



“Solar- Powered Outdoor Lighting System: Components, Performance, and Efficiency”

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ABSTRACT:

In response to the need for sustainable energy solution, using of solar powered lighting system is very much necessary. This paper presents the different components, its uses and the efficiency. Using photovoltaic cells generates clean energy during the day and provides reliable illumination at night or lowlight condition. A solar panel captures sunlight and charges a lithium ion battery which ensures safe, regulated charging without risk of overheating or over loading. This stored energy is later used to power the system at night. The LEDs are highly efficient-offering bright, long lasting illumination with minimal power consuming. Two sensors, a PIR and LDR are the main key to energy efficiency. This low maintenance and eco friendly system is beneficial for rural or isolated region. Combination of renewable energy with smart sensing technology offers a sustainable lighting solution results in reducing carbon emissions.

Keywords: Solar energy, solar panel, battery, light sensor, photo electric infrared, photovoltaic, outdoor, renewable energy systems, energy efficiency, passive infrared, light dependence resistor.

Introduction:

Solar energy plays an important role in reducing green house gas emissions and mitigating climate change, which advances in protecting people, wildlife and ecosystems. It can also improve air quality and reduce water use in energy production. Also, it is a noise free energy. It is growing to be the strongest technology in generating electricity. Solar power is the process of converting renewable energy from sunlight to electricity either directly or indirectly using solar panels (Photovoltaic Cells) [10]. The lifetime of the solar cell is more than two decades which is helping the consumers to minimize the expenses of maintenance and management. PV generation has limitations on the amount of sunlight available, temperature raised in different places and different seasons, and other environmental conditions like fog, smoke and dust formation. Thus, to minimize this weakness, different techniques were suggested to increase the efficiency of the solar cell and electric power consumption by the users [6]. This present article mainly focuses in imparting knowledge of solar energy including the concepts of their advantages and disadvantages.

Methodology:

It is an exploratory work done to review the article by using search engines like Research gate, Academia, CERA etc. to collect the information related to the solar power lighting system. This article is also consisted of an in-depth review of the existing literature and the findings. Various devices are also traced out and presented in this paper. The relevant literatures were selected and analyzed and summarized through Meta analysis. And the results obtained were discussed.

Components of solar lamps/lighting system

Solar panel:

The solar panel is primary source of energy and provides D.C current to the monitoring circuit where it is used to charge the battery. Basically three types of solar panel available they are single crystalline, polycrystalline and thin film. It is the most efficient and its efficiency is approx. 15-18 per cent. A large chunk of silicon crystal makes it different from others.

The solar panel work in three steps they are following:

- a) Panel is made from semiconductor materials such as silicon; they observe photon when sunlight falls on the panel.
- b) Photon raises an electron to a higher energy state and then flow of this high-energy electron to an external circuit. Due to the special composition of solar panel, the electrons follow in a single direction.

c) Generation of current in a solar cell, known as the “light-generated current” or direct current (D.C) electricity[2].

Battery:

A battery is an important part of portable LED lamp since it stores power that can be used to drive the load in absence of solar energy. The battery is charged when it is given energy from external source to restore its energy and when a battery is connected to the load, energy stored in it gets utilized thus discharged. Manufacturers produce batteries for specific applications of the customer.

Types of batteries:

Batteries can be categorized in terms of the materials used to build them. They differ in terms of capacity, cost and area of usage. In this categorization, there are four types:

- Nickel cadmium (Ni-Cd) Battery
- Nickel- Metal Hydride (Ni-Mh) Battery
- Lead-Acid Battery
- Lithium-Ion (Li-Ion) Battery

Among these four batteries mostly Lead-Acid Battery and Lithium-Ion battery are used in the solar lamps [2].

Comparison of lead acid battery and lithium ion battery: To compare different types of batteries, it is important to consider various parameters.

