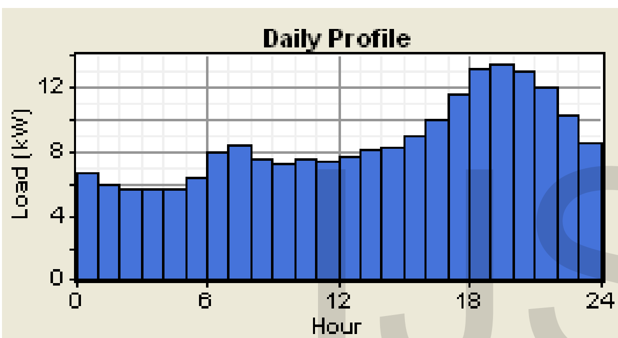

Fig. 2(a). Daily load profile in Kuala Besut

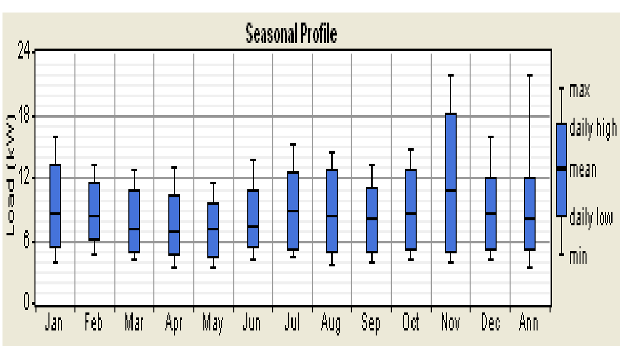

Fig. 2(b). Seasonal load profile for selected village in Kuala Besut.

2.2 Wind Speed

The wind speed data was obtained from NASA Atmospheric Science Data Centre [10]. The average wind speed ranges from 1.97m/s to 4.33m/s with an annual average of wind speed is about 3.00m/s. Though the wind over the country is generally light and variable, there are some uniform periodic changes in the wind flow patterns. This is illustrated in Fig. 3. It can be seen that the wind speed is much greater during November until March because this time is known as northeast monsoon. The southwest monsoon season is usually established in the latter half of May or early June and ends in September. The prevailing wind flow is generally southwesterly and light. With this information, the scale annual average of the wind speed was estimated to 3.174m/s. The Weibull parameter (k) which describes the distribution of wind speeds variation over one period of year is assumed 2 with an autocorrelation factor of 0.85. The diurnal pattern strength is 0.25 whereby a high value of diurnal indicates that there is a relatively strong dependence on the time of day.

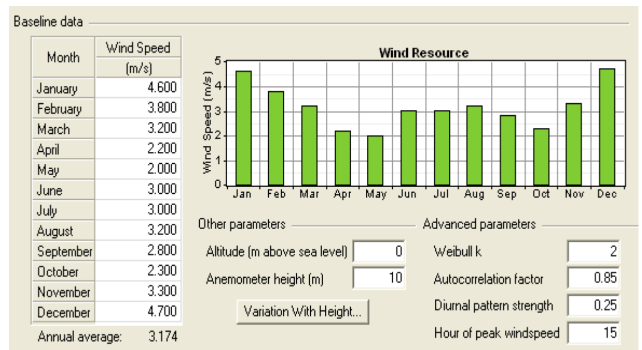

Fig. 3. Wind speed data pattern flow.

3 Design Specification

In this design, the GCWT system consists of three main components are discussed. The system configures of wind turbine, grid model and primary load. The data selected of GCWT system is listed in Table 1. Fixed speed wind turbine is used to generate the wind speed when it is above cut-in wind speed. Whereas, when wind speed reaches the cut-out wind speed, the wind turbine is shut down due to high mechanical load. A random variability factor was given to HOMER software as an input. Based on all the assumption made, the annual energy demand required is 71.91MWh or 197kWh/day as represented in Fig. 4.

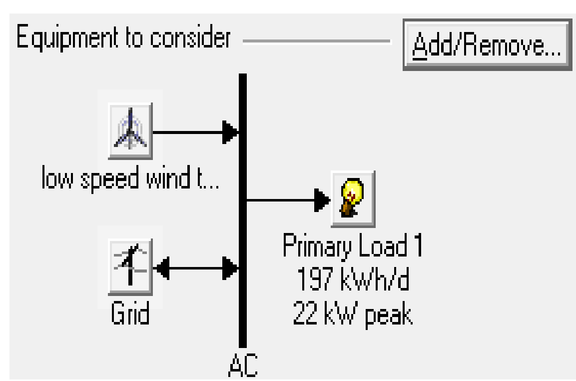

Fig. 4. Design configuration of grid connected wind turbine system.

