Optimum Sizing of Photovoltaic-Wind Power Hybrid System For Small Information System Center in Perlis, Malaysia

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ABSTRACT

This paper presents a methodology for calculation of the optimum sizing of photovoltaic (PV)-wind power hybrid system. Data of temperature, solar radiation and wind speed throughout the year of 2011 in Perlis was recorded and analyzed. These data were used to calculate the power of PV and wind generation. Power difference between the inverter demanded power of the small information system center and generated power was calculated. To find the optimum sizing of PV-wind power hybrid system, a wind power generation was decided to be hybrid with number of the PV module. The result shows that the optimum PV module number is 18 (difference between the generated power and demanded power is zero). It is assuming that the inverter demand power of small information system center for the working day and public holiday were 500 W and 100 W, respectively.

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1. INTRODUCTION

Since the oil crisis in the early 1970s, utilization of renewable energy has become increasingly significant, attractive and cost-effective [1]. Solar irradiance and wind speed are energy resources to study energy generations using photovoltaic (PV) and wind power generation. Each of these depends on factors such as latitude, altitude load profile, season, sea and land breeze and solar activities [2].

In recent years, PV - wind power hybrid has become viable alternatives to meet environmental protection requirement and electricity demand. It has advantages, the first it may gain a certain level of reliability of supply without the need for an unreasonable increase of the size of converters or storage often occurring for stand alone system, the second it reduces the battery storage and diesel requirements, the third it can operates on the alternation of day and night and change of weather, it not only affects normal energy consumption but also results in batteries being discarded too early [3, 4, 5].

Various optimization technique of the PV - wind power hybrid sizing have been reported in the literature such as [1, 5] suggested a methodology to perform the optimal sizing of an autonomous PV and wind power hybrid system. The methodology aims at finding the configuration, among a set of systems components, which meets the desired system reliability requirement, with the lowest value of levelized cost of energy. Modeling a PV - wind power hybrid system that is considered as the first step in the optimal sizing procedure. The second step consists to optimize the sizing of a system according to the loss of power supply probability (LPSP) and the levelized cost of energy (LCE) concepts. A modeling a PV - wind power hybrid system is proposed by [4] and considered as the first step in the optimal sizing procedure. The second step consists to optimize the sizing of a system according to the loss of load probability (LOSP) and the life cycle cost of energy (LCC) concepts. An algorithm to find optimum sizing of the PV - wind power hybrid system was developed by [6]. The data of solar irradiance and wind speed every hour of the day and manufacture's specification on a PV module and wind power generation were used to calculate the average power generated by PV module and wind power generation for each hour of a typical day in a month. The least square method is used to determine the best fit of the PV array and wind power generation to a given load. A procedure to determine size of the PV array and wind power generation in a PV - wind power hybrid system was proposed by [7]. Using the measured values of solar irradiance and wind speed at a given location, the method employs a simple graphical construction to determine the optimum configuration of the two generators that satisfies the energy demand of the user throughout the year.

This paper presents a methodology for calculation of the optimum sizing of PV-wind power hybrid system. Data of temperature, solar radiation and wind speed throughout the year of 2011 in Perlis was recorded and analyzed. These data were used to calculate the power of PV and wind generation. Power difference between the inverter demanded power and generated power was calculated and found the optimum sizing of the PV-wind power generation.

2. RESEARCH METHOD

The proposed optimum sizing of PV - wind power hybrid system based on mathematical modeling of the PV panel, wind power generation and battery as explained below.

a. Data of solar irradiance, temperature and wind speed.
Daily data of solar irradiance, temperature and wind speed through the year of 2011 are needed to calculate maximum power of PV and wind power generation. These data are recorded by Centre of Excellent for Renewable Energy (CERE) Station, Universiti Malaysia Perlis, in Kangar, Perlis, Northern Malaysia.

b. Inverter demanded load
The daily inverter demanded power load through a year is observed and calculated, the total energy as given below [8].

$$W_{dem} = \sum_{n=1}^{365} \left[(\Delta T)(P(n)_{dem}) \right] \qquad (1)$$

Where W_{dem} is inverter demanded energy, ΔT is the time between the samples (in this case one day), P_{dem} is inverter demanded power, *n* is the sampling time (day in year).

c. Type selection of PV module, wind power generation and battery.
Data sheet of the PV module, wind power generation and battery are needed to calculate maximum power of them that related to the solar irradiance, temperature and wind speed.

