Photovoltaic (PV) Street Lighting Systems Based on Meteorological Data in Perlis

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***Abstract*—This paper presents 25 W bulb design of photovoltaic (PV) street lighting system, this design was based on meteorological data in Perlis. Monthly solar radiation data was got from Meteorological Station, Chuping Perlis. From the data can be calculated peak sun hours (PSHs) and then calculated average PSHs for a year. Using average PSHs, a minimum size of PV module and ampere hours of battery can be found. The PV street lighting system was installed in front of Cluster Power Electronic and Machine Design, School of Electrical System Engineering, University Malaysia Perlis. The observation result shown that the system perform well. The bulb can light on without charging battery until 4 days and with charging battery on sunny, cloudy or raining the battery voltage above 12 V.**

***Keywords* — Photovoltaic; Street lighting system; Sun radiation; Peak sun hours (PSHs)**

I. INTRODUCTION

The PV street lighting systems have been used in many place, especially in many developing country. According to a typical rural environment, stand alone PV lighting systems can be mainly applied as lighting for dangerous points or intersections, pedestrian crossing, ferry station, access to the village or the town, public place, bus stop, camping sites, areas for activities and so on [1]. In 1988, 15 PV street lighting systems were installed in the village of Sukatani in the province of West Java of Indonesia [2]. The village were not connected to the electricity grid of the PLN utility.

Sun energy is the biggest energy in the world. Sunlight enters the earth's atmosphere, some is absorbed, some is scattered and some passes through unaffected by the molecules in the atmosphere. When skies are clear and the sun is directly overhead, the resultant solar radiation on the earth, namely global irradiance or solar radiation, remains about 1000 W/m^2 [3].

The monthly solar radiation data are an extremely important element to estimate output of PV systems [2], [4]. The output of PV module depends on solar radiation, temperature and operating point of the system [5].

To take solar radiation into account, solar radiations integrated over time. Normally, the time frame for integration is one day. Since the PV module is rated at the solar radiation level of 1000 W/m^2 and the PV cell temperature of 25^0 C, the peak sun hours (PSHs) is often used to express solar radiation so that daily output of the PV module is easily calculated by simply using the peak watt (Wp) of the PV module times the PSHs, where the PSHs is the length of time in hours at an radiation level of 1000 W/m^2 needed to produce energy equivalent to the total energy in one day [5].

II. METHODOLOGY

In this PV street lighting system used a classical PV battery system. The system is presented in Figure 1. In this configuration, PV charges the battery during the day and then it supplies the street light during the night [6].

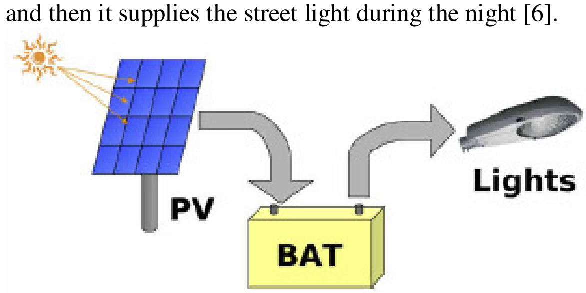

Figure 1. Classical configuration layout

The design of PV street lighting system follows considered items below [1], [7]:

A. *Solar Radiation and PSHs*

Solar radiation data can be got from Meteorological Station, Chuping Perlis. Unit of solar radiation is Wh/m^2 or J/m^2, to convert a quantity given in Wh/m^2 to J/m^2, it should be multiplied by 3600 [8]. PSHs are ratio of solar radiation (Wh/m^2) to solar radiation level of 1000 W/m^2 [5]. The solar radiation and PSHs are needed to calculate a minimum size of PV module.

B. *Lamp For Lighting Sytem*

Wattage of bulb that was used in this design is 25 W. From the wattage can be calculated a lamp energy in watt hours, according to how long time the lamp light on, usually 12 hours from 07.00 pm to 07. 00 am.

