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Design the Balance of System (BOS) for Photovoltaic Application at CERE Building for Low Load Application: An Application of HOMER Pro

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Abstract. The reliable renewable energy systems will effective when the optimal output can be achieved. This paper presents a design of the BOS system at the CERE building for low load application. The entire system is being optimized by HOMER Pro software represented the effectiveness system. The HOMER Pro produced the optimal and economic hybrid system configuration. The result indicated the capacity of the PV array is 0.6 kW, 4 units of 1 kWh lead-acid battery and 0.3 kW of inverter was selected to complete the system. The impact of the ambient temperature also has been analysed. The total electrical energy production reduced with considering temperature coefficient. An optimization produced productive configuration over the system lifetime.

Introduction

A stand-alone system is where the power is generated and consume in the same place and which does not interact with the main grid. The Balance of System (BOS) term has referred to the balancing the power generated by the solar array with the power of the load demand. The BOS system covered all the components in the system other than the photovoltaic panel including the battery, charge controller and also the inverter. The system must have optimal energy balancing output in order to produce reliable production.

Various methods have been utilized by different researchers in planning and sizing the system configuration. A lot of software used to simulate hybrid energy system such as HOMER, Hybrid 2, RETScreen and INSEL. But the most widely used software is HOMER. Ahmed.M.A. Haidar et al. used Homer software to optimize a photovoltaic (PV) - wind- diesel generator hybrid system. The software evaluated the economic performance of the proposed hybrid system [1]. R. Sen and S.C. Bhattacharyya compared the optimal off-grid option with conventional grid extension using Homer software [2]. K.Y. Lau used Homer in performed the techno-economic feasibility of hybrid PV/diesel energy system. The impact of PV penetration and battery storage on energy production cost of energy and the number of operational hours of diesel generators also have been investigated using this software tool [3].

HOMER Pro, the micro power optimization which can evaluate the many possible and feasible system configurations. HOMER Pro allowed the user to input the resources data, load (AC or DC) demand and type of renewable energy required. It will use the input to simulate different system configurations and evaluate generates results as a list of feasible configurations sorted by net present cost [4]. This paper designed BOS due to develop PV-battery storage system configuration for low load application. HOMER Pro software was used to optimize the energy balancing calculation. Besides, the simulation used to investigate the impact of temperature on total energy production over the year.

Sites Descriptions

Perlis lies on the northern part of the west coast of Peninsular Malaysia. This study was conducted at the Centre of Excellence for Renewable Energy (CERE) which located in the capital city of Perlis. CERE located at 6°26.3’N latitude while longitude of 100°11.2’E has big potential in developing solar system [5].

a. Load profile

This study was implemented based on the load requirement. The fourteen units of LED bulbs which each bulb rated at 11W applied for once of room at the CERE building. All load assumed to be used only during office hour, from 8 am to 12 noon and 1 pm to 5 pm every day except for weekends. The daily average energy consumption is 1.232 kWh/day.

b. Solar radiation

Based on the Figure 1, the average annual daily solar radiation is 5.271 $kWh/m^2/day$. It also shows the potential solar radiation at the site location varied from 4.757 kWh/m^2 to 6.134 kWh/m^2. This range indicated that the sky is very clear with high solar intensity in Perlis. All of the data retrieved online from the Homer Energy website, which is the data set: National Renewable Energy Laboratory (NREL).

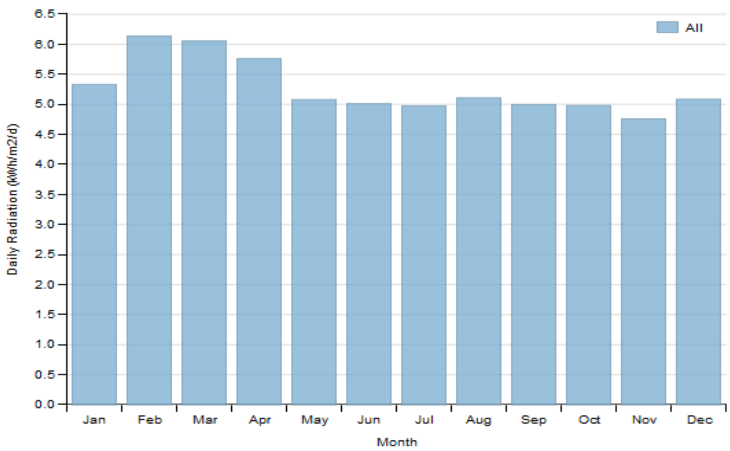

Fig. 1 Solar radiation data input using HOMER Pro.

c. Ambient temperature

An ambient temperature is one of the most important factors in analyzing energy production of solar system. A high ambient temperature will result in high temperature of PV module. A PV system normally designed based on the average ambient temperature surrounding the site installation. The highest temperature of site location found in April with 30.1 °C and the lowest is 28.65 °C in October.

Design Specification

This proposed model constructed by the combination of its three main components which are PV modules, batteries and inverter. All the components have their own different function due to generate power or energy between DC and AC line.

a. PV module

PV module gives DC output in direct proportion to incident solar radiation. The DC output generated depends on the characteristic of the PV module. Table 1 shows the characteristics of the

PV module used in this proposed model. The PV capacity was assumed to be 0.6 kW. The capital cost and replacement cost of 0.6 kW installments are $1995 for each both. Whereas the operation & maintenance (O&M) cost is $20 respectively.

