Solar Smart Street Light

Submitted in the fulfillment of the requirements

of the End Term Project

by

P7 EE 2nd Year

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Acknowledgement

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Aim and Objectives

Aim:

The main aim of this project is to develop a solar lighting system that is inclined at an angle to trap maximum solar irradiation, use it to charge a battery during daytime and offer energy to the LED to glow at night.

Objectives:

- To design a 6m tall 25 Watt Street light, with sufficient luminance.
- The Street light should be solar powered, with a battery pack.
- The Street light should have sufficient power backup.
- Calculate solar panel size, battery size, street light orientation, cost of setup.

Introduction

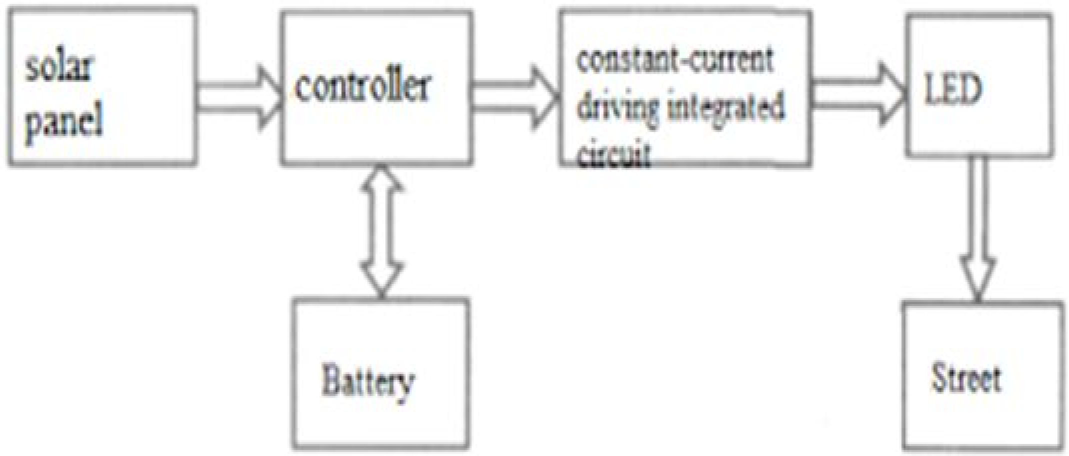
1. Solar Street Light

Solar energy is the most direct, common, and clean energy on our planet which can be harnessed in many ways. One such way is to design a smart solar street lighting system by combining LED's low power, high illumination characteristics, with sensors to make the system more energy-efficient.

Solar street lights are raised light sources which are powered by solar panels generally mounted on the lighting structure or integrated into the pole itself. The solar panels charge a rechargeable battery during the day, which powers a fluorescent or LED lamp during the night. We can also use a controller to control lighting, dimming and battery charging.

This system has a double advantage in both utilization of new energy and energy-saving.

<u>Block diagram (solar street model):</u>



2. Solar Panels

It is also called photovoltaic as it converts light energy directly into electrical energy. Solar panels are designed to absorb sun rays as a source of energy for generating electricity and heating. A large number of small solar cells are spreaded over a large surface area which can work together for provision of sufficient power to be used. Larger the amount of light that falls on a cell, larger is the amount of electricity generated.

