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An Automatic Off-Grid Solar Street Lighting System

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Abstract: In this paper a photovoltaic solar power system will be designed to power an LED light. The main components of the system that need to be designed PV module: Convert the solar energy to DC electricity, Battery bank: To store energy and use it in the days when there is no sun ray, Charge controller: Organize charging and discharging the battery, and The load (LED light).it is important to determine the average daily solar insolation [kWh/m² per day]. I have to know how many battery is required to cover our load for one night using different equations.

Keywords: Lighting, Street, Technology, An automatic, Solar.

I. INTRODUCTION

Energy is one of the most important things in our life which makes it easier and better. We use energy every day and everywhere. In the house we use electricity to power a lot of things like lights, TV and refrigerator. Imagine that we lost electricity for some reasons, for example there is no fossil fuel which is the main source of energy that we are using, and then our life would be so hard and difficult. Therefore, we should start to think about another source of energy that is renewable, clean, and easy to get. As we know solar energy is one of these kinds of energy and people should be aware about solar energy and its uses.

Primarily, solar energy is energy comes from the sun, and as we know that solar energy is renewable and infinite. Because solar energy depends on the sun we need a sunny area to use this kind of energy. So if we want to generate electrical energy from sun energy, we need special equipment to convert it, this equipment is called the "solar cell" which is made from silicon with specific structure. The group of solar cells are called the "solar panel." Solar energy is easy to use anywhere and it is so safe. The efficiency of solar panels is around 17%, which is a good percentage. It is easy to install solar panels anywhere with cheap cost, but if you want to buy a solar energy system for your home, for example, that will cost you too much. Solar energy is expensive. Solar panels do not need frequent maintenance. Gradually the usage of this energy is increasing around the world.

Using solar energy to produce electricity will solve many problems like reducing pollution and stopping the reliance on fossil fuel [1].

Various municipality/local governing bodies are thinking to do business around street light pole by providing other services apart from lighting. In the pursuit of making our highways and streets safer, "Adopt a Light" [5] developed the revolutionary concept of lighting up highways through had vertising on street lighting infrastructure. Over the years, many leading organizations have joined the effort and are adopting highway lights for advertising and brand building.Thus in turn enhancing security and adding value to the city'slandscape. Several services are possible by making street light poles intelligent and as energy control points. Intelligent street lighting system comprises of a wireless digital infrastructure that allows street lights to be controlled remotely and a computational device inside each street light with primary functionalities such as "security, energy management, data harvesting, advertising, video surveillance". Solar street lighting infrastructure can act as emergency charging stations to fuel electric cars or electric scooters and also as energy kiosks. This approach with multiple services will help to accelerate the sales and adaptation of electrical vehicles.

Though, the decentralized system meets the lighting load seven under worst cases but in most part of the year, the system remains underutilized. Since, the initial investment for an off grid solar LED Street lighting system is higher compared to conventional grid powered street lights, it is more important to utilize the solar energy much more effectively. In any typical year, the surplus energy varies from 5% to 30% of total watt-hour load per day. The small amount of surplus energy from a single street lighting system is not sufficient to meet local energy needs [3]. However, in a centralized street lighting system, cumulative surplus energy will be high enough to meet some of the local energy needs. The surplus energy can be used for charging electric vehicle battery or for providing charging outlets for mobile lighting units / mobile-phones etc. The centralized station can also work as micro power distribution center. This leads to lower pay-back period for the entire system, light weight and low cost pole structures along with several other benefits. There is also possibility for grid interconnectivity in future, which will further lead to reduction in battery capacity and hence further lower payback period. There is secondary benefit also; as the centralized system can be guarded within the fenced boundary to minimize the risks of theft and sabotage. It is also easy to operate and maintain centralized system. Dust deposition on PVpanels significantly impact PV output performance. Thiscan be avoided in centralized system by cleaning panels atregular intervals which is nearly

impossible to do in decentralized system. Finally, there is no need of design change in pole's mechanical structure.
A photovoltaic solar power system will be designed to power an LED light. This system converts solar energy to electricity [DC Electricity] using a photovoltaic module. We considered UB as our location to design the system. In this project a light/dark circuit (LDR sensor) is used in order to detect if it is night or not to turn on/off the light. This project will be followed the following steps:

- Study the solar radiation.
- Sizing the PV panel.
- Sizing the charge controller.
- Sizing the battery.
- Design the system.
- Wire and build the system.
- Back up battery bank for 1 days.
- Using sensor to detect the light (Turn on/off the light).
- Cost estimation.