Table 1 The characteristic of PV module

Parameters	Characteristic
Rated capacity	0.075 kW
Efficiency module at STC	11.8%
Derating factor	85%
Temperature coefficient	-0.45%/°C
Lifetime year	25 years

b. Battery storage

A stand-alone system needs to operate in bad weather (there is not much sunlight) or during the night, thus battery storage is required as for electricity storage. Battery storage for this proposed model is 12 V with connection of several batteries in one string. The battery stacks may contain a number of batteries ranging from 4 to 9 units. The battery selected was generic 1 kWh Lead Acid (LA) battery with the nominal voltage of 12 V. While a nominal capacity of each battery is 83.333 Ah. For Homer Pro simulation, each battery was assumed to have a capital cost to $300; replacement cost $290; O&M cost $ 10/year.

c. Inverter

The converter used in inverter mode as the load consumes AC mode. It was rated based on the output from the PV array selected. In this system, the initial capital of a 0.3 kW inverter is $50 with a replacement cost of $50. There was no operating and maintenance cost estimated. The expected lifetime of the inverter is 20 years. The typical inverter efficiency was assumed to be 90% because of electrical losses.

Results and Discussion

HOMER Pro simulation was performed by comparing the performance of a stand-alone PV system to consider on temperature coefficient vice versa. The main purpose of this comparison is to analyze the impact of ambient temperature on the output of the solar system due to the high intensity of solar radiation in Perlis. Besides, the result also discussed the flow of energy balancing and total net present cost (NPC). Figure 2 represented the overall system for this proposed method. The system was generated by optimization combination and sensitivity variables.

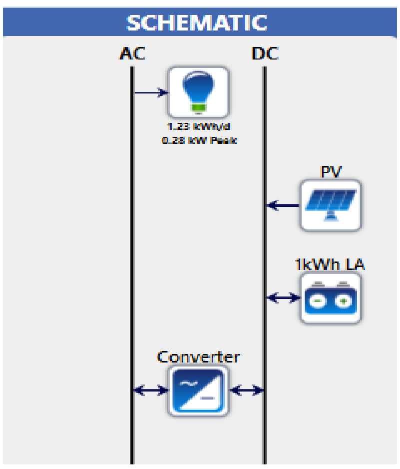

Fig. 2 The overall system configuration

a. Optimal combination using HOMER Pro

Homer Pro simulated every system in the search space and ranks all the feasible system when each sensitivity case has been solved. The objective of the optimization process is to determine the top rank system configuration according to the selected variables. Several variables such as the size of the PV array, the size of the converter and the number of batteries affected the optimization result. Table 2 displays the optimal result of the proposed method. The top configuration consists of 0.6 kW PV array capacity, 4 units of 1 kWh lead acid batteries and 0.3 kW of inverter. For the same configuration, the lowest net present cost (NPC) found at $4469.

Table 2 The optimization result using HOMER Pro

Architecture			Cost ($)
PV (kW)	1 kWh LA (unit)	Inverter(kW)	NPC ($)
0.6	4	0.3	4469
0.6	5	0.3	5024
0.6	6	0.3	5580
0.6	7	0.3	6136
0.6	8	0.3	6691
0.6	9	0.3	7247

b. A stand-alone PV system with or without consider the temperature coefficient

The operating temperature of the PV module plays important role in the performance of the PV performance. This operating temperature depends on the surrounding or ambient temperature of the site location selected. The high level of the solar radiation generated higher average of ambient temperature. This climate condition will cause the degrading the electrical efficiency [7]. For this proposed method, the type of PV module selected is from Yingli manufacturer with each capacity of 75 W. The temperature coefficient for this type of module is -0.45%/^{o}C. Therefore, the power output of the PV module will decrease 0.45% with the increasing of 1^{o}C of module temperature. This will result in decreasing energy production from the PV array as well as electricity production.

Table 3 represented the output from PV array configuration with or without considering temperature coefficient. The total electrical production considering temperature coefficient have seen less than the total production without considering temperature coefficient. The average power (mean output) and the maximum output of the PV array over the year also decrease with considering temperature coefficient. The results proved the operating temperature affected the electrical production by the PV array. It is because the high temperature with high level of solar radiation will produce heat energy more than electrical energy.

Table 3 The PV array output

Result	Without temperature coefficient	With temperature coefficient	Unit
Electrical Production	986	897	kWh/yr
Mean output	2.7	2.5	kWh/d
Maximum output	0.62	0.54	kWh/yr

The energy produced by the battery storage vice versa compared to the PV array configuration. Table 4 shows the energy production from battery storage. The batteries need to store more energy due to the low production from the PV array due to satisfied load demand. But the energy output with considers the temperature coefficient is higher than without considers the factor. It caused by the low level in the production of a PV array.

A 0.3 kW inverter only operates during office hour followed the load demand. There is no different between with or without considering temperature coefficient for inverter performance. An inverter must satisfy the rated capacity power to ON the load demand.

Table 4 The battery storage production

Result	Without temperature coefficient	With temperature coefficient	Unit
Energy in	77	83	kWh/yr
Energy out	62	66	kWh/yr

Conclusion

The optimal configuration of BOS component for 14 units of LED bulbs was optimized by using HOMER Pro software. The HOMER Pro software performed simulations due to achieve the optimum system for serving the desired load. The energy balancing production was generated by the simulation software. The flow of energy of each component can be analyzed respectively. Besides, the ambient temperature as sensitive variable of plays important role in generating electrical energy of the solar system also have been investigated.

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