C. *PV Module Sytem*

Monthly average PSH is needed to calculate a minimum size of PV module. From the lamp energy in watt hours, minimum size of PV module can be calculated using this formula :

$$PV \ \ module = \frac{Lamp\ energy\ (watt\ hours)}{Monthly\ average\ PSH} \quad (1)$$

D. Battery Capacity and Box

A water proof battery box is commonly used and closed with special anti- theft screws. This makes it difficult to access for maintenance of the battery with regulator addition of water. Maintenance free batteries with valve regulated sealed are strongly recommended. This is because they will never require water. Even though lead-acid batteries are commonly used for PV street lighting systems. The battery of 12 V was used in this design and can operate the lamp for 4 days, if the weather is cloudy or raining . Its ampere hours can be calculated using this formula.

$$ampere\ hours = \frac{Lamp\ energy\ (watt\ hours)}{12\ volt} x\ 4 \qquad (2)$$

E. Lighting Controller

The PV lighting controller is the heart of the energy management of PV power system. This is because it controls the energy of the battery and the way it is spent on the different parts of the system. The design of a control circuit was experimentally done in this research. PV street lighting system consists of a lamp lighting controller, a charger controller, a battery and a PV module.

The bulb lighting controller uses light dependent resistor (LDR) circuit controller, its main components consist of transistor BC 140 and relay of 12 V DC.

F. Cable and Fuse

The cable and fuse size that were used in this design arranged according to current flow through part of circuit, the chosen cable and fuse ampere were higher than the current flow through them, For earth cable, according to Malaysia standard MS1837; 2005 recommends a minimum of 6 mm^2 single core copper cable.

G. Testing

To know that the PV street lighting system can perform well, so battery voltage measurement and observation of the bulb on-off were done. The voltage of battery was measured every morning and afternoon, three condition were be taken, the first the battery was not charged, it is needed to know that the battery can run the bulb for 4 days. The second, the battery was charged on sunny and the third, the battery was charged on cloudy or raining. For the second and third were needed to know that the battery can be charged until above 12 V.

III. Result And Discussion

A. Solar Radiation and PSHs

PSHs are needed to determine the required PV module. The PSHs can be determined from solar radiation in one area.Solar radiation data from Meteorological Station, Chuping Perlis for the past 26 years are shown in table 1 [9].

Table 1. Solar radiation and PSHs in Perlis (1979-2006)

Month	Solar Radiation		PSHs
	(MJ/m^2)	(Wh/m^2)	(hour)
January	18.69	5191.67	5.19
February	19.84	5511.11	5.51
March	20.82	5783.33	5.78
April	20.48	5688.89	5.69
May	17.81	4947.22	4.95
June	17.76	4933.33	4.93
July	16.48	4577.78	4.58
August	18.36	5100	5.1
September	17.29	4802.78	4.80
October	16.41	4558.33	4.56
November	16.12	4477.78	4.48
December	16.35	4541.67	4.54
Average	18.69	5191.67	5.19

Figure 2 and 3 show solar radiation and PSHs, respectively.

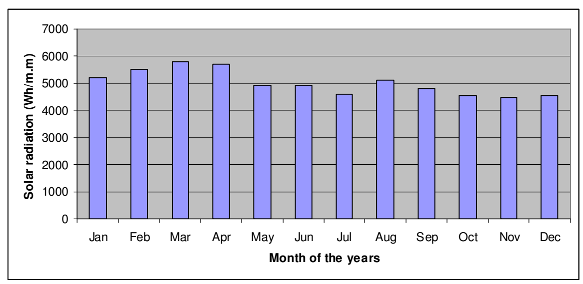

Figure 2. Monthly solar radiation for the past 26 years in Perlis

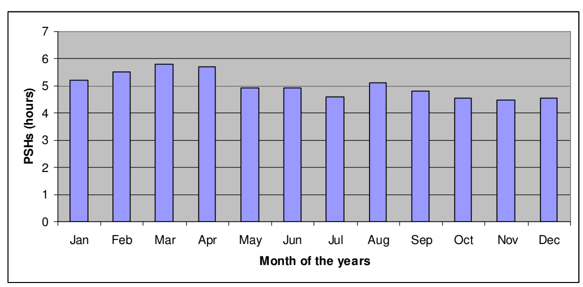

Figure 2. Monthly Peak Sun Hours (PSHs for the past 26 years in Perlis

Figure 2 and 3 shows the highest monthly solar radiation and PSHs are on March and April. PSHs average in Perlis Malaysia is 5.01 hours.