II. SITE ANALYSIS

As mentioned before that this system will be used and installed at University of Bridgeport campus. Thus, solar radiation has been studied the at UB.

Using Google maps, we can find the latitude and longitude as the following:
Latitude, Longitude = (41.165809, -73.190038) = (41.165809 N, 73.190038 W) figure 1.

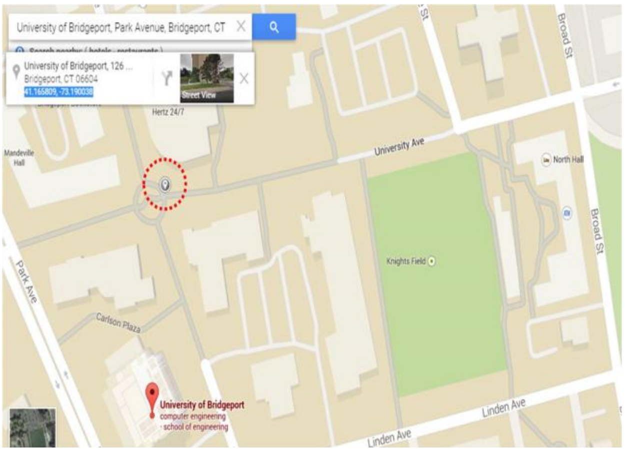

Figure 1: Project Site

NASA table of insolation is used to get the insolation profile of our location, where the following table shows the Monthly Averaged Radiation Incident Onan Equator-Pointed Tilted Surface (kWh/m2/day) fig 2:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Tilt 0°	1.86	2.72	3.76	4.50	5.20	5.76	5.55	4.99	4.10	2.99	1.94	1.62	3.75
Tilt 26°	2.83	3.68	4.48	4.76	5.16	5.49	5.42	5.13	4.67	3.86	2.79	2.58	4.24
Tilt 41°	3.19	3.98	4.58	4.60	4.80	5.02	5.00	4.88	4.69	4.09	3.09	2.94	**4.24**
Tilt 56°	3.37	4.05	4.45	4.23	4.24	4.34	4.35	4.41	4.46	4.11	3.22	3.14	4.03
Tilt 90°	3.07	3.42	3.35	2.78	2.53	2.48	2.51	2.75	3.18	3.36	2.86	2.92	2.93

Figure 2: An Equator-Pointed Tilted Surface (kWh/m2/day):

III. PV MODULE ORIENTATION

I have to know that the tilt angle of the PV module is the angle between the PV module and the ground. Therefore, an optimum tilt angle has to be chosen to receive the maximum amount of solar radiation [2].
The PV module will have a fixed during the year. So, will choose the best tilt angle where the module will receive maximum amount. From the insolation table, it can be noted that the maximum annual insolation value is 4.24 kWh/m2/day which this is at tilt angle of 26° and 41°. But will choose tilt angle of 41° because the optimum tilt angle is the closest to the latitude of the location where the system will be installed. Because we are in the northern hemisphere, the PV module will be installed by facing the true south figure 3.

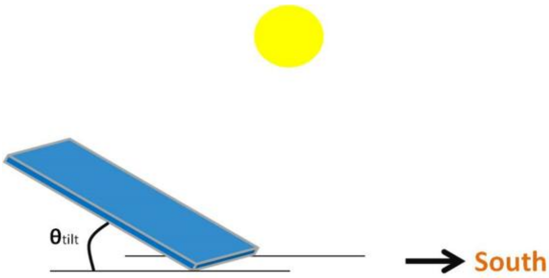

Figure 3: PV Module Orientation

In the considered DMPPT architecture the convertersare connected in series to form strings which are furtherconnected in parallel to the central inverter over a common high voltage DC bus. This is the same as in conventional PV systems, but the addition of the converter effectively decouples the PV module from the rest of the system, increasing its functionality. The converter ratings are predetermined by the used PV module. In this case, the available module has a maximum power point voltage of approximately 30V, for the power range from 10W to 120W. Fig. 3 shows the converter circuit schematic. The synchronous buck-boost topology is chosen due to its robustness and low number of components. The output voltage from the PV module can be either increased or decreased in order to compensate for the changes in the rest of the PV array [4].