d. Mathematical modeling of PV module
The hourly maximum power of PV module relates to the solar irradiance and temperature falling on the PV module. To calculate the daily maximum power of the PV module, firstly current and voltage of the PV module calculated following [9]. Secondly, I-V curve of the PV module is plotted and found its maximum power. The maximum power is found by the genetic algorithm.

e. Mathematical modeling of wind power generation
The daily maximum power of wind power generation is related to the wind speed that moves its blade and calculated following [10].

f. Mathematical modeling of PV - wind power hybrid system
The daily maximum power of the PV module and wind power generation are used to calculate the total annual energy generated by the PV - wind power hybrid system that calculated using this equation [8].

$$W_{gen} = \sum_{n=1}^{365} \left[(\Delta T)\left(K_w P(n)_w + K_{pv} P(n)_{pv}\right) \right] \qquad (2)$$

where W_{gen} total annual energy is generated by the PV - wind power hybrid system, K_w and K_{pv} represent the number of wind power generation and PV module used, P_w and P_{pv} are the power generated by a specified wind power generation and PV module, respectively.

g. Number of PV module and wind power generation
The number of PV module and wind power generation is found using this formulation.

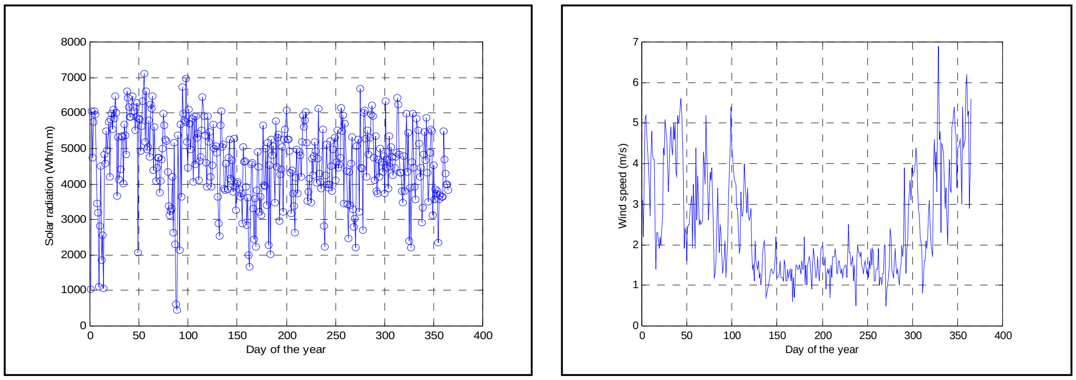
$$\Delta W = W_{gen} - W_{dem} \qquad (3)$$

where ΔW is difference between the generated energy and demanded energy.

Number of PV module and wind power generation is optimum if the system is balance. In order for the hybrid system and load to balance over a given period of time, the curve of ΔW versus time must have an average of zero over the same time period. A positive value of ΔW indicates the availability of generation and negative ΔW indicates generation deficiency.

3. RESULTS AND ANALYSIS

The daily solar radiation and wind speed in Perlis is analyzed according to the measured data at CERE Station, Kangar for the year of 2011 as shown in Figure1.



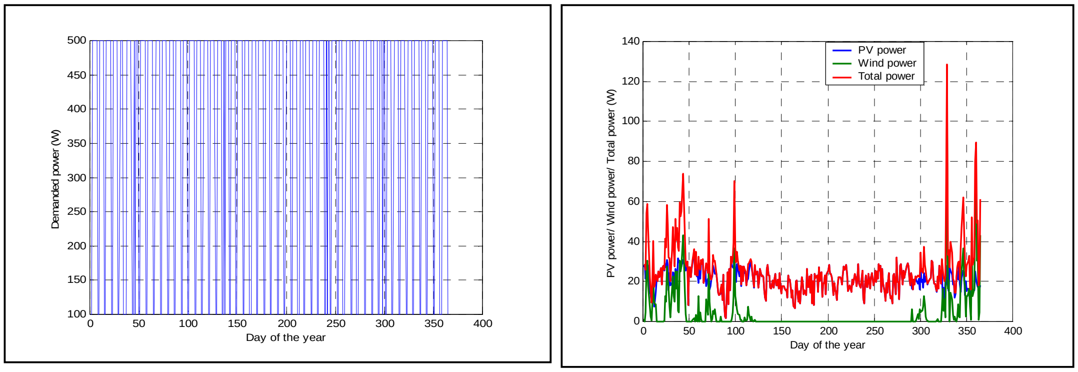
(a) Solar radiation (b) Wind speed

Figure 1. Perlis's weather throughout the year of 2011

Figure1 (a) shows that the highest solar radiation of 7057.4 Wh/m^2, 6580.2 Wh/m^2 and 7108 Wh/m^2 recorded on 7th February 2009, 22nd February 2010 and 24th February 2011, respectively. For the three years, the highest solar radiation occur in same months (January to April). Average daily solar radiation values were high during this period, they are due to during the months, Perlis's weather was dry and warm [11].