Parameter	Lithium ion battery	Lead acid battery
Depth of discharge(DOD)	80%	50%
Life cycle	1900-3000@80% DOD	500-1000@50% DOD
Efficiency	97%	75%
Life time(year)	12	10
Cost/kW	150	100
Maintenance cost/kW	0.04-3.1	0.03-6.6
Environmental effect	Low	High

The result shows that Lithium-Ion battery has better discharging voltage, discharging current than Lead- Acid battery at various percentages of state of charge. It also shows that while maintaining constant load voltage, Lithium-Ion battery delivers more power to utility grid. Lead Acid battery consumes more power when charged to 100% state of charge and it is 2.79 times costlier than Lithium Ion battery. So, for a solar lighting system with high power demand, a Lithium Ion battery is more suitable both performance wise and cost wise [8]. And Lead Acid batteries also consist of a lead and sulphuric acid mixture in which Lead is a highly hazardous and sulphuric acid is an abrasive electrolyte. So, it should not be discarded in a solid waste landfill. This is because; they are likely to spill and cause pollution negatively impacting the environment. But, Li-ion batteries contain various mediums like cobalt, copper and lithium. These mediums are considered not to be as toxic as LA batteries. Hence, recycling is significantly difficult especially for Lead-Acid batteries requiring frequent replacement [4].

Battery Monitoring:

Sealed maintenance free battery has long life span and requires low maintenance. Battery is connected to the monitoring circuit where it is efficiently charged and utilise. Battery will be charge through one source at a time depends on the availability of the power source. Every status of battery is display on the LCD. The battery is prevented from over current or over charging by the charge controller. The charge controller is an electronic circuit comprising an operational amplifier, an electronic switch and electro mechanical switch. The circuit is switched ON or OFF by the transistor in saturation region or cut off region respectively [5].

Light sensor:

The sensor is used to detect the intensity of light. When the light is too low such as at dusk or under heavy overcast skies: the switching circuit within the street light system is ignited by the sensor to activate the flow electricity. When the sensor detects too much light, the sensor will tell the switching circuit to deactivate the light. The switching circuit is responsible for the activation and deactivation of light based on the response received from the sensor [3].

PIR:

A PyroelectricInfraRed or Passive infrared sensors (PIR) is an electronic sensor. It is also named as ‘IR motion’ sensors. These sensors measures infrared light that is radiating from the objects in its vicinity. If the motion of human body is detected within the coverage area, light will be activated automatically. Otherwise light will be deactivated. These sensors are also helpful in detecting the heat source similar to the human body temperature. It

senses only when the object is in motion. It captures the infrared rays radiated from the objects by using the array of Fresnel lens. Security lighting can be provided by using these sensors. But one of the limitations is that it is temperature sensitive [11].

Due to advancement in technologies, a solar power lighting system can include some other different components such as a device for anti corrosion treatment, anti theft protection and a solar tracking device to follow the solar movement and to keep the PV panel facing towards the sun. This tracking device tracks the sun's path during the day by rotating solar panels towards the sun light. In fact, more solar energy upto 30% can be captured by this process [7].

IoT (Internet of things): The emergence of the IoT and related technologies has enabled the development of smart automated lighting systems that can control illumination levels based on real time data. It is a transformative technology enabling the interconnection of various devices and systems through the internet, facilitating data exchange and remote monitoring and control. These systems have the potential to significantly improve energy efficiency, reduce operational costs and enhance road safety by providing adaptive and optimized lighting conditions [1].

Advantages:

1. It is environmental friendly and has low heat and light pollution.
2. It has long life time and low cost.
3. It is maintenance free and has a plug and play capability.
4. There is no need to wiring.
5. It has resistance to shock and physical impact.
6. It does not generate electromagnetic wave or interference signals and it does not contain heavy metal within.
7. An expandable infrastructure that supports multiple applications such as traffic, weather and motion monitoring.

Disadvantages:

1. The initial investment for solar panels is substantial, including expenses for panels, inverters, batteries, wiring and installation.
2. Solar panels rely on sunlight, so their efficiency decreases on cloudy or rainy days.
3. Installing solar panels requires a significant amount of space.
4. Although it is a clean energy, its production and installation involve emissions and the use of hazardous materials.

Conclusions:

Solar energy is one of the alternatives to fossil fuels in terms of producing electricity parallel with today's rapidly changing technology. It is the cleanest energy source in almost every field. Usage of alternative energy for lighting in the local parks, garden and streets, long distance highway and road has become popular and inevitable. In power plants, there is a transmission cost in addition to the production cost where as solar power system has no transmission cost so usage of them are growing rapidly and beneficial to the user to a great extent. Therefore, to enhance advancements in photovoltaic materials and efficiency, the search parameters can be refined by focussing on specific factors, such as new material compositions, conversion efficiency, long term stability, manufacturing techniques and improvement in cells and modules. Additionally, considerations for anti reflective and anti soiling coatings and emerging technologies should be included.

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