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Solar Radiation Potential as Energy Source of Photovoltaic Powered Uninterrupted Power Supply in Perlis, Northern Malaysia

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Abstract: *This paper presents analysis of the solar radiation characteristics as energy source of photovoltaic (PV) powered uninterrupted power supply (PV-UPS) in Perlis, Northern Malaysia for the year of 2011 to 2013. The characteristics consist of daily, monthly and annual solar radiation. Peak sun hours (PSHs) of the solar radiation and PV power generation capacity are also analyzed. The potential of solar radiation as energy source of PV-UPS based on their values. They are low solar radiation (below 2.6 kWh/m^2), moderate solar radiation (between 2.6 – 3 kWh/m^2), high solar radiation (between 3-4 kWh/m^2) and very high solar radiation (above 4 kWh/m^2). The results show that the average monthly solar radiation for the past three years is 4.8 kWh/m^2. The annual total solar radiation in Perlis is 1761.1 kWh/m^2 which will generate a total electric energy of 228.9 kW/m^2 per year of PV module, if all the lands in Perlis are filled with horizontal PV panels, nearly 181.97 GWh of electricity could be produced per year. This shows the big potential of solar radiation for PV UPS in Perlis, Northern Malaysia.*

Keywords: *Solar radiation; Peak sun hours (PSHs); Photovoltaic; Uninterrupted power supply*

I. Introduction

Energy is one of the essential inputs for economic development and industrialization. Fossil fuels are the main resources and play a crucial role to supply world energy demand. However, fossil fuel reserves are limited and usage of fossil fuel sources has negative environment impact. Therefore, management of energy sources, rational utilization of energy, and renewable energy source usage are vital [1].

Renewable energy has an increasing role in achieving the goals of sustainable development, energy security and environmental protection. Nowadays, it has been recognized as one of the most promising clean energy over the world because of its falling cost, while other renewable energy technologies are becoming more expensive [2].

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 [3].

When the solar radiation enters the earth's atmosphere (figure. 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/m^2 [4]. Although the global irradiance on the surface of the earth can be as high as 1000 W/m^2, 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 [3], [5],[6]. Solar radiation is greater than 3 kWh/m^2 indicates that the sky is clear, its intensity very high and very good for PV application [7].

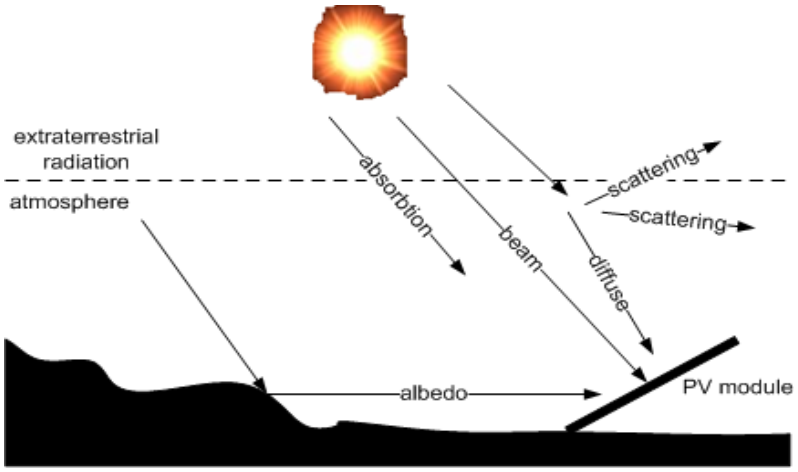

Fig. 1. Solar radiation on the earth's atmosphere

II. Methodology

The data collection of solar radiation for this present are obtained from the Centre of Excellence for Renewable Energy (CERE) Station in Kangar, Perlis, Northern Malaysia, which its area location is as shown in Perlis's map in figure. 2. The weather station at CERE uses Vantage Weather Station Pro2. Solar radiation data are recorded every minute by the weather station. The solar radiation data are recorded every minute as purpose of analysis. It is monitored from at 07.00 am until 07.00 pm. This is to obtain average daily solar radiation.

Fig. 2. CERE Station in Kangar, Perlis, Northern Malaysia

Matlab program is used to perform the daily and monthly solar radiation data throughout year 2011 to 2013. The profile of the data will be processed and consequently plotted using Matlab which are stated as below.

