Ensuring energy sustainability in rural areas by the provision of solar street lighting system

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Abstract

Odisha is a state of hills, and mountains, plains and rivers, forest, villages, and a good diversity of wildlife. Even though government of Odisha has developed many places and interconnected them with roadways and electricity, still there are places where proper communication by both roads and rail services are lagging. Streetlight facilities can someway help to overcome these problems and make life of rural people easier. Another critical problem lies in the remote areas is the communication system. Proper electric supply also has not reached these places, frequent power cuts, lack of maintenance, illiteracy, lack of technology are some of the problems faced by the people of these areas. Hence use of solar powered streetlight can solve these problems. Solar energy is freely available and only major cost is involved in the installation process. The maintenance cost is very minimal and with local technicians the maintenance work can also be done. In this paper solar street lighting system is designed using LED for ensuring energy sustainability in rural Odisha.

Keywords. Inverter, LED, Microcontroller, Photovoltaic, Rural, MPPT

1 INTRODUCTION

In the present scenario improving lighting efficiency is one of the ways of energy conservation and build sustainable energy development. The consumption of electricity from lighting sector is nearly 22% [1]. Moreover, emphasize is made on the use of renewable as it decreases the presence of carbon dioxide in the atmosphere [2]. Even use of non-conventional source helps nation to get rid of dependence on fossil fuels which causes much pollution [3]. From several years it has been seen that among various lighting systems solar streetlight using LED is more common [4]. Generating electricity from solar energy through the process of photovoltaic (PV) is safer, noise free, environmentally benign and is rugged [5]. Solar energy has the ability to enhance resilience in the communities by providing power even if the grid is not there.

In comparison to other lights LED has many advantages like provides uniform illumination, consumes less energy, comfortable to eye, hence drive compatible. Many road accidents can be avoided with proper street lighting system.A.P. Niruka designed SSL for campus environment [6] L.P. Huai compared conventional street lighting system with that of solar streetlight and found that the solar streetlight saves 64.7% of the total cost in comparison to conventional

method. He also explained that the SSL system provides greater stability and very less chance of electrocution. [7]. People are deprived of basic necessities in the remote hilly and rural areas. With the sunset life comes to a hault at these remote places. Movement of people to different places becomes difficult [8]-[9].
The main objective of this paper is to design provision of solar streetlights for illumination of village roads and open meeting grounds. The paper mainly focuses on the rural villages of Odisha like Kalahandi and Mayurbhanj districts. Village people often gather in common places for meetings and evening is the best free time for them as most of them are busy with field work during the daytime. Solar streetlights can be beneficial for them so that they can move around during off sunshine hours. Even if some villages are getting electricity supply from common grid but frequent local problems like theft, falling of trees, branches during stormy weather are common happenings in these rural areas. The critical problem lies in that once the power failure occurs for days on no service and no maintenance happens. Thus, the rural people suffer a lot. Hence solar based streetlights are standalone system which are capable to generate the own electricity sufficient to charge the LED unit. The various advantages of solar street lighting system are as follows.

- Rural electrification focusing on the streetlights powered by solar
- Convenience to village people
- Improved transport system
- Energy conservation
- Less maintenance
- Improved lifestyle of rural people.

2 SOLAR STREET LIGHT SYSTEM

Solar PV based street lighting system is a standalone application of solar energy which is used for illumination of streets, corridors, basement, and open areas. There are different types of lights which are commercially available in market like CFL, tungsten filament, mercury vapour lamp, LEDS. Among all these LEDs leads the present time in terms of light intensity, efficiency, lumens, and long life. Lighting through LEDs have been used at different places and also finds its market in street lighting systems. Solar energy is clean and green form of energy hence combination of solar energy and low power consuming LEDs provides a promising solution for streetlights [10]-[11].