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TABLE 1
DATA FOR SELECTED COMPONENTS

Description		Data
Wind turbines		
	Size	35 kW
	Capital cost	$5000/kW
	Replacement cost	$500/kW
	Operating and maintenance cost	$100/kw/yr
	Lifetime	20 yrs
Grid		
	Rate 1	
	Price	$0.900/kWh
	Sellback	$0.50/kWh
	Demand	$10.0/kWh/mo
Load		
	Average (KWh/d)	197
	Average (KW)	8.19
	Peak (KW)	21.7
	Load Factor	0.377

3.1 Wind Turbine

The basic concept of the wind energy generation is using the wind flows to rotate a turbine generator. The output power of the wind turbine depends on the stochastic nature of the wind speed characteristic. The higher the wind speed, the greater output power is produced. Thus, in this design, low speed wind turbine is used where cut-in wind speed is 2m/s and cut-out wind speed is 15m/s.

To determine the cost related to the wind turbine, economics of wind energy have been studied. According to previous studies, smaller farm or residential scale turbines cost less but they are more expensive when per kilowatt of energy producing capacity is applied on the rates [8].

In this manner wind turbines would cost roughly $3000 to $5000 per kilowatt of capacity [9].The design of wind turbine size is rated at 35 kW, 2V nominal voltage with wind penetration is 95.1%. The load demand is about 22kW peak. For analysis, it was assumed that wind turbine module would cost $5000/kW. The replacement cost was assumed as $500/kW. For newer machines, the operating and maintenance cost is estimated in the range around 1.5 to 2 per cent per year of the original turbine investment [9]. Hence, the operating and maintenance cost was assumed $100/ kW/ year where 2% is chosen.

3.2 Grid

The grid, which is an auxiliary source, used as back-up to cope with load demand. If possibilities the wind turbine cannot deliver the amount of energy, the grid system will make up the different. For this analysis, the limitation of HOMER is the rates are only applicable if the changes are according to the time of day or the day of the year. Therefore, the system just used one rate that applied the whole month in the year as stated in Table 1.

4 RESULT AND DISCUSSIONS

The system of grid connected wind turbine and grid only are compared based on a projection period of 20 years and 8% annual real interest rate. The annual average wind speed was estimated about 3.174m/s. The optimization result is shown in Fig 5. It highlighted that zero capital cost involved in grid system. However, the total NPC is higher compare to GCWT system with the total NPC approximately $849709 compares to $697240 as in GCWT system. It concluded that the wind turbine grid connected has benefited significantly since it was the cheapest. In addition, the operating cost for GCWT system is lower than the grid system with cost of energy (COE) is $0.759/kWh. It shows that at lower price, user would save their money for paying electricity.

	PGE35	Efficiency Measures	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
	1	No	1000	$ 175,000	40,853	$ 697,240	0.759	0.42
	1	Yes	1000	$ 175,000	40,853	$ 697,240	0.759	0.42
		No	1000	$ 0	66,470	$ 849,709	0.924	0.00
		Yes	1000	$ 0	66,470	$ 849,709	0.924	0.00

Fig. 5. Optimization results for different energy system

To determine the feasibility of GCWT system, a sensitivity result is ranked according to Net Present Cost (NPC) for each type of system. The sensitivity result is shown in Fig 6. As highlighted previously, the total NPC of GCWT system is lower compare to grid only system.

	PGE35	Efficiency Measures	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
	1	No	1000	$ 175,000	40,853	$ 697,240	0.759	0.42

Fig. 6. Sensitivity results for GCWT system

The breakdown of NPC is presented in Fig. 7. It can be no-

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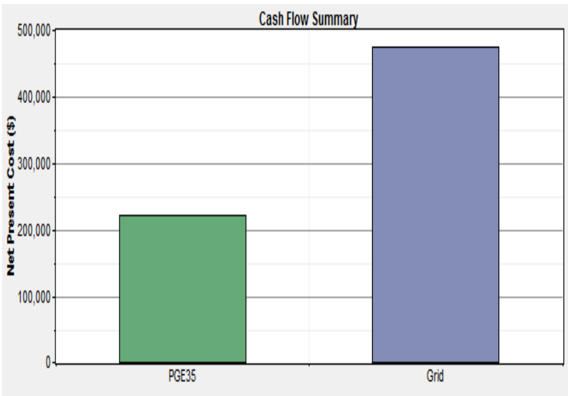
ticed that the largest portion of NPC came from the grid system, due to high maintenance is required. The costs for fuel seem zero since wind energy is extremely friendly to the surrounding environment where no fuels are burnt to generate electricity.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
low speed wind turbine	175,000	5,457	44,742	0	-3,058	222,140
Grid	0	0	475,100	0	0	475,100
System	175,000	5,457	519,842	0	-3,058	697,240

Fig. 7. Total NPC for grid connected wind turbine OF GCWT system.