Figure 1 (b) shows the daily wind speed data throughout the year of 2011. The wind speed in Northeast monsoon (November to march) and intermonsoon (April and October) was higher than Southeast monsoon (May to September). In the Northeast monsoon, the wind speed was high due to by an outburst of cold air which flowed out of Siberia and toward Southeast Asia interacted with low pressure atmospheric system were formed near equator resulting in strong winds to Peninsular Malaysia [12].

Figure 2 (a) shows the inverter demanded power of the small information system center throughout the year of 2011 assumed that its power for the working day and public holiday were 500 W and 100 W, respectively. Figure 2 (b) shows total power of a 60 W, 22 V PV and 300 W wind power generation when they were applied in Perlis throughout the year of 2011. PV power could be generated by PV module throughout the year, but power of the wind power generation was very low depended on the wind speed, it was affected by three seasons (Northeast monsoon, Southeast monsoon and intermonsoon). The highest average output powers of the wind power generation were in the Northeast monsoon, it was caused by the strong wind speed as effect of cold air which flowed out of Siberia and toward Southeast Asia interacted with low pressure atmospheric system are formed near equator and enter to Peninsular Malaysia. In Southeast monsoon throughout the year, there were no average output power of wind power generation, it was caused by the wind speed was below 2 m/s and in this season had little land - sea temperature difference[11].



(a) Inverter demanded power (b) Generated power by PV and wind power generation

Figure 2 Demanded and generated power

To find the optimum sizing of PV-wind power hybrid system, a wind power generation was decided to be hybrid with number of the PV module. Figure 3 shows the change of PV module number related to demanded and generated power. The optimum PV module number is 18 (difference between the generated power and demanded power is zero).

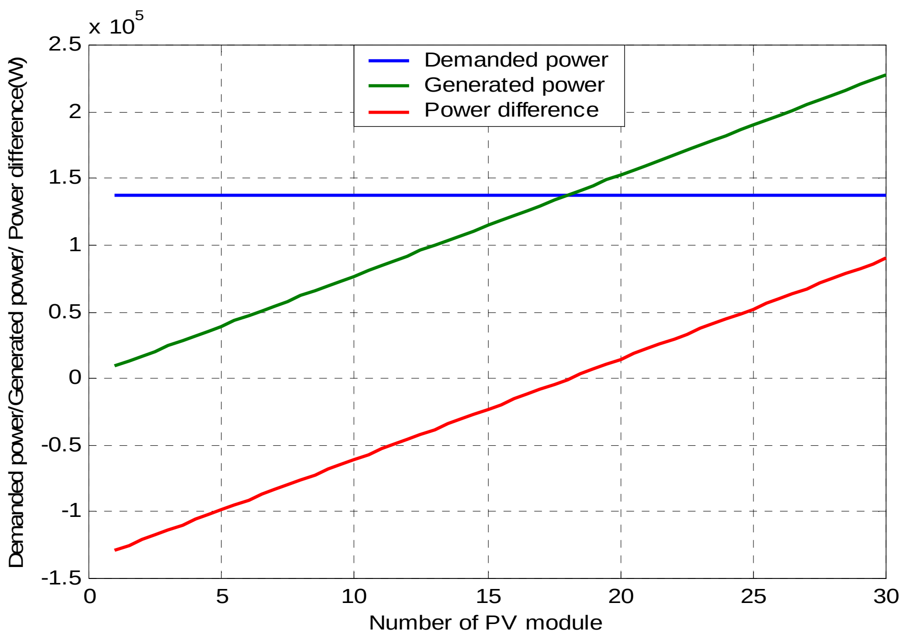


Figure 3. Curve of power against PV module number

4. CONCLUSION

According to result shown can be summarized as below:

1. Solar radiation in Perlis was suitable for PV power application and wind speed still can move the wind power generation throughout the Northeast monsoon.
2. Optimum sizing of PV-wind power hybrid system for the required inverter demanded power was a wind power generation and eight PV modules.

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