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A New Technique of Photovoltaic/Wind Hybrid System in Perlis

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Abstract

The increment of energy costs and decreasing prices of turbines generator and photovoltaic (PV) panels caused photovoltaic/wind hybrid system (PWHS) utilization is becoming popular. This paper presents a new topology of PWHS. It is consists of two main parts: the cooling system for photovoltaic module and the combination method of Savonius and Darrieus for wind turbine. The PWHS is installed in front of Centre of Excellence for Renewable Energy (CERE), University Malaysia Perlis, Northern Malaysia. The main energy source of this system is gain from PV array and wind power generation. It is well known that the power and efficiency of photovoltaic (PV) module usually falls at the rate of ~0.5%/°C and ~0.05%/°C respectively as increase of ambient temperature. The electrical efficiency of PV cell depends on its operating temperature during absorption of solar radiation. For this reason, an active PV cooling system was design using the DC brushless fan with inlet/outlet manifold for uniform airflow distribution. It was attached at the back of the PV panel. Where else, the improvement of wind is using Vertical Axis Hybrid Wind Turbine (VAWT) through the combination method of Savonius and Darrieus types. From the results, it shows that the improvement of PWHS give the big advantages in term of supply the energy in Perlis.

Keywords: Photovoltaic, Photovoltaic/Wind Hybrid System, Savonius and Darrieus

1. Introduction

Solar radiation is the result of fusion of atoms inside the sun. Part of the energy from the fusion process heats the chromosphere, the outer layer of the sun that is much cooler than the interior of the sun, and the radiation from the chromosphere becomes the solar radiation incident on the earth. The sun acts as a blackbody with a temperature around 6000 K [1], transports its vast energy to the earth in the form of

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electromagnetic radiation with a wide spectrum of frequency range that varies from infrared, visible lights to ultra-violet. The amount of solar power perpendicular to the beam outside the Earth's atmosphere is known as solar constant (S), approximately 1367 W/m2 [1],[2]. When the solar radiation enters the earth's atmosphere (Fig. 1), a part of the incident energy is removed by scattering or absorption by air molecules, clouds and particulate matter usually referred to as aerosols. The radiation that is not reflected or scattered and reaches the surface directly in line from the PV module is called beam radiation. The scattered radiation which reaches the ground is called diffuse radiation. Some of the radiation may reach a receive after reflection from the ground, and is called the albedo. The total solar radiation on a horizontal surface of PV module consisting three components is called global irradiance. When the skies are clear and the sun is directly in line from the PV module, the global irradiance is about 1000 W/m2 [1]. Although the global irradiance on the surface of the earth can be as high as 1000 W/m2, the available radiation is usually considerably lower than this maximum value due to the rotation on the earth and climate condition (cloud cover), as well as by the general composition of the atmosphere. For this reason, the solar radiation data is the most important component to estimate output of photovoltaic systems [2], [3], [4]. Solar radiation is greater than 3 kWh/m2 indicates that the sky is clear, its intensity very high and very good for PV application [5].