B. Determination of the Load (wattage)

A bulb of 25 W DC was used in this determination. For a lighting system operates for 12 hours (12 hours are taken from a data record of Meteorological Station, Chuping, that from 19.00 pm until 7 am no solar radiation).

Load = 25 watt x 12 hours
= 300 watt hours

Allowing for 5% loss, can be said that the load is 300 x 1.05 = 315 watt hours

C. Determination of the Required PV Module

In 5.02 hours, the solar module must generate at least as much electricity as is used by the load.

$$\frac{315 \ watt \ \ hours}{5.01 \ \ hours} = 62.8 \ watt$$

The system requires a minimum 62.8 watt rated PV module

D. Determination of the Battery Capacity

Battery deep cycle is rated in ampere hours. Solar battery supply is 12 volt. Using the formula :

$$Battery \ (ampere \ \ hour) = \frac{load \ (watt \ \ hours)}{voltage \ \ (volt)}$$
$$= \frac{315}{12}$$
$$= 26.3$$

In most case it is recommended that the battery is sized that they have around 3 to 4 days capacity. This allows for days with low sunlight (rain or cloudy) and reduce the daily depth of battery discharge resulting in longer battery life.

With 4 days storage capacity, the battery size would be as follows :

26.3 x 4 = 105.2 ampere hour (Ah)

So the required battery is 105.2 Ah

E. Determination of the PV Charger Size

A solar regulator or charger controller must be able to handle the maximum current produced by the solar panel. In specific sunlight and temperature conditions, the output current can increase and the regulator must be able to handle this.

Read the specification of the solar module (from catalogue or test label attached to solar module)

A 64 W UniSolar solar module has a rated output current 3.88 A and a short circuit current of 4.8 A.

Minimum solar regulator for a single 64 W UniSolar solar module is :

Short circuit current of solar module x 125% = 4.8 A x 1.25 = 6 ampere

It is recommended that the regulator selected is even slightly larger than 6 ampere.

F. Fuse

In a PV system, fuse is used to protect over current in the system.Fuse should be connected directly to battery to protect any short circuit at the battery wiring.The fuse should take the charge controller nominal current

F. Earth Cable

Malaysia standard MS1837;2005 recommends a minimum of 6 mm^2 single core copper cable.

F. Size of Cable

Size of cable can be selected according to the current flows through it.

F. Wiring Diagram

Wiring diagram for bulb of 25 W is shown in Figure 4.