1. The daily solar radiation data in MJ/m^2 are stated into a column of 365 which significant the number of days in a year throughout year 2011 to 2013.
2. The daily solar radiation is converted to Wh/m^2 by multiplying each element of the matrix with 1000000/3600. It is suitable relationship between units of MJ/m^2 and Wh/m^2 as stated below.

   $1\ MJ/m^2 = 1x10^6\ Ws/m^2$
   $=1000000/3600\ Wh/m^2$
3. The daily and monthly solar radiations are plotted for each year. Their maximum, minimum, average and annual total solar radiation data are calculated.
4. The data of daily solar radiation, minimum, maximum and average monthly solar radiations are evaluated. The lowest minimum, the highest maximum and the highest average values are determined and shown in a table and graph format.

5. Distribution of the daily solar radiation is classified as 1 – 2 kWh/m^2, 2 – 3 kWh/m^2, 3 – 4 kWh/m^2, 4 – 5 kWh/m^2, 5 – 6 kWh/m^2, 6 – 7 kWh/m^2, and 7 – 8 kWh/m^2 which is related to the number of days in a year. It is also based on solar radiation classification by [8] who stated that solar radiation can be classified into four categorizes. They are low solar radiation (below 2.6 kWh/m^2), moderate solar radiation (between 2.6 – 3 kWh/m^2), high solar radiation (between 3-4 kWh/m^2) and very high solar radiation (above 4 kWh/m^2). It is important to know the skies condition and its potential towards PV application in Perlis, Northern Malaysia.
6. The monthly solar radiations are divided by 1000 W/m^2 to obtain the peak sun hours (PSHs). Weixiang et al. (2005) explained that peak sun hours (PSHs) is the length of time in hours at a radiation level of 1000 W/m^2 needed to produce energy equivalent to the total energy in one day or it is ratio of solar radiation (Wh/m^2) to solar radiation level of 1000 W/m^2. Values of PSHs are plotted in a bar graph format. Their minimum, maximum and average value are calculated and displayed in a table.
7. In order to estimate the potential generating of PV module, it is necessary to estimate the area which is suitable for PV integration. The efficiency of PV module is an important figure for the estimation of PV output. A conservative value of 13 % for popular single crystalline silicon modules was used although higher efficiency modules are available [7]. The annual potential electricity generating capacity from PV systems, E_{out}, can be estimated by [7]

$$E_{out} = \left(\sum E_{solar,i}\right) x\, A_i \, x\, \eta_{pv} \, x\, f \qquad (1)$$

where

$E_{solar,i}$ = available solar radiation on different orientation surfaces

A_i = area of orientation surface,i

η_{pv} = efficiency of PV modules

f = utilization factor

III. Results And Discussion

3.1 Daily Solar Radiation

The daily solar radiation data in Perlis through the year of 2011 to 2013 is shown in figure. 3 The minimum, maximum daily solar radiation and its average for each year are shown in Table 1. It was recorded at Centre of Excellent for Renewable Energy (CERE) Station, Kangar. From the daily solar radiation data, the monthly, annual and PSHs can be obtained and analyzed.

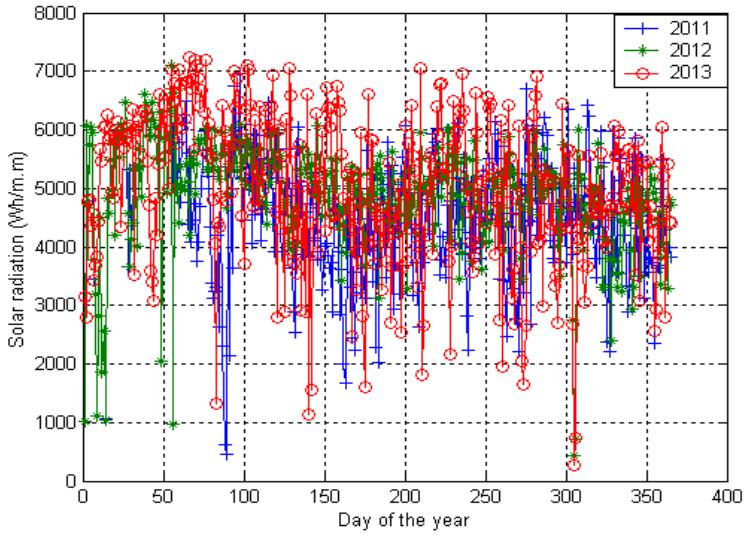

Fig.3. Daily solar radiation through the year of 2011 to 2013

Table 1. Minimum, maximum and average solar radiation through the year of 2009 to 2011