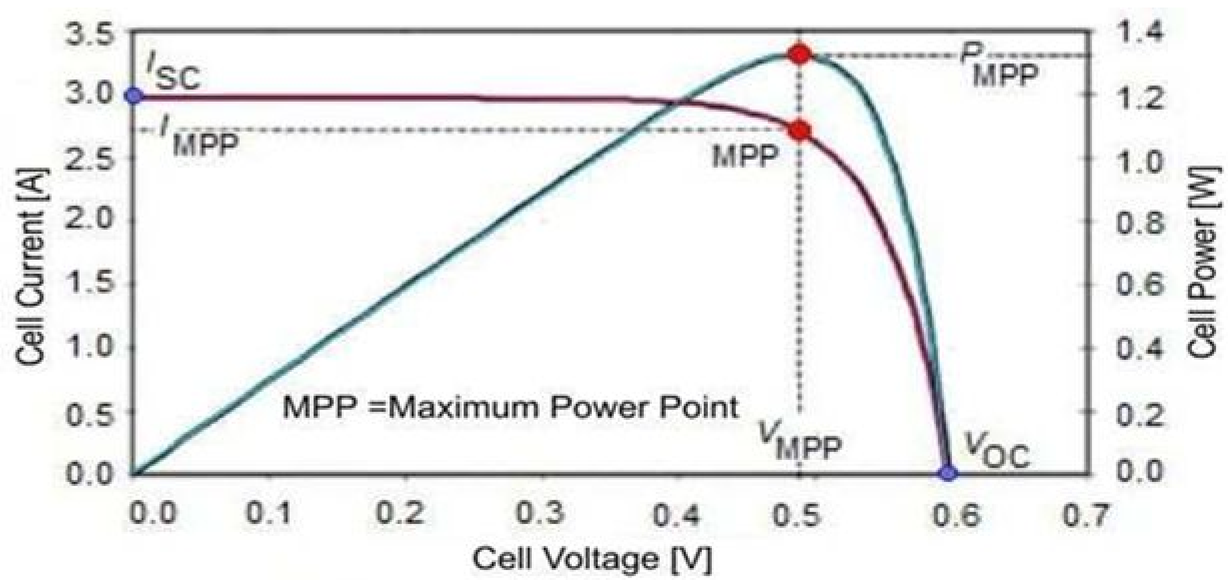
2.1 Solar cells

Working principle

The Photovoltaic (PV) cell is composed of at least two layers (n type and p type)of the semiconductors which have been “doped” with different impurities. When the photovoltaic cells are irradiated with sunlight, some photons are reflected and the others are absorbed by the solar cell. When the photovoltaic cells keep enough photons, the negative electrons are released from the semiconductor material. Due to the manufacturing process of the positive layer, these free electrons naturally migrate to the positive layer which creates voltage differential. When the solar cell is connected with the external load, there will be a current circulation in the circuit.

2.2 VI Characteristics of Solar Cells

The curve has two parts, one indicates the trend of current with respect to increasing voltage. The other curve is the power-voltage curve and is obtained by the equation P=V*I. If no load is connected with the solar panel which is working in sunlight, an open-circuit voltage Voc will be produced but no current follows. If the terminals of the solar panel are shorted together, the short-circuit current Isc will flow but the output voltage will be zero. When a load is connected, we need to consider the V-I curve of the panel and V-I curve of the load to find out how much power can be transmitted to the load. The maximum power point (MPP) is the spot near the knee of the V-I curve, and the voltage and current at the MPP are designated as Vm and Im. For a particular load, the maximum point is varying following insolation, shading and temperature. It is important to operate panels at their maximum power conditions.



When these cells are connected in series or parallel accordingly VI characteristics of panel changes.If connected in series then Voc(open circuit) will increase , else Isc(short circuit) will increase , still we can find out power curve through V*I and we will operate it too at maximum power point.

2.3 Construction of Solar Panels

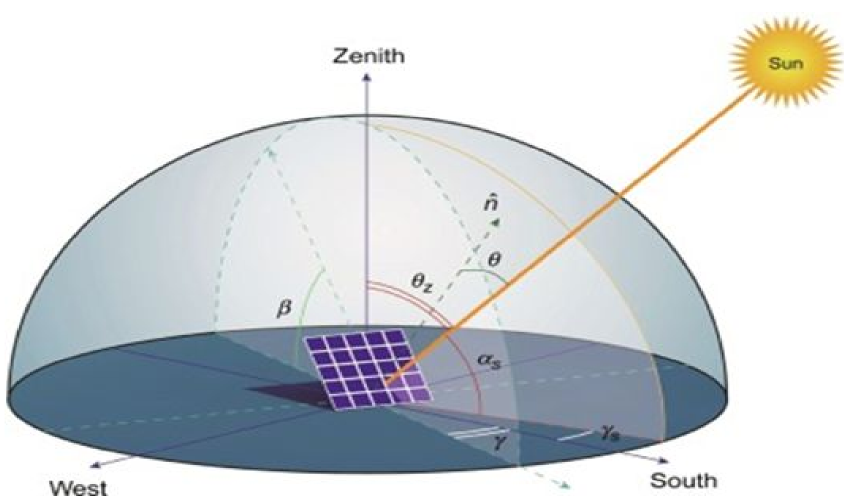
Most solar cells are a few square centimetres in area and protected from the environment by a thin coating of glass or transparent plastic. Because a typical 10 cm × 10 cm (4 inch × 4 inch) solar cell generates only about two watts of electrical power (15 to 20 percent of the energy of light incident on their surface), cells are usually combined in series to boost the voltage or in parallel to increase the current. A solar, or photovoltaic (PV), module generally consists of 36 interconnected cells laminated to glass within an aluminum frame. In turn, one or more of these modules may be wired and framed together to form a solar panel.Depending on our power requirement , we can use as many solar panels in combination to meet our demands.