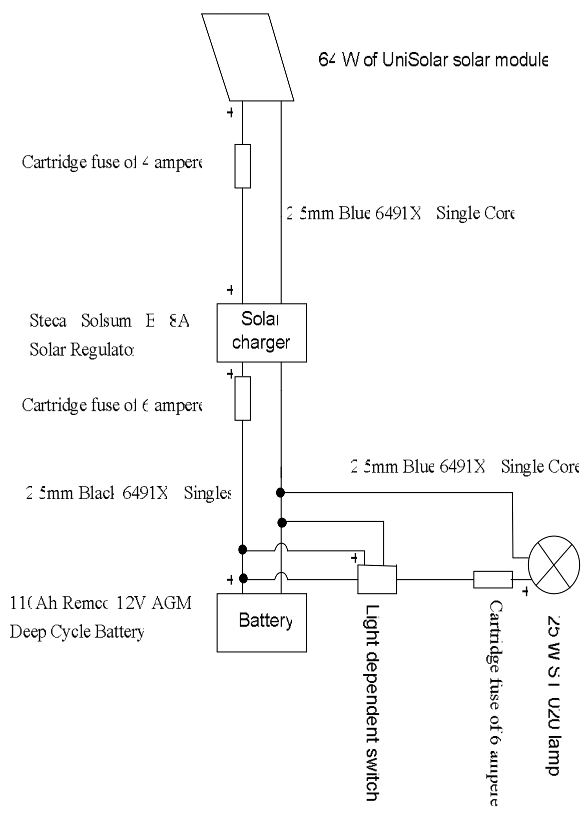

Figure 4. Wiring diagram for bulb of 25 W

The PV street lighting system was installed in front of Cluster power Electronic and Machine Design University Malaysia Perlis (UniMAP) . Observation result shows that the PV street lighting system perform well, every day the bulb of 25 W lights on 7.00 pm and off on 7.00 am. Every morning and afternoon the battery voltage is measured, it is done to know that the solar charger can charge the battery or no. The measurement result can be seen in Figure 5 to 7.

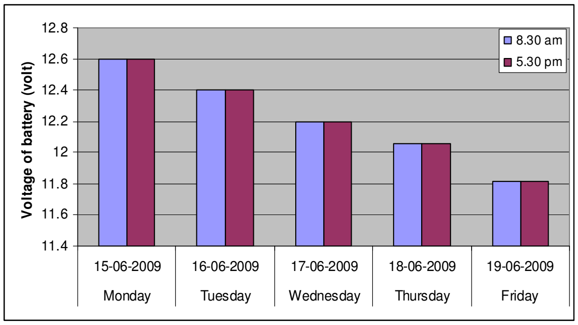

Figure 5. Battery was not charged

Figure 5 shows that the battery was not charged until 4 days. The early battery voltage was 12.6 V on monday (15th June 2009), next day the battery has been used to supply bulb for 12 hours and the battery voltage became 12.4 V, until the forth day the battery voltage became 11.81 V. The battery voltage drop average for 4 days was 0.2 V and the bulb could still light.

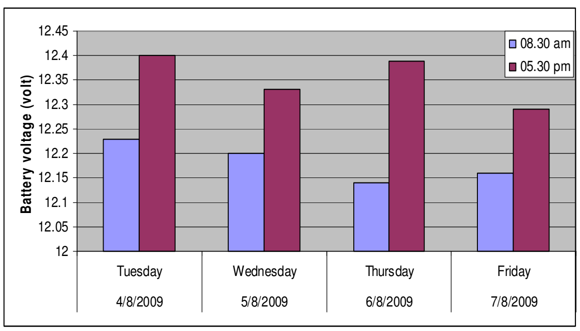

Figure 6. Battery was charged on sunny

Figure 6 shows that the battery was charged on sunny, the charging result always above 12 V. The battery voltage increasing average for 4 days was 0.17 V.

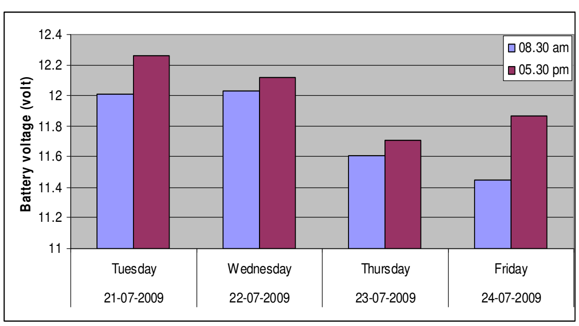

Figure 7. Battery was charged on cloudy and raining

Figure 7 shows that the battery was charged on cloudy and raining. For three days, the weather was cloudy and raining, so the battery voltage could not be above 12 V, but the bulb could light.

CONCLUSSION

According to research result can be concluded that :

1. Based on meteorological station, Chuping Perlis, peak sun hours is 5.02 hours.
2. For designing a 25 W bulb of PV street lighting system, minimum size of PV module is 62.7 W, and minimum ampere hours of 12 V battery is 105.2 Ah.
3. For the PV street lighting system that was installed in front of Cluster power Electronic and Machine Design University Malaysia Perlis (UniMAP) perform well.

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