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Design and Installation of Solar LED Street Lights in High Altitude and Cold Regions

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Abstract

With the development of solar photovoltaic power generation technology and LED lighting technology, solar LED street lamps will be increasingly widely used in road lighting. The design of the solar LED street lamp system should be based on the geographical environment and meteorological data of the proposed installation site, and through efficient, scientific, and reasonable calculation methods, select matching equipment to ensure the safe and reliable operation of the solar LED street lamp. The design of a solar LED street lamp system mainly includes the calculation of LED lamp power, battery capacity, and solar panel power, the selection of intelligent controllers, and the design of lightning protection and grounding.

Keywords

High Altitude and Cold Regions; Solar Energy; LED Street Lights; Design and Installation.

1. Introduction

Road lighting is an important component of urbanization construction. Currently, the annual power consumption of road lighting in China accounts for about 4% to 5% of the total power generation in the country, which has exceeded the annual power generation of the Three Gorges Hydropower Station. This article aims at solving the problems related to traditional road lighting, such as low light efficiency and high-power consumption of street lamps, and advocates vigorously developing and utilizing new energy sources. With the purpose of practical application, it is a future development trend to further effectively improve the utilization ratio of renewable energy sources on the basis of achieving green, energy-saving, and environmentally friendly road lighting. Solar energy is a clean and renewable energy source. With the continuous development of solar photovoltaic power generation technology and energy-saving LED lighting technology, solar LED street lamps have been widely used in road lighting [1-2]. Solar LED Street lamps have the characteristics of independent operation, no need to lay cables during the installation process, only one-time investment, no subsequent payment of electricity fees, and low operation and maintenance costs. For areas with sufficient sunlight and difficult power supply, solar LED street lamps will gradually be promoted and used [3-4].

2. Introduction to Solar Streetlight

The solar street lamp is essentially an independent photovoltaic system composed of solar photovoltaic modules, light source controllers, batteries, load lamps, etc. The street lamp using AC lamps is also equipped with an inverter, which can meet the lighting requirements of roads or venues. Its working principle is shown in Figure 1. Photovoltaic modules are key components in solar street lamps, whose main function is to absorb solar energy and convert it into electrical energy. There are various light source controllers, including voice control, light control, timing control, and so on. The

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main control forms of solar street lamps include light controlled on - light controlled off, light controlled on - time controlled off, and time controlled on - time controlled off. In order to extend the service life of the battery, it is necessary to restrict its charging and discharging conditions to prevent overcharging and deep charging of the battery. In places with large temperature differences, qualified controllers should also have temperature compensation functions.

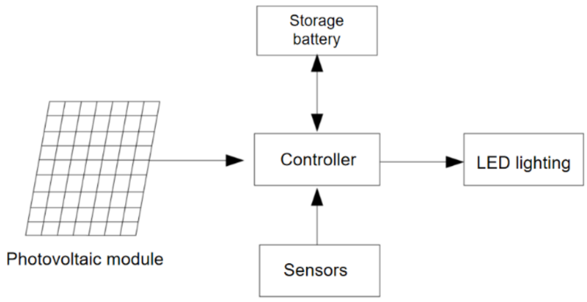

Fig 1. Working principle of solar LED streetlight

Solar streetlight should use energy storage batteries that are suitable for deep discharge and have a long cycle life. The design of battery capacity should comprehensively consider the design life of the battery, the imbalance of inclined surface radiation, photovoltaic module power, system efficiency, etc. The backup days for solar street lamps should be 3 to 7 days. The power of solar cells must be more than four times higher than the load power to ensure the normal operation of the system. The voltage of solar cells should exceed the working voltage of the battery by 20% to 30% to ensure normal charging of the battery. The battery capacity must be more than 6 times higher than the daily load consumption [5].

3. System Design

3.1 Design of LED Lamps

Compared to traditional light sources, LED lamps have advantages such as DC low-voltage drive, high luminous efficiency, low power consumption, long service life, and easy realization of dimming and color adjustment temperature. Therefore, LED lamps are recommended for use in the design of solar street lamps. LED lamps should choose LED light sources with high luminous efficiency, and their total luminous flux is:

$$\phi = P_{led} L \tag{1}$$

Where: P_{led} is the LED lamp power, W; L is the luminous efficiency of LED light source, lm/W.

The average illuminance of road surfaces is generally calculated using the utilization coefficient curve method based on standard straight sections [6]. The calculation formula is:

$$E_{av} = \frac{\eta_{led} \phi K N}{S W} \tag{2}$$

Where: η_{led} is the lamp utilization coefficient, which is searched from the lamp utilization coefficient curve based on the installation arm length, height, elevation angle, and road width of the lamp; K is the maintenance coefficient; W is the road width, m; S is the installation spacing of street lamps, m; N is related to the arrangement of street lamps. When the street lamps are arranged on one side or staggered, N=1, and when they are arranged on opposite sides, N=2.

3.2 Design of Storage Battery

The capacity and working voltage of the battery should match the requirements for solar photovoltaic modules, LED lamp power, and lighting time. The working voltage of the general storage battery should be 20% to 30% lower than the working voltage of the solar photovoltaic module to ensure

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normal charging of the storage battery; The battery capacity should be more than 6 times higher than the daily power consumption of LED lamps to ensure reliability of operation.