For solar street light purpose , generally two types of solar panels are used :

1. Poly-crystalline Solar Panel
2. Mono-crystalline Solar Panel

2.4 Installation of Solar Panels

Two very important angles are those required to define the position of the Sun in the sky at any moment. They are the solar altitude angle and the solar azimuth angle. These angles are physical parameters of the position of the Sun with respect to a given place on Earth, and therefore are independent of the inclination and orientation of the surface. Once these two angles are established, it will help to define exactly the solar energy reaching the point on Earth where the solar energy system (thermal, photovoltaic or hybrid) is going to be erected.



Solar altitude angle αs , zenith angle θz, Solar azimuth angle γs

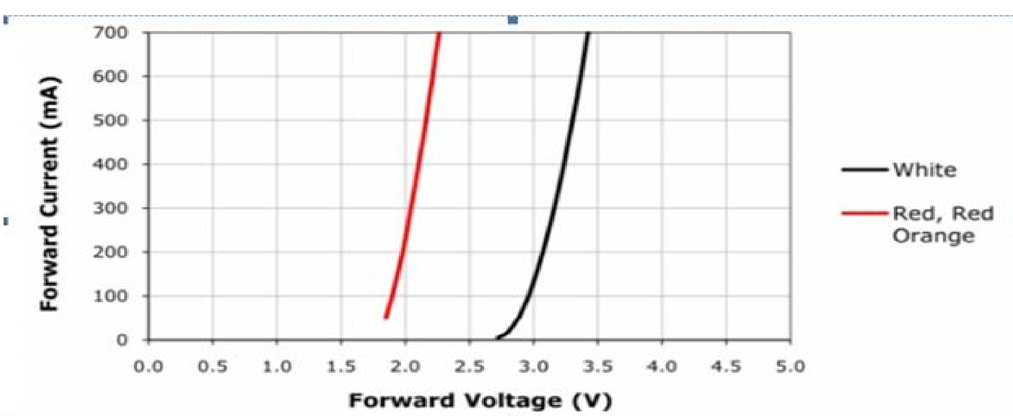
Two angles related to the sun position and the angles *β* and *γ* define the PV module position. *β* is the tilt angle and *γ* is the surface azimuth angle. Further, the angle *θ* between the normal to the PV surface and the incident beam radiation is indicated.

3.LED (LIGHT EMITTING DIODE)

3.1 Working Principle

All LEDs emit light spectra with narrow-band light (almost monochromatic). Heterochromatic light which is required to illuminate environments is obtained by radiation mixing. Mostly we rely on white led for lighting.There are two primary ways to produce white light-emitting diodes. One is to use two or more different color lights and then mix them together to form the white light. For example, the RGB technique which uses the three primary colors (red,green, and blue). Hence the method is called the multi-color white LEDs. This method is particularly interesting in many uses because of the flexibility of mixing different colors. In principle, this mechanism also has higher quantum efficiency in producing white light. Also there are many other types of the multi-color white LEDs: Dichromatic, Trichromatic and Tetrachromatic. Another technique is Phosphor-based LEDs, that means a phosphor material is used to convert monochromatic light from a blue or UV LED to broad-spectrum white light, much in the same way as fluorescent light bulbs work.