The fundamental components of a solar powered street lighting system using LED consists of the following components:

- Solar Photovoltaic Module
- LED unit
- Rechargeable Battery (Deep cycle)
- Control Circuit consists of Solar charge controller
- Pole
- Supporting structures

3 COMPONENT DESCRIPTION

3.1 Solar PV Panel

Photovoltaic modules are used to convert solar energy i.e., photons to electrical energy in DC form by the principle of photoconduction. There are different types of panels like crystalline like monocrystalline, multicrystalline, thin film like, amorphous and dye-sensitized, nano based, cadmium telluride etc. While choosing solar module for the project careful selection based on material is require so that irrespective of any climate condition the efficiency will be better, and output will be more.

Table 1 Shows comparison of different types of Solar module

Solar Module	Efficiency	Lifetime	Price	Power/Area
Monocrystalline silicon	10-13%	25 years	High	High
Polycrystalline silicon	9-13%	10 years	Moderate	Moderate
Amorphous silicon	6-8%	10 years	Low	Low

3.2 Light emitting diodes

Lighting system uses lamp which converts gas or electrical energy into light energy. Depending upon the device efficiency depends on the amount of light produced. The unit of measurement of visible light is lumen. Different types of lamps are used for lighting purpose like compact fluorescent lamp, mercury vapour lamp, tungsten filament lamp, metal halide lamps, light emitting diodes, organic light emitting diodes, light emitting polymers etc. Different types of these lamps have different efficacy and different ratings. Mostly LEDS are convenient for street lighting system. LED stands for Light emitting diode. They have a better life span and higher efficiency in comparison to other lamps. LED emits more than 100 lumen per watt. For solar lighting systems LEDS are most preferred as it takes very less voltage, less heat and less power. The components are made of Gallium nitride material doped by phosphorous. LEDS does not require warm up time to

come to its full brightness. These require controlled DC supply for its operation and are affected by high temperature hence special heat sinks and cooling fans are included in its circuit.

Table 2 Specification of different types of solar street lighting system

SSLA Type	Lamp size (Watt)	PV module size (Wp)	Battery Size for Lead Acid (AH)	Battery size for Lithium Ion (AH)	Charge controller (Ampere)	Pole height (m)
1	10	50	40	30	5	7
2	20	100	60	45	10	7
3	30	150	80	60	12	7
4	40	200	100	75	15	8
5	60	300	150	115	25	8
6	80	400	200	150	30	9
7	100	500	250	180	40	10

3.3 Battery

For storing electricity generated by solar PV panels batteries are used. Battery acts like backup. During daytime electrical energy generated by the PV panels are supplied to the battery and when the load demand exceeds or during sunset these batteries supply the load. Different types of batteries are available in the market. Among them deep cycle batteries are commonly used as they can withstand deep discharges. The various rechargeable batteries include:

3.1.1 Lead-Acid (LA) Battery

Lead acid batteries finds its wide application in solar systems as its technology is matured and are also available at low cost. For extending its life they are used with low depth of discharge (DOD) i.e., 65%-80%. Basically, there are two varieties of lead acid batteries like flooded type and valve regulated lead acid batteries. These types require very less maintenance.

3.1.2 Nickel-Cadmium (Ni-Cad) Battery

Nickel batteries are costly and are also dangerous as cadmium disposal is hazardous. These batteries have many merit points like greater life span, high discharge tolerance. Foe solar powered system Nickel cadmium batteries are not often used as they are very costly and also available in limited edition.

3.1.3 Lithium-Ion (LI) or Lithium-Polymer (LP) Battery

Studies shows that lithium-ion batteries are better than Nickel cadmium batteries with high depth of discharge, more number of charging cycles and high energy. But still these are also not preferred for PV application-based lighting systems as these are available at higher price.

3.4 Charge Controller

One of the major components of solar streetlight system is the charge controller. Charging of batteries are controlled by charge controllers. Photovoltaic panels provide variable output which needs to be adjusted hence controller comes into picture as it takes the variable input from solar panels like voltage or current conditions it with its logic to fit the battery charging process. Over-charging of batteries can be prevented by the use of these charge controllers. Charge controller uses either pulse width modulation or maximum power point tracking technique to perform its operation. There are different types of MPPT techniques which can be used for the operation. The operation of charge controllers is mostly at three stages. But these stages vary depending on battery voltages.