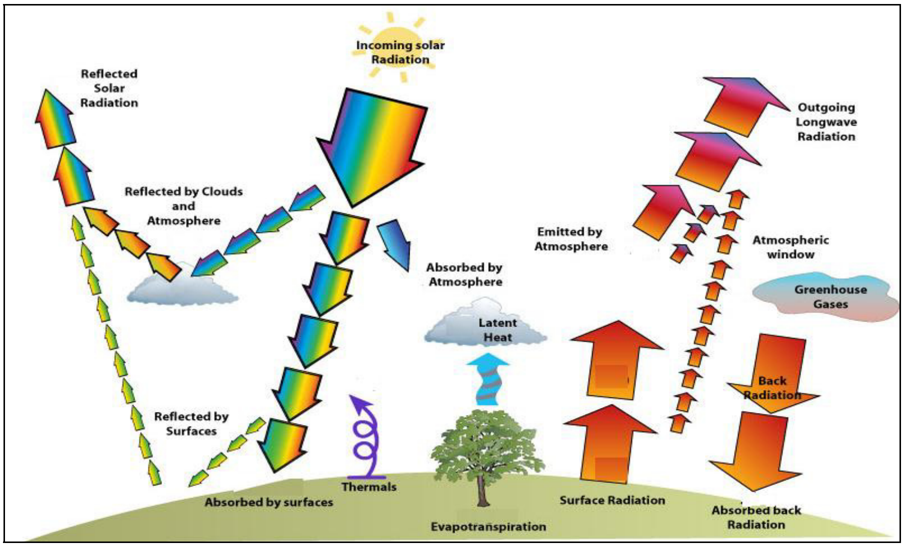

Fig. 1. Solar radiation in the earth's atmosphere [6]

Wind energy is generated by harnessing the wind and is the world's fastest growing energy source. It is becoming more important for electricity companies to use wind energy as it is a renewable and free resource. Electricity companies harness wind energy with wind turbines. A wind turbine is a rotating machine which converts the kinetic energy of wind into mechanical energy. If the mechanical energy is used directly by machinery, such as a pump or grinding stones, the machine is usually called a windmill. If the mechanical energy is instead converted to electricity, the machine is called a wind generator, wind turbine, wind power unit (WPU), wind energy converter (WEC), or aero generator. When the wind flows past the turbine's rotor blades, the blades turn and convert the wind energy into kinetic energy. This energy spins a rotor inside a generator where the kinetic energy is converted into electrical energy. Once the wind energy is converted into electricity, the electricity flows through cables in the turbine, down the turbine tower to connect with the output from the other wind turbines in the wind farm before entering local electricity networks. The greater the wind speed, the more electrical energy generated. Usually see more than one wind turbine working to generate electricity and this is called a wind farm. All the wind turbines in a wind farm work independently. The output of each turbine is combined before it enters a local electricity network or the National Grid. Malaysia chooses the wind energy as an alternative way besides solar energy to replace the fossil fuel that may finish in the future. The studies show that Malaysia has a good potential in wind energy. However, one big issue that delays the development of it is the location and the speed of the wind that not constantly high and sometimes varies in month and location [7]. This research is focus with two elements of renewable energy sources which is solar energy and wind energy. By using with them, the new development of hybrid system will setup to require the energy demand in Malaysia.

1.1 Classification of Data

Malaysia which consists of Peninsular Malaysia, Sabah and Sarawak is situated in the equatorial doldrums area. According to Malaysian Meteorological Department, wind over this country is generally light, but there still some homogenous periodic changes in the wind flow patterns. Due to these changes, Malaysia face four seasons, namely the southwest monsoon, northeast monsoon and two shorter periods of inter monsoon seasons. Usually the southwest monsoon started to establish u In the middle of May or early June until in the end of September. These wind flow is generally light with the speed less than 8 m/s [8]. Otherwise, wind energy is contrary to solar radiation because Malaysia naturally has abundant sunshine. However, it is extremely rare to have a full day with completely clear sky even in periods of severe drought. The cloud cover cuts off a substantial amount of sunshine and thus solar radiation. On the average, Malaysia receives about 6 hours of sunshine per day [9]. Based on Meteorological Station in Chuping, Perlis (60 29' N , 1000 16' E) as shown in Fig.2 has about 795 square kilometers land area, 0.24% of the total land area of Malaysia, with a population about 204450 people [10]. Perlis's climate is tropical monsoon. Its temperature is relatively uniform within the range of 21°C to 32°C throughout the year. During the months of January to April, the weather is generally dry and warm. Humidity is consistently high on the lowlands ranging 82% to 86% per annum. The average rainfall per year is 2,032 mm to 2,540 mm and the wettest months are from May to December. In this research, the data are presented in daily averaged maximum and minimum temperature, and daily averaged solar radiation.