MAIN PARAMETERS



CURRENT VOLTAGE GRAPH OF LED

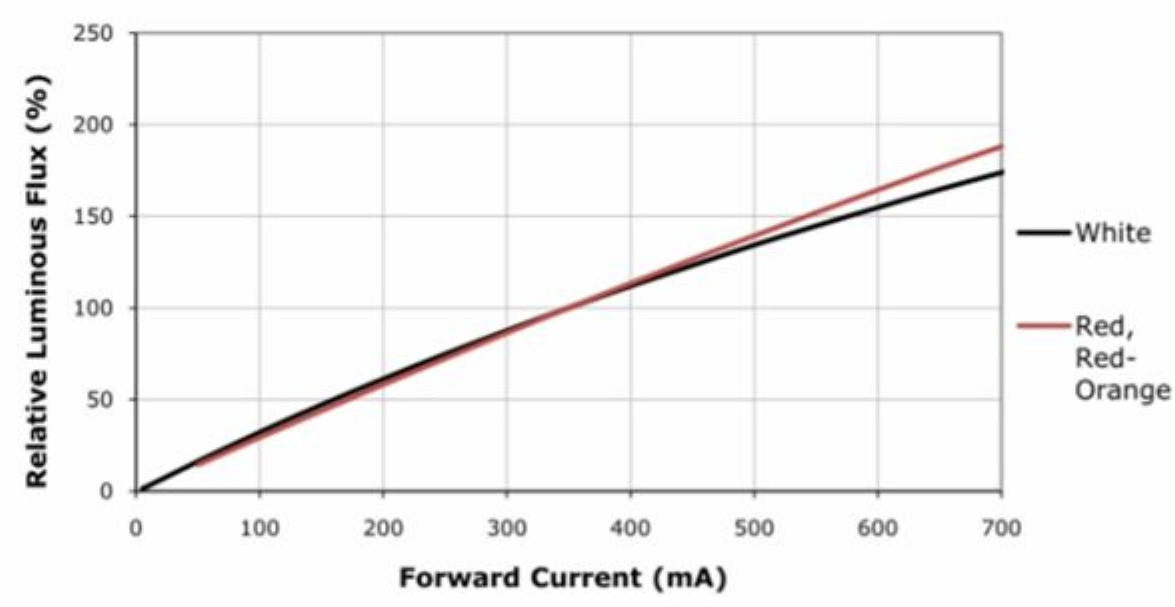


CHART OF DRIVE CURRENT- FLUX EMITTED

ADVANTAGES:

- Long lifetime (35,000 to 50,000 hours of useful life);
- Low maintenance costs and replacement costs;
- High efficiency;
- Clean light (no IR and UV components);
- Safety (working in low voltage 3 ~24 V);

DISADVANTAGES:

- Voltage sensitivity (must be supplied with the voltage above the threshold);
- Temperature dependence (depends on the ambient temperature);

4.Battery

Battery provides uninterrupted smooth power supply , during load hour, for lighting. As it goes under discharging and charging continuously . We prefer to use secondary cells.

Batteries store electricity from solar panels during sunny hours and deliver this energy to the fixture during night or load hours.

4.1 Battery Selection

As we require continuous charging and discharging , that is why we go for secondary cells(as they can be charged and used again.)

In addition, the factors to measure the quality of battery are:

- Long life as long as life of the system.
- High charge acceptance efficiency which can maximize output power of the solar cell, and also shorten the charging time.
- Good sealing performance, no acid or gas leakage, so the battery can be set with a controller.

Three types of batteries are usually used which are Lithium ion, Gel Cell Deep Cycle battery and Lead Acid Battery.

Depending on our power requirement we can calculate the size of battery to be used (factors like battery self-discharging rate, dod(depth of discharge), max demand ,affect the battery size) .

Here we are using Lithium ion batteries because of many of its benefits over other types of batteries.

5.Controller

The Controller is the intelligent core of the solar light system . It is an essential part of all power systems that charge batteries . Controllers decide to switch on/off charging and lights. It blocks the reverse current and prevents the battery from overcharging . Some charge controllers also prevent battery from over discharge , electrical overload and display battery status and power flow.