3.5 Sensors

Sensors are essential electrical components require to sense the ON/OFF the solar powered LEDS. It makes the system economically and technically viable. There are different types of sensors available in the market to be used for PV system like infrared sensors, LDRs, ultrasonic sensors. These sensors control the LED lamp functionalities such that the system can be made more energy efficient. Depending upon the intensity of the light these sensors get activated.

4 INSTALLATIONS

Design of a solar streetlight system must be strong and robust as these are generally installed in the roadsides where it is exposed to different weather conditions like rain, pollution, dust, snow, fog, mist, sun etc. Moreover, care should be taken while its design that it should not affect the street plan and beauty of the roadways and any hindrance to the city structures.

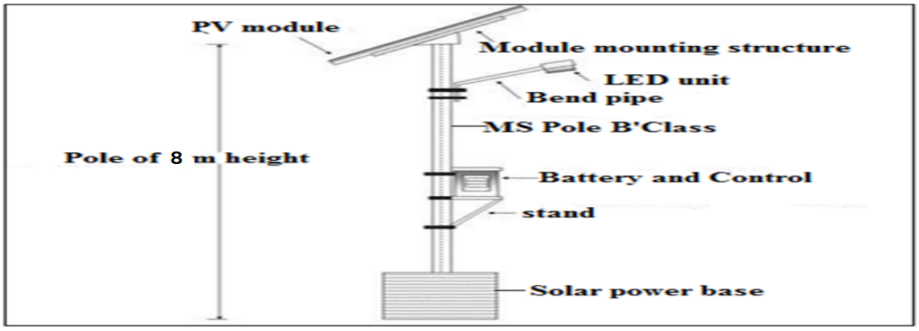

Figure 4.1. Shows pole mounted installation of solar based streetlight system

The components of the solar powered lighting system include PV module mounted on the structure. The module mounting structure is 32*32*3mm. The luminary part consists of LEDS supported with the help of bend pipe. A single pole M.S class B is used of height 8 m. Battery box along with the control circuit is positioned towards the base of the pole. The pole rests on a solid base of broader cross section area. Generally solar panels are mounted on the top to avoid any kind of shading effect on the panel and prevent ground hindrance and local dust.

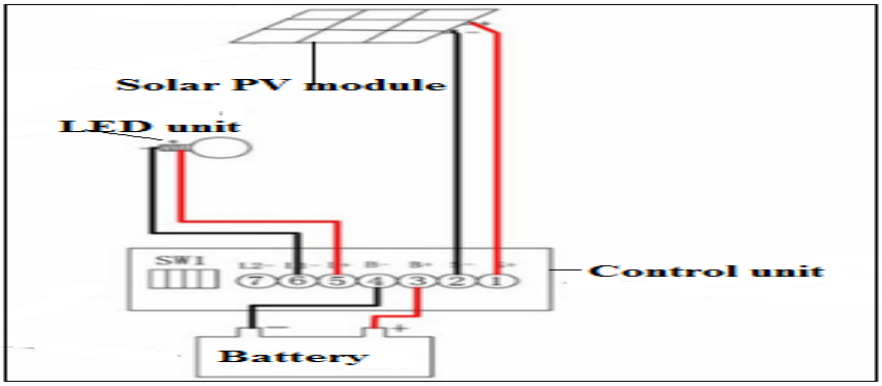

Figure 4.2. Shows the wiring connection of the solar streetlight system

The solar module provides the necessary DC current to the battery such that it gets charged during the sunshine hours. The charging and discharging of the battery is controlled by the control unit which is a solar charge controller. The LED unit is controlled by sensors i.e LDR light dependent resistor, current and voltage sensors.