Fig. 2. Map of Perlis has latitude 60° 29' N

2. Data Acquisition

Fig. 3 shows the data-acquisition unit is based on a USA made DAVIS Weather Station Vantage Pro2 (DWS) and Electrocorder that configured perfectly by Renewable Energy Team of the university to meet the specific needs of the research. The station was installed and maintain at the Centre of Excellence for Renewable Energy (CERE), by the University as an independent unit. The solar radiation, temperature, rain falls, wind speeds, wind directions, pressure and humidity were measured by a DWS cup anemometer and vane installed at the top of a 10 mast located few meters. The parameters of data were transmitted to the acquisition unit through the wireless system straight to the receiver that connected to a 24 hours operated computer located in the CERE.

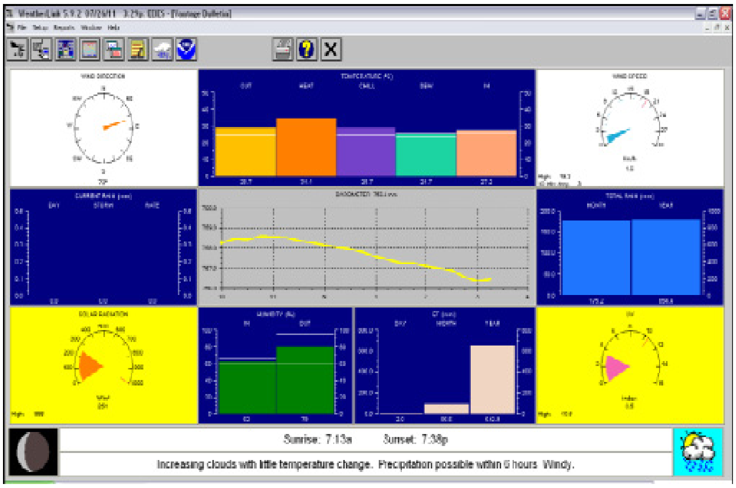

Fig. 3. DAVIS Weather Station Pro2 mimic diagram

Voltage measurements were carried out by the Electrocoder in Fig. 4 with normal DC voltage that connected to the VAWT. The Electrocorder will record the data every second and it manage to save the data up to seven days. The data will be manually downloaded to the computer once a week to ensure that it can continue recording the rest of the voltage data. The data on DWS and Electrocorder will be synchronizing due to data recorded for both are in every second.

Fig. 4. Electrocorder for output voltage measurement

3. Method of PV cooling system

It is well known, the efficiency of solar cells decreases with an increase of temperature. The general rule this decrease is determined first of all by the drop of open circuit cells voltage. During the operation of the solar cell in the outdoor performance, the solar cell suffers from the high temperatures reached under high irradiation conditions. The temperature of solar cell can reach 60-80°C.Therefore an efficient performance of solar cells in conditions demands cooling. Open circuit voltage (V_{oc}), short circuit current (I_{sc}), curve factor (CF) and efficiency (η) are temperature dependent parameters and the performance of a solar cell is influenced by temperature. When the temperature increase, V_{oc} will decrease at a rate of ~2.3 mV/K whereas I_{sc} increases slightly with temperature (T). CF also decreases all these lead to an overall decrease in the cell efficiency [11]. An experimental setup was designed to investigate the electrical performances of the PV system at the Center of Excellence for Renewable Energy (CERE) Universiti Malaysia Perlis. A 130W, 22.V, 8.09A Sharp Solar Module ND-130T1J Solar Panel was used with the peak efficiency 13% under standard condition (25ºC, 1000 W/m^2), and an area of 0.924m^2. The design of cooling system was shown in Fig 5. Aluminum was fitted underneath the PV module and DC brushless fan mounted between aluminum. The heat is distributed by the aluminum to increase the heat transfer rate.

Fig. 5. DC fan attached with PV module.