Design

Street light

A 6 meters tall 25 watt street light

Wattage and light type

GENERAL PURPOSE BULBS
LUMEN COMPARISON

Lumens	Incandescent	HID	CFL	LED
250 lm	25W	18W	6W	2W-3W
560 lm	40W	29W	10W	3W-6W
800 lm	60W	43W	13W	7W-10W
1100 lm	75W	53W	18W	10W-15W
1600 lm	100W	72W	23W	15W-20W
2600 lm	150W	100W	42W	20W-30W

TAKE 3 LIGHTING

- We select a **<u>single 25 watt LED panel</u>**
- From the Lumen chart, we see LED has the highest Efficacy i.e Lumens/Watt = 90 lm/Watt (low power, more brightness)

  Another selection criteria is high lifetime of LEDs = 60000+ hrs
- Selecting Voltage rating (of each component) = 12V

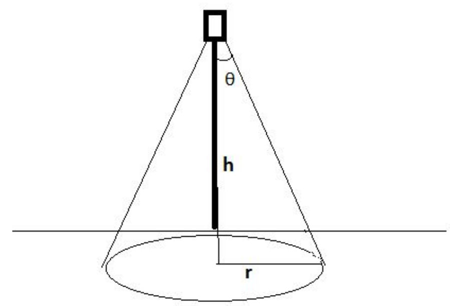
Lumens = Wattage x Efficacy

→ 25*90 = 2250 lm

Lumen & Lux

Illuminance for Various Roadway Types (ANSI/IES RP-8)	
Road Type	**Illuminace Lux**
Urban Freeway	10
Freeway Interchange	14
Commercial Arterial	20
Residential Collector	8
Local	6

We select an average of 6 lux as illumination



2θ is the Cutoff angle (approx field angle),

$r = h \tan\theta$

Area = π rxr

Lumen = Average Lux x Area

→ 2250 = 6 x π x h x h x tan θ x tan θ

→ tan θ = 1.8209

→ θ = 61.22°, approx Field angle = **<u>122.44°</u>**

Battery size calculation

Energy consumption of battery per day (assuming 8 hrs of use per day) = 25*8 = 200 Watt hrs

Considering 2 days autonomy (Backup for 3 days) in case of cloudy or rainy days, energy consumption = 200*3 = 600 Watt hrs

Considering the depth of discharge(DoD for Li-ion battery is 80%) = 600/80% = 750 Watt hrs. We assume a 12 V battery, Hence the battery capacity should be = 750/12 Watt hrs = 62.5 Amp hrs(Capacity in Watt hrs / Voltage).

So we take a **<u>12V, 65 Amp hr</u>** capacity battery.

Capacity of Solar Panel

Assuming total energy required per day to charge the 12 V battery = 62.5 x 12 = 750 Watt hrs (Safety margin : charging 3 day backup in a single day)

Assuming there is an average sunlight of 4 hrs in a day,
Capacity of solar panel = 750/4 = **187.5 W**

Size of Solar Panel

- Since solar panels rated 187.5 W are not easily available commercially, and assuming a safety margin let us rate the panel to be 200 W.
- The efficiency of a solar panel refers to the percentage of solar energy incident that is converted to electrical energy through the photovoltaics.
- And Solar Irradiance here is the average intensity of sunlight incident on the earth on a fine sunny day. The value of this globally is taken as 1000 W/m^2. It depends on various factors like the angle of the panel with the incident light ray, the latitude of the location and position of the earth around the sun which revolves in an elliptical orbit.

Output power = Total area (A) x Solar Irradiance x Efficiency
200 = A * 1000 * (15/100)
→ A = **1.34 m^2**

Approximate Cost

- Cost of one 25W LED light panel = ₹500
- Cost of one 200W solar panel = ₹6000
- Cost of one 12V-65Ah battery = ₹7000
- Cost of pole = ₹1000
- Other costs = ₹500

Total fixed cost = ₹500 + ₹6000 +₹7000 + ₹1000 + ₹500 = **₹15000**
Total maintenance cost per year = **₹500**

Conclusion

Maintenance of Street light

For the street lights to work all the time there **should be both routine and non-routine maintenance**.

For routine street lighting maintenance, one shall undertake regular nightly inspections once every two (2) months and provide a report on the following:

- lamp outages, and
- damaged or missing diffuser.