Production	kWh/yr	%
Wind turbine	32,359	42
Grid purchases	44,786	58
Total	77,144	100

Consumption	kWh/yr	%
AC primary load	71,905	93
Grid sales	5,239	7
Total	77,144	100

Quantity	kWh/yr	%
Excess electricity	0.000389	0.00
Unmet electric load	0.00	0.00
Capacity shortage	0.00	0.00

Quantity	Value
Renewable fraction	0.419

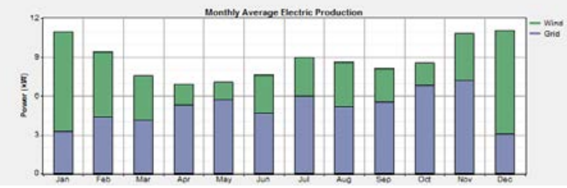


Fig. 8. Monthly average electric production for grid connected wind turbine.

Quantity	Value	Units
Total rated capacity	35.0	kW
Mean output	3.7	kW
Capacity factor	10.6	%
Total production	32,359	kWh/yr

Quantity	Value	Units
Minimum output	0.0	kW
Maximum output	39.1	kW
Wind penetration	45.0	%
Hours of operation	8,368	hr/yr
Levelized cost	0.537	$/kWh

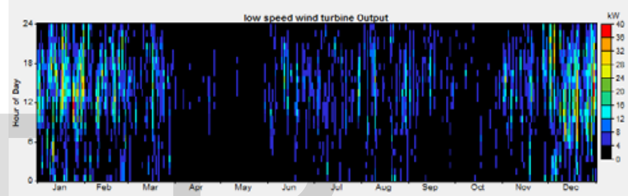


Fig. 9. Power output of low speed wind turbine.

The graph of monthly average electric production is shown in Fig 8. The pattern of electricity production along a year most came from the wind turbine in December, January, and February. Wind turbine produces more electricity since the average wind speed is higher in that month as clearly seen in Fig. 2(b). On the other hand, when the wind speed is lower, the average electricity production came from the grid. Thus it could be further noticed that the monthly average electric production match the monthly wind speed profile.

From electrical analysis, it shows that the total electricity generation by GCWT is 77,144 KWh/year. The electricity produced by wind turbine also stated in Fig 8. About 42% electricity produced by wind turbine and grid 58%. The wind turbine produces 32,359 KWh/year and the grid gives 44,786 KWh/year. The renewable fraction is 0.419 which means that the wind turbine operates less compared to the grid. It also be noted that the electricity production of wind turbine totally depends on the stochastic nature of the wind speed.

The detail of power production by low speed wind turbine along a day for each month throughout a year is illustrated as in Fig.9. It is indicates by the colours where black refers to the lowest power output while red refers to the highest power output. From this figure, it can be noticed that power output generated is lower in between March and Jun, as well as September and November. Penetration of the wind turbine is 45%. The percentages seem lower but it is good enough to supply electricity in order to encourage the usage of alternative energy as a new power generation. By having wind turbine in the system, carbon dioxide emission can be reduced since wind energy is environmental friendly.

The energy purchased, energy sold, net purchased, peak demand, and demand charge for each month is shown in Fig. 10. Annually, the total energy purchased is 44,786kwh meanwhile, the excess energy produced by the wind turbine that has been sold to utility company is about 5,239kwh, hence gave the net purchased about 39,546kwh. The total energy charge is $35,592 which indicates the amount of bill should be paid by the users based on the energy used. The total demand charge is about $1,574.

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Month	Energy Purchased (kWh)	Energy Sold (kWh)	Net Purchases (kWh)	Peak Demand (kW)	Energy Charge ($)	Demand Charge ($)
Jan	2,431	1,787	645	14	580	138
Feb	2,939	622	2,317	13	2,085	129
Mar	3,074	293	2,781	12	2,503	116
Apr	3,813	5	3,808	12	3,428	116
May	4,278	1	4,277	10	3,849	105
Jun	3,370	140	3,231	13	2,908	127
Jul	4,460	81	4,379	13	3,941	135
Aug	3,867	220	3,647	14	3,282	136
Sep	3,992	32	3,960	11	3,564	112
Oct	5,091	8	5,083	14	4,575	137
Nov	5,187	115	5,072	18	4,565	184
Dec	2,281	1,934	347	14	312	139
Annual	44,786	5,239	39,546	18	35,592	1,574

Fig. 10. Detail energy description of GCWT.

4 Conclusion

The wind speed in Malaysia is not greater since its annual average only about 3.17m/s. However, the combination of wind turbines and grid would ensure continuous electricity. The potential of wind energy can be further explore in this village as monsoon season were most of the wind flow there. HOMER simulation result shows that although the penetration of wind turbine is 45%, but it is still economical to be installed to minimize the usage of diesel as a source of electricity. The net present cost contribute by the wind turbine is lower compared to the grid, which is about $697,240. Grid connected wind turbine system reduces the electricity bill to $0.759/KWh instead of $0.924/KWh. From the cash flow summary, wind turbine system shows that about $3,058 save cost compared to system without wind turbine. For more effective, the extraction of energy from the wind can be improved by proper design of wind turbine. Low speed wind turbine should be designed as efficient as possible to suit with Malaysia condition. Wind turbines give more advantage on greenhouse effect which provide environmental safe and reduce emission in future. A further innovation research and development is recommended to transform to more efficient and cost effective technology.

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