3.1 Mathematical Formulation

The junction temperature T_j is taken as the average value of the surface temperatures of the bottom side T_{bot} and the top side T_{top}. The average surface temperature is given by the following Eq. 1:

$$T_j = T_{ave} = (T_{top} + T_{bot})/2 \quad (1)$$

4. Method of vertical axis hybrid wind turbine (VAWT)

Fig 6 shows the VAWT that have the main rotor shaft running vertically. The generator or gearbox can be placed at the bottom, near the ground so the tower doesn't need to support it and that turbine doesn't need to be pointed into the wind. There are two distinct type of vertical axis wind turbine which are Savonius type and Darrieus type.

Fig. 6. Hybrid wind turbine of Savonius and Darrieus

The relationship between the kinetic energy, mass of the air and the velocity is as shown in Eq. 2 and the power equation for this kinetic energy is followed by Eq. 3. The kinetic energy of moving air is equal to half the mass of the air, *m* times the squares of its velocity, where *m* is in kilograms, *f* is in Hz and V is in m/s. In addition, *mf* is the mass flow rate per second [7].

$$\text{Kinetic energy} = mV^2 \quad (2)$$

$$\text{power} = 0.5(mf)^2 \quad (3)$$

4.1 Turbine Selection

The criteria of turbine selection is depends on the wind speed characteristic in Perlis, Northern Malaysia. The wind turbine must be meets the following criteria [6]:

- Good self-starting characteristic for low wind speed application.
- High power coefficient (C_p) in order to achieve maximum output from the available power.
- High Tip Speed Ratio (TSR) in order to avoid gearbox.
- Multidirectional and good ability to produce power for different wind speed conditions.
- Low environmental impact.

A combination of Savonius and Darrieus type of VAWT has got many advantages over individual Savonius and Darrieus wind turbine through their simplicity in construction, starting rotation and commercially availability. Table 1 are briefly specifications of Savonius and Darrieus turbine for hybrid turbines configuration:

Table 1: The parameter specification of Savonius and Darrieus turbine

Item	*Savonius*	*Darrieus*
Rotor diameter	120 mm	1m
Rotor Swept area	0.03 m2	0.7 m
Rotor Height	250 mm	0.7m^2

5. Result and Discussion

Fig 7 describes the daily average solar radiation for the March 2011 to February 2012. The highest total daily average solar radiation of 7517.84 Wh/m^2 was recorded on 17th March, and the lowest of 1089.41 Wh/m^2 was recorded on 12th May. Daily average solar radiation values were high during the period of January to April. Average daily solar radiation for the whole year was 5121.67 Wh/m^2 per day and the annual total solar radiation in Perlis was 1721.22 kWh/m^2 per year.

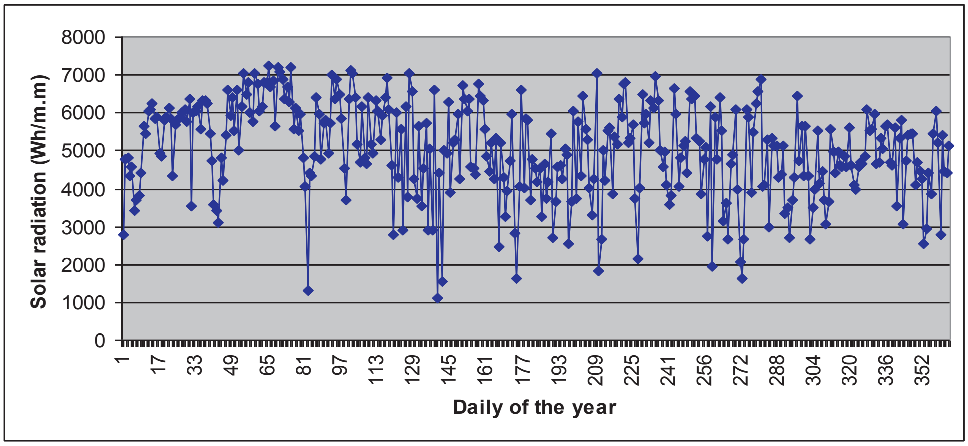

Fig. 7. The graph of the daily average of solar radiation throughout 2011 to 2012

The daily wind speed for one year period that is from March 2011 to February 2012 is shown in Fig 8. Following to the graph, the minimum daily wind speed is 0.2019 m/s and occurs on September. The maximum daily wind speed is 11.6176 m/s and occurs on April. The average daily wind speed is 2.3458 m/s. From the graph, it can be said that the wind speed in Perlis is quite low. However, the light wind speed in other month still can generate power at certain location.