5 WORKING PRINCIPLE

Solar radiations fall on the solar PV panel and by the effect of photo conduction produces electrical energy. The output of the solar panel is fed to the charge controller and the control circuit. The control circuit consists of micro controller

and two sensors one is light or dark sensor, and the other is infrared sensor. The output of the micro controller is fed to the light driver circuit and hence the light driver circuit supplies the LED lamp which glows.

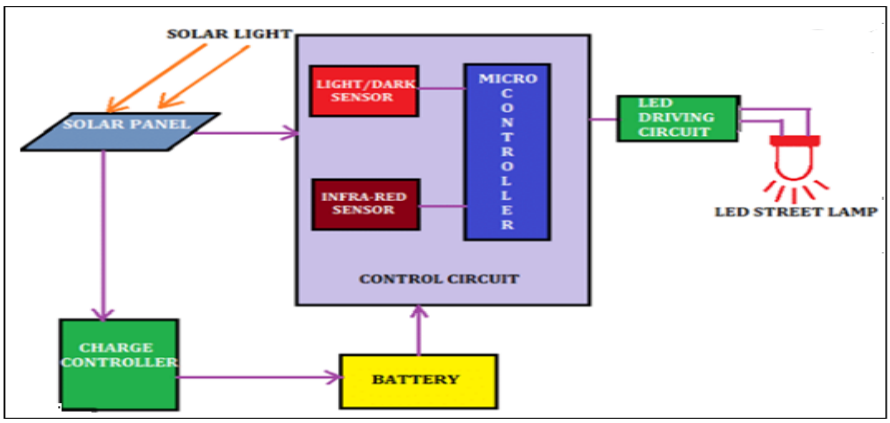

Figure 5.1. Shows the block diagram representation of the solar powered streetlights using LEDs

6 CALCULATION OF DESIGN OF SINGLE POLE

We consider the solar streetlight system consists of 1 unit of 60 watt LED lamp and 12 V Lithium battery.

Therefore, **current capacity** is given as

$$\text{Current (I)} = \text{Power (Watt)/Voltage (volt)} \quad (6.1)$$

=60W/12V=**5 A**

6.1 Battery capacity

Considering different cases like evening hour, night and rainy time the total lighting time per day is 7 hours. Hence the battery capacity can be calculated as 5A* 7 hours* 6 days= 210 Ah. Battery just discharges up to 80%. Therefore, actual battery capacity can be taken as 210Ah *125%=**262.5Ah**.

6.2 Calculation of Illumination in Lumen

Considering E= 32 Lux and d =height of the pole =6m

Illumination id defined as

$$I = E \times d^2 \quad (6.2)$$

= 32*36

=1152 lumens ~ 1200 lumens

6.3 Calculation of Power of solar panel (Wp)

The solar module has voltage 17.4 volt.

solar streetlight works for 7 hour each night. But it is observed that the solar panel takes solar radiations for 4.5 hours. Therefore, power is calculated as

$$\frac{Wp}{17.4} = \frac{5A \times 7h \times 120\%}{4.5} = 162\ Watt \tag{6.3}$$

In real case there are different constraints like power consumption of controller, connections, rectifier unit hence a little higher side PV rating is considered. Thus, we take 200-Watt PV panel. Therefore, two solar modules with 100-120Wp are best suited. This is the design for one solar powered pole. Therefore, for designing the solar powered street lighting system for the entire village we consider fifty such poles supplying electricity to the village.

7 CONCLUSION

Energy from sun is the cleanest form of renewable energy. Moreover energy suitability in the rural areas mostly villages can be ensured by provision of solar operated street lights. Use of LED in comparison to other lamps are more beneficial and also the efficiency improves by 755. Not only this there is also an increased percentage of energy saving by the use of solar streetlight system. Lifestyle of the village people can be improved with this facility, empowering them with the modern system. In this paper advantages of LED is highlighted. Design of one single solar powered LED lighting pole is done. The current, battery, power rating of the panel are calculated and thus with the calculation a rough estimation is made for the entire village.

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