The choice of switching frequency will have the major impact on the converter size and losses. Rather than going for a predetermined value, a loss analysis will be conducted for a range of switching frequencies, keeping in mind the thermal and spatial constraints. The next parameter to consider is the inductor current ripple.

Varying its value, the trade-off between the DC and A Cinductor losses can be made. Depending on the ratio of the AC-to-DC winding resistance, the optimum current ripple will be somewhere in the CCM mode, moving toward the boundary mode as this ratio decreases. Based on previous measurements, the optimal peak-to-peak current ripple is found to be 150% (6A), and this value will be used in the design procedure. After the switching frequency and the inductor current ripple are known, the converter losses can be estimated.

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IV. PHOTOVOLTAIC PANELS SIZING

First, it is important to determine the average daily solar insolation [kWh/m² per day] at where you are going to install the system [IN UB]. From the insolation table, the tilt angle of 41° is chosen because the optimum tilt angle is the closest to the latitude of the location where the system will be installed. Where, the maximum annual insolation value is 4.24 kWh/m2/day at this tilt angle. From the insolation table again, we can see that the lowest value of insolation when the tilt angle is 41° is 2.94 kWh/m2/day which occurs in December. So based on this insolation values we will design our PV panel figure 4.

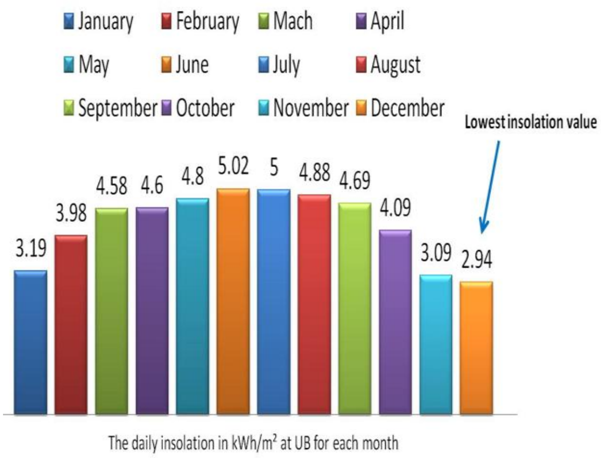

Figure 4: Photovoltaic panels sizing

So, the insolation for our location = 2.94 KWh/m²/day, and as calculated before, the total energy of the load for one day = 108 Wh/day. But, because of losses we will add 25% of the total energy, therefore:
Total PV panel energy needed = 108 × 1.25 = 135 Wh/day
So, that means that the PV panels should provide us with energy of 157.5Wh/day. Assume that 50-W polycrystalline panels are available to use.
Now, Number of PV panels needed =

$$\frac{Required\ energy\ per\ day}{insolation\ \times\ rated\ power\ of\ the\ PV\ panel}$$

= 135 / (2.94 × 50) = 0.918 @ 1 panel
Now, 50-W panels at 2.94 insolation, then: the produce energy = 1 × 2.94 × 50 = 147 Wh.
The panel has the following specifications at STC:

Electrical Specifications

Optimum Operating Voltage (Vmp):	19.12 V
Optimum Operating Current (Imp):	2.62 A
Open - Circuit Voltage (Voc):	22.64 V
Short- Circuit Current (Isc):	2.8A
Maximum Power at STC:	50 W
Operating Module Temperature:	-40°C to + 85°C

STC: Irradiance 1000 W/m², module temperature 25°C, AM=1.5;

We are going to use a number of 12v-batteries with 18 Ah capacities, we have to know how much battery is required to cover our load for one night, Battery should be connected in parallel.

V. CONCLUSION

PV module. Integrating the converter into the PV module during the module assembly could reduce the number of packaging layers reducing the cost and increasing the functionality of PV modules. The main challenges to achieve successful integration are very low profile flexible construction, suitable magnetic materials and efficient heat extraction and dissipation. In this paper the approach using the flexible low permeability magnetic sheets as the inductor core material and the converter PCB as theheatsink are investigated. As shown, very low profile construction with overall converter thickness of 1.3mm is achieved while achieving the efficiency. The efficiency of solar panels is around 17%, which is a good percentage. It is easy to install solar panels anywhere with cheap cost, but if you want to buy a solar energy system for your home, for example, that will cost you too much solar energy is expensive. Solar panels do not need frequent maintenance. Gradually the usage of this energy is increasing around the world.

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