	Solar radiation (Wh/m^2)		
	Minimum	**Maximum**	**Average**
2011	447.22	7108.33	4566.76
2012	435.11	7108.61	4886.68
2013	277.8	7239	5005

Based on figure. 3, there are only two, one and two days in 2011, 2012 and 2013, respectively that had the daily solar radiation below 1000 Wh/m^2. The minimum solar radiations for each year are shown in Table 1. The solar radiations are categorized in the low solar radiation and have no potential to generate PV powered UPS system [6]. The maximum and average solar radiation are above 7000 Wh/m^2 and 4000 Wh/m^2, respectively. They are categorized in the very high solar radiation and have big potential to generate PV powered UPS system [7].

Classifications of the daily solar radiation from year 2011 to 2013 are shown in figure. 4. Day number and its percentage of the solar radiation which are lower than 1 kWh/m^2, between 1 and 3 kWh/m^2 and higher than 3 kWh/m^2 in each the year are shown in Table 2.

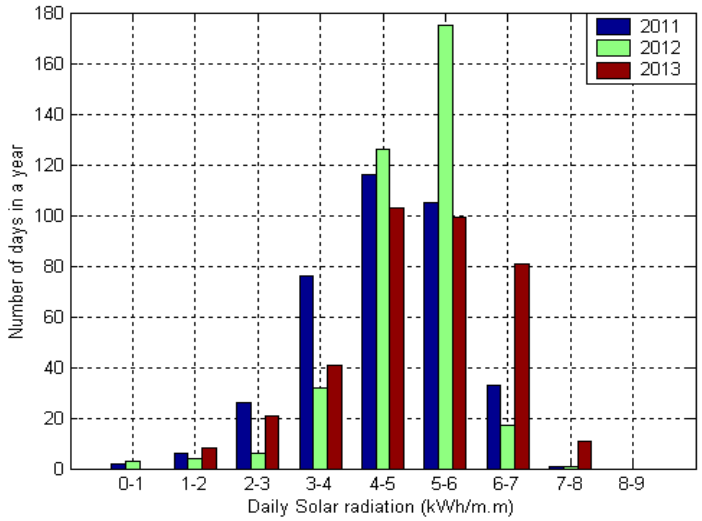

Fig.4. Distribution of the daily solar radiation for year 2009, 2010 and 2011

Table 2. Day number and its percentage of the solar radiation are lower than 1 kWh/m^2, between 1 and 3 kWh/m^2 and higher than 3 kWh/m^2 for year 2011 to 2013

Solar radiation (kWh/m^2)	**2011**		**2012**		**2013**	
	Day number	**Percentage (%)**	**Day number**	**Percentage (%)**	**Day number**	**Percentage (%)**
lower than 1	2	0.5	3	0.8	0	0
1 to 3	32	8.7	10	2.7	8	2.1
higher than 3	331	90.7	352	96.4	357	97.8

Figure. 4 and Table 2 show that every year, the day number which has no potential (solar radiation is lower than 1 kWh/m^2) to generate the PV powered UPS system is only below 0.8%. The day number which has still potential (solar radiation is between 1 kWh/m^2 to 3 kWh/m^2) is between 2.1% to 8.7%. The percentage of highest day number which has big potential (solar radiation is higher than 3 kWh/m2) is above 90%, it is indicates that Perlis has big potential to generate the PV powered UPS system.

3. 2 Monthly Solar Radiation

Figure. 5 shows the average monthly solar radiation for the past three years (2011 to 2013). November had the lowest average monthly solar radiation of 4390.14 Wh/m^2 and the highest of 5549.0 Wh/m^2 was experienced in February. The average monthly solar radiation for the past three years was 4824.81 Wh/m^2. The average monthly solar radiation still indicates that the solar radiation in perils is categorized in the very high solar radiation and have big potential to generate PV powered UPS system [7].