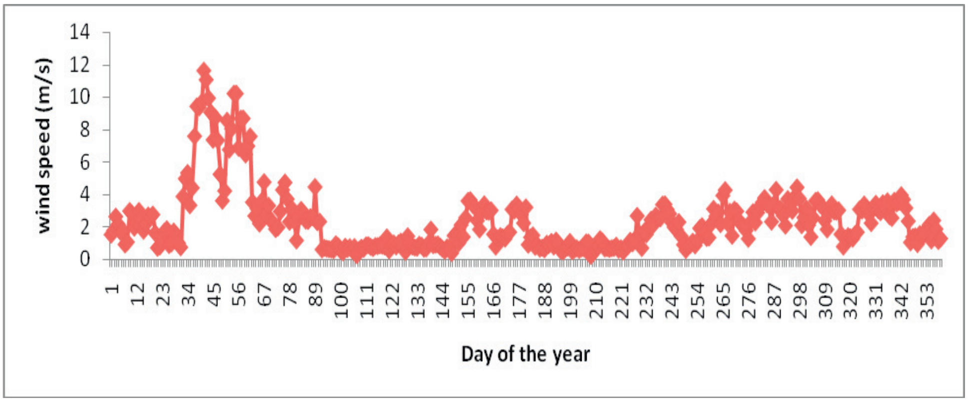

Fig. 8. The graph of the Daily average of wind speed throughout 2011 to 2012

The average of the surface temperatures T_{ave} at the bottom side T_{bot} and the top side T_{top} were determined using Eq. 1. In order to determine surface temperature, a thin T- type thermocouple was installed into the PV at the bottom side and the top side. T_{ave} were measured and recorded every 1 minute using Midi Logger GL220 on 30 Mac 2012. The temperature measurement of the PV module is presented in Fig 9. It can be observed that the temperature of PV module is higher than ambient temperature. This also shows that the increase of temperature of PV module without the cooling mechanism is higher than the cooling mechanism under the same meteorological condition. The variation of temperature between the cooling and non-cooling cases can be as high as 6ºC.

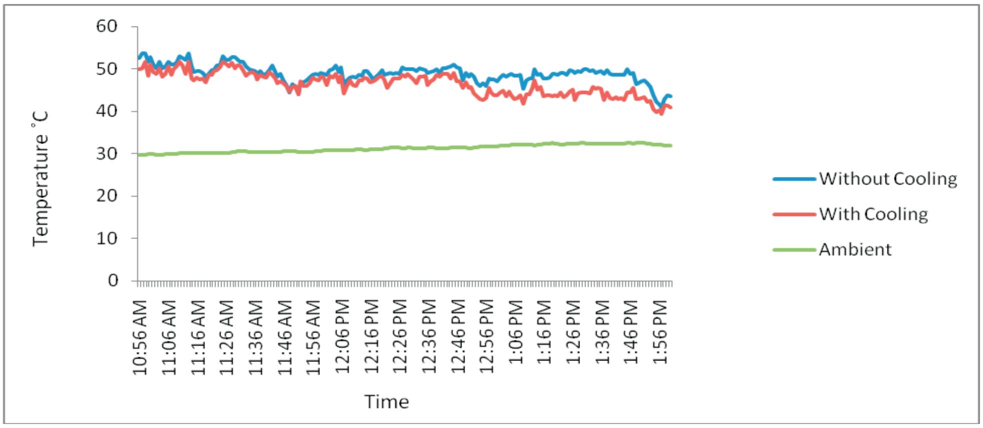

Fig. 9. Comparison between ambient temperature and average panel temperature under cooling and without cooling condition.