The calculation formula for daily power consumption of LED lamps is:

$$Q = \frac{P_{led} t}{U_{battery}} \tag{3}$$

Where: t is the daily working time of LED lamps, h; $U_{battery}$ is the nominal voltage of the battery, V.

The calculation formula for battery capacity is:

$$C = \frac{Q(d+1)}{\mu\sigma} \tag{4}$$

Where: d is the number of consecutive rainy days, d; μ Is the discharge depth of the battery, typically 0.75; σ Is the safety factor of the storage battery, generally ranging from 1.1 to 1.4.

According to the calculated battery capacity, select an appropriate number of fully sealed maintenance free gel batteries to form a battery assembly.

3.3 Design of Photovoltaic Modules

The type selection of solar panels should be based on the geographical environment and climatic data of the area to be installed. The power of the solar photovoltaic module should meet the daily power consumption of LED lamps and the capacity of the battery that needs to be restored after continuous overcast and rainy days. The charging current of solar photovoltaic modules that meet the daily power consumption of LED lamps is:

$$I_1 = \frac{\lambda Q}{\eta_{battery} \eta_{control} t} \tag{5}$$

Where: λ Is the comprehensive loss coefficient of solar charging, generally taken as 1.05; $\eta_{battery}$ refers to the charging efficiency of the battery, which is generally taken as 0.85; $\eta_{control}$ is the correction factor for controller efficiency, dust shielding, and other losses, typically taking a value of 0.9.

The charging current of solar photovoltaic modules that need to restore battery capacity after continuous rainy days is:

$$I_2 = \frac{\mu C}{tD} \tag{6}$$

Where: D is the interval between two consecutive rainy days, d.

The power of the solar photovoltaic module is:

$$P_s = (I_1 + I_2) U_s \tag{7}$$

Where: U_s is the working voltage of the solar cell module, V.

Select an appropriate number of solar modules with standard solar specifications based on the calculated P_s. The power generation efficiency of solar photovoltaic modules is closely related to the installation tilt angle of solar photovoltaic modules. In order to ensure the efficiency of solar panel power generation, in the design of solar LED street lamp systems, the tilt angle of solar photovoltaic modules should be determined based on the latitude of the installation location, so that the solar irradiation amount can meet the maximum and uniformity, thereby minimizing the investment cost of solar photovoltaic modules.

3.4 Design of Controller

The main function of the controller for solar LED street lamps is to achieve intelligent control of the lighting process and smooth dimming and color adjustment temperature, and to have protective functions such as overcharge, over discharge, short circuit prevention, anti-reverse connection, and

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lightning protection. In places with large temperature differences, intelligent controllers should also have temperature compensation function.

3.5 Design of Lightning Protection and Grounding

The working voltage of solar LED street lamps is generally 12V or 24V, which is a safe voltage and may not be electrically grounded. However, in order to ensure the safe operation of solar LED street lamps, lightning protection and grounding design should be carried out. For lightning protection grounding, metal lamp poles can be used as both lightning arresters and down conductors, and street lamp foundation reinforcement can be used as a grounding body. The grounding resistance should not be greater than 10 Ω [7]. If the grounding resistance does not meet the requirements, artificial Earth electrode shall be added. In special places, wind resistant devices should also be considered for severe weather such as strong winds to avoid unexpected weather affecting the operational quality of solar LED street lights.

4. Installation of the System

4.1 Installation of Photovoltaic Modules and Controllers

(a) The installation of photovoltaic modules should be reliable, fastened with vibration resistant screws, and the inclination angle should be determined according to design requirements. Solar street lamps rely on solar radiation for their work, so the installation site requires sufficient sunlight. The layout of street lamps should be based on local actual conditions and meet the requirements of relevant standards.

(b) The controller is installed on the lamp pole of the street lamp to prevent sunlight or rain.

4.2 Installation of Storage Battery

The storage battery is buried underground and placed in a waterproof box. Waterproof and anti-theft measures should be considered. According to local actual conditions, only concrete cover plates are used during installation of the project.

4.3 Commissioning of Solar LED Street Lamps

The solar LED street lamp consists of four components: a controller, a battery, a solar photovoltaic module, and an LED street lamp. The battery adopts a 12V-150Ah model, with a solar photovoltaic module power of 140W and an LED street lamp power of 45W. The controller can measure parameters such as charging capacity, current, discharge capacity, battery voltage, and regulate the discharge power of the LED street lamp. The acceptance photo of the solar LED street lamp is shown in Figure 2.

Fig 2. Acceptance Photo of Solar LED Street Lamp

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5. Conclusion

Solar LED Street lamps combine solar photovoltaic power generation technology with energy-saving LED lighting technology. With the efficiency improvement and cost reduction of solar photovoltaic modules, solar LED street lamps will increasingly meet lighting needs in the future. Through the verification of practical engineering design, the calculation process in this article can effectively, scientifically, and reasonably meet the design of solar LED street lamps.

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