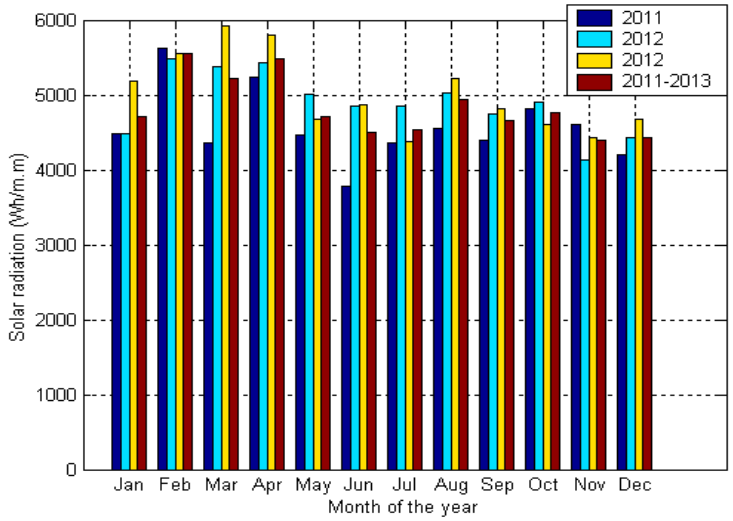

Fig.5. Average monthly solar radiation for year 2011, 2012 and 2013

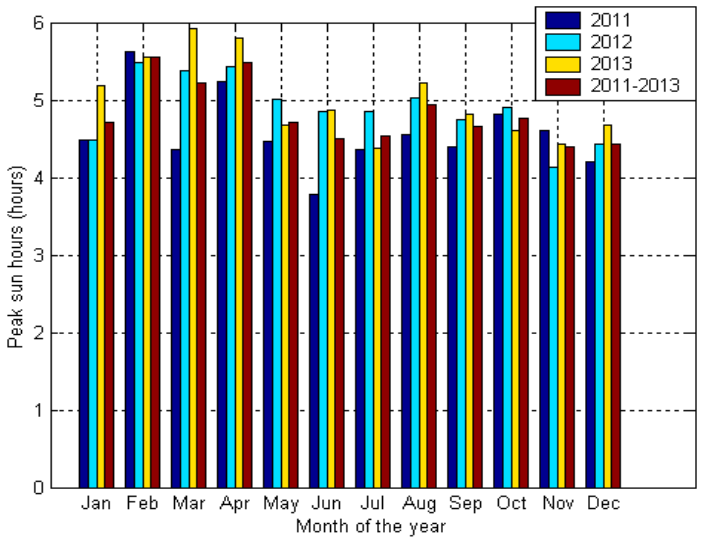

Fig.6. Peak sun hours (PSHs) in Perlis for year 2011, 2012 and 2013

Average peak sun hours (PSHs) for the past three years (2011-20013) are shown in figure. 6. December experienced the lowest PSHs of 4.4 hours and the highest of 5.5 hours was experienced by February. The average PSHs for the past three years was 4.8 hours.

3.3 PV Power Generation Capacity

Based on the average monthly solar radiation for the past three years, the annual total solar radiation in Perlis is 1761.1 kWh/m^2. If this amount of solar radiation is converted to electricity by PV technology with the its efficiency and utilization factor were 13% and 1, respectively, using Equation (1) so will generate a total electricity energy of 228.9 kWh/m^2 per year of PV module, provided that the PV modules are horizontally installed.

If all the lands in Perlis (795000000 m^2) are filled with horizontal PV panels, nearly 181.97 GWh of electricity can be produced per year. This shows the big potential of solar radiation for PV powered UPS system in Perlis.

IV. Conclusion

According to result can be concluded that;

1. The average monthly solar radiation for the past three years was 4824.81 Wh/m^2. The average monthly solar radiation indicates that the solar radiation in perils is categorized in the very high solar radiation and have big potential to generate PV powered UPS system.
2. The annual total solar radiation in Perlis is 1761.1 kWh/m^2 which will generate a total electric energy of 228.9 kW/m^2 per year of PV module, if all the lands in Perlis were filled with horizontal PV panels, nearly 181.97 GWh of electricity could be produced per year. This shows the big potential of solar radiation for PV powered UPS system in Perlis.

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