For non-routine maintenance of street lights, one shall fault-dispatch and/or attend street light sites on a 'call-out' basis to inspect and repair reported faults in the equipment or operation of the street lights.

Typical causes of street lighting faults shall include but shall not be limited to

- Control gear malfunctions,
- accident damage,
- storm damage,
- andalism,
- vermin damage,
- fire damage,
- blown lamps.

Future Scope of Solar Street Light

As we reduced wastage and saved power by replacing conventional street lights with solar street light, there are many amazing features that we can add to it. First of all, we can see some future prospects.

- **Cost Effectiveness:** The poles are wireless and hence they could easily be installed without hiring too many workers. Also, there is no additional electricity cost.

- **Clear Light:** The LEDs used in these lights provide clear visibility at night. This light helps pedestrians and also avoid accidents

- **<u>Automatic</u>:** They can be designed such that as soon as it detects that ambient light is not enough, LEDs are automatically switched ON. This will also increase backup time of the light.

- **<u>Eco Friendly</u>:** These LEDs contain no toxic elements and so it helps to protect the environment from any toxic waste.

- **<u>Motion Sensor</u>:** It will help in saving energy as it detects any motion of pedestrian or vehicles and switches on all LEDs.In areas where there is no traffic, there is no need to switch on street light for the whole night.

- **<u>Smart Technology</u>:** Street lights could be operated and controlled by mobile phones or computers from any location. We can also control brightness of LEDs. It will allow you to increase or decrease brightness from a remote place without the need of being actually present at a remote place. It can also provide real time information and helps to detect if there is any problem.

<u>Other Services</u>

They can also be modified to serve other purposes as well. Some are as follows:

- Inbuilt pollution monitors
- Mobile device charging points
- Button for emergency services
- Wi-Fi routers
- CCTV cameras
- Digital information display for traffic congestion
- Information on nearby parking spaces
- Charging stations for electric vehicle

Advantages of Solar street lights

1. Solar street lights are raised outdoor light sources, which are powered by PV (photovoltaic) panels which have a rechargeable battery, providing power to the fluorescent or LED lamp during the entire night.

2. Although the installation cost of solar street light is high, its maintenance cost is very less.

3. Due to the off-grid nature of solar street lights, solar street lights incur minimal operational costs.

4. Due to the absence of external wires, these lights do not pose any threat of accidents like electrocution, strangulation and overheating.

5. Infact, solar lights illuminate the streets throughout the night irrespective of power cuts and grid failures.

6. Solar street lights are environment-friendly because its panels are solely dependent on the sun, hence eliminating your carbon footprints contribution.

7. Compared with traditional street lighting, solar street lighting uses solar energy—completely renewable with no consumption of fossil fuels.

8. The huge increase of population becomes a challenge for the survival of human beings due to lack of coal and natural gas where solar energy becomes an alternative and acts as a savior.

Disadvantages of solar street lights

1. **Expensive than conventional lights**- These lights are a bit expensive compared to other conventional street lights, which is the main reason behind not opting for solar street lights.

2. **Risk of theft since its non-wired**- Since these lights are wireless and costly, the risk of theft is high compared to regular street lights.

3. **Frequent checking when placed in extreme weather conditions**- When placed in extreme weather conditions like snow or dust, there are chances of

moisture getting accumulated in horizontal PV-panels leading to reduced or full stoppage of energy production.

4. **Replacement of batteries**- Like any other components, rechargeable batteries also get exhausted they must be replaced a few times within the lifetime of the fixtures

Concluding,

Solar energy is one of the renewable sources of energy. There are many advantages associated with it. With that, it can also be used for other purposes as well.
Seeing all advantages, disadvantages etc. one thing that we can conclude is that there is a problem of maintenance and initial investment on solar street lights.However, with the advances in technology and good resource planning we can cut down the cost of the project and with use of good equipments maintenance frequency can also be reduced.
It can save about 40% electricity from street lights. So if we use these solar street lights it will eliminate the energy crisis to a large extent.

So following development of the outdoor lighting technique, the solar LED street light system has shown us it will have promising application and infinite vitality.

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