The temperature has a negative effect on the panel performance. The influence of temperature on open circuit voltage is presented in Fig 10. It show that the open circuit voltage of the PV module with cooling system higher than PV module without the cooling system. The maximum power voltage decreases with the increase of the panel temperature.

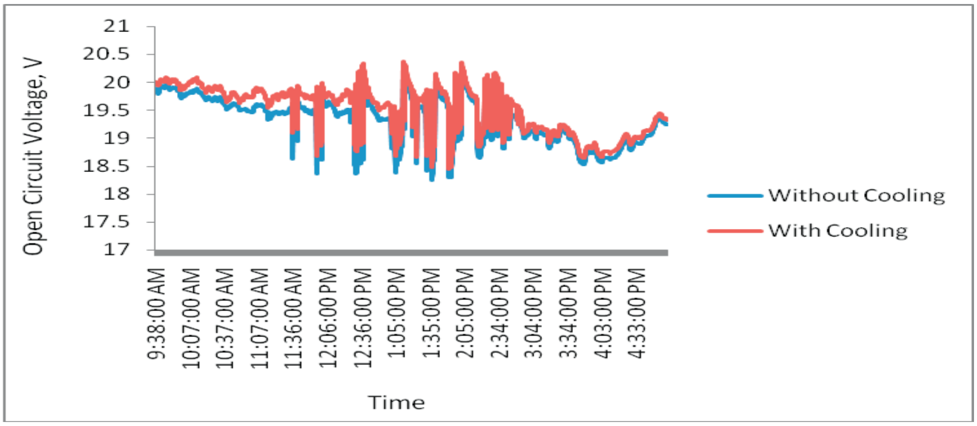

Fig. 10. The graph of the open circuit voltage under cooling and without cooling condition.

Fig 11 shows the graph of average output voltage was generated from VAWT has been taken on 30 Mac 2012. The output voltage was recorded using the Electrocorder. The maximum voltage was generated is 28.43 V_{dc} with the speed of wind is 4.9 m /s. These results of the output voltage shows that the VAWT is suitable to use for the area with low wind speed.

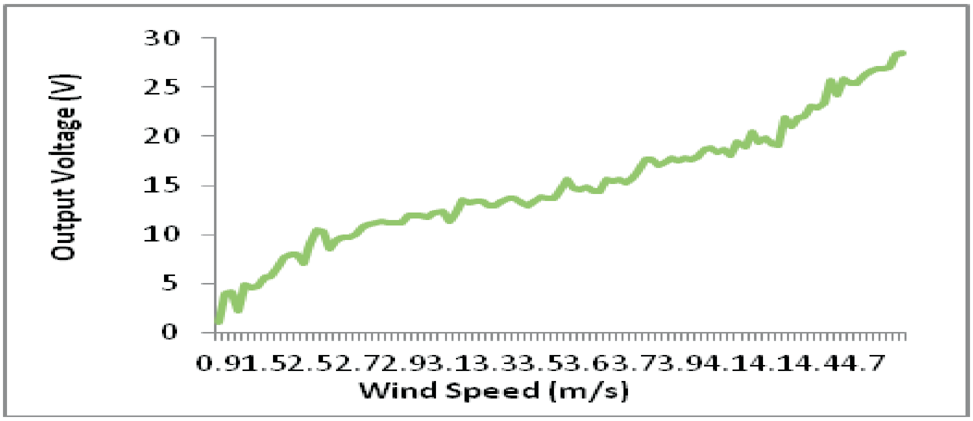

Fig. 11. The graph of output voltage from vertical axis hybrid wind turbine

6. Conclusion

This paper presents a new topology of PWHS through the cooling system for photovoltaic module and the combination method of Savonius and Darrieus for wind turbine. Under cooling condition, the temperature can be reduced to effectively increase the efficiency of solar panel. From the results of output voltage, it can be conclude that the PWHS overcome the disadvantage between the traditional hybrid systems in term of battery charging period, can running with low wind speed and produce higher voltage.

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