Smart Mini Solar High Mast System

Mr.Kishor.P.Jadhav
Dept. of Electrical Engineering SKNSCOE,Pandharpur kishorjadhav@sknscoe.ac.in

Mr. Sudake Nitin
Dept. of Electrical Engineering SKNSCOE,Pandharpur nitinsudake051@gmail.com

Mr. Chavan Prathamesh
Dept. of Electrical Engineering SKNSCOE,Pandharpur
prathmeshchavan2205@gmail.com

Mr.Ranjit Bansode
Dept. of Electrical Engineering SKNSCOE,Pandharpur ranjitb3939@gmail.com
Mr. Gaikwad Sanket
Dept. of Electrical Engineering SKNSCOE,Pandharpur sanketg401@gmail.com

ABSTRACT-

The growing demand for outside lighting has led to greater adoption of solar-based lighting systems in public and rural areas. This paper presents the design and presentation analysis of a Smart Mini Solar High Mast Striking System tailored for small public spaces such as streets, parking lots, campuses, rural, and hilly regions. The proposed system participates a solar panel, battery, LED, and an involuntary control unit to ensure reliable operation with minimal human mediation.
The smart controller simplifies automatic dusk-to-dawn operation finished light sensing, battery charge protection, and optimized energy use. Designed to function autonomously of the electrical grid, the system is ideal for remote and semi-urban places. Key design parameters containing solar panel capacity, battery size, LED load, and pole tallness are selected based on local solar conditions and daily lighting requirements.
Performance estimation covers energy generation, battery independence, lighting reliability, and system efficiency under real environmental situations. An economic analysis evaluates installation costs, maintenance needs, and long-term savings compared to unoriginal grid-based lighting. Results validate that the smart mini solar high mast system offers a cost-effective, eco-friendly, and reliable lighting solution with reduced operational costs and carbon productions.
This study highlights the practical benefits and flexibility of smart solar high mast systems for sustainable organization development

KEYWORDS -

Smart Solar Light system, Mini Solar High Mast, Solar System, LED Street Light, Battery Storage, Renewable Energy, Energy Efficiency.

INTRODUCTION

Outdoor brightness is crucial for road safety, vehicle movement recognition, and public activities during evening. Unadventurous street and high mast lighting systems largely rely on the utility grid, resulting in high energy consumption, increased electricity costs, and dependence on limited power age group resources. Given the growing energy demand and environmental worries, there is a pressing need for sustainable and energy-efficient lighting explanations today.

Solar-based lighting systems are careful an effective alternative to conventional grid-powered light. These systems bind renewable solar energy during the day, loading it in batteries for use at night when solar power is inaccessible. Accordingly, solar high mast systems are broadly used to illuminate large open areas such as highways, parking lots, industrial zones, college sites, and rural public spaces. However, outmoded solar lighting systems often face trials like inefficient energy use, lack of system checking, and shortened battery life due to scarce control devices.

To address these borders, the concept of a Smart Mini Solar High Mast System has been familiarized. This system joins intelligent control features such as automatic operation based on Maximum Power Point Tracking (MPPT), time-based and light sensor wheels, battery charge-discharge protection, and LED load supervision. The term "mini" states to a compact high mast system designed for small to medium-sized areas, making it practical for both city and rural applications.

The smart control unit confirms reliable operation by acclimating system behavior according to environmental conditions and battery status, thereby improving overall efficiency and lifespan. The use of high-efficiency LED luminaires decreases energy consumption while providing satisfactory illumination. Additionally, the off-grid nature of the system eradicates dependency on the utility grid, making it ideal for locations with fly-by-night or unattainable power supply.

This research focuses on exploiting performance using AC LED lamps. Existing systems characteristically supply the DC energy generated by solar panels and stored in batteries directly to DC LED lamps through a smart controller. However, in this projected system, the stored DC power is first converted to AC using an inverter before powering AC LED spotlights. The study evaluates system components, operational performance, energy efficiency, and economic aspects. By integrating automatic control and renewable energy, the proposed system aims to deliver a workable, cost-effective, and reliable outdoor lighting solution for modern arrangement development.

Specifically, the objectives include:

1. To design a smart mini solar high mast system suitable for small and medium outdoor applications.
2. To study the operation and mixing of the major system components, counting the solar panel, battery storage, LED lighting, and smart controller.
3. To test the energy generation and consumption characteristics of the system under real environmental conditions.
4. To evaluate the performance of automatic control features such as automatic power ON and OFF operation and battery protection.
5. To appraise the reliability and efficiency of the system in providing continuous nighttime brilliance.
6. To perform an economic analysis since installation cost, maintenance requirements.

METHODOLOGY

The methodology adopted for this study is structured to methodically evaluate the design, operation, and presentation of the Smart Mini Solar High Mast System, as illustrated in Fig. 1. Initially, system preparation and requirement analysis were conducted by evaluating the lighting needs based on the specific application area. Key parameters such as required brightness levels, daily functional hours, pole height, and local environmental conditions remained taken into account. Based on these requirements, imprecise ratings for the solar panel, battery storage capacity, LED load, and smart controller were selected to confirm reliable night operation.

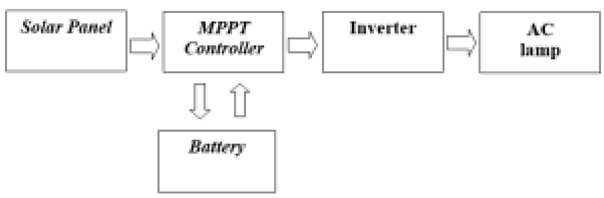

Fig 1. Smart Mini Solar High Mast System

The battery stores the electrical energy and foods DC power to the inverter during evening operation. The inverter translates the DC power into AC power needed by the LED lamp. The LED lamp, riding on the high mast pole, provides competent brilliance. All machineries are consistent with properly rated manacles and shield devices to ensure safe and steadfast operation.

In the next step, full system design and component selection were doing. The system was calculated with a solar panel as the primary energy source, a rechargeable battery for energy storage, a high-efficiency LED lamp as the capacity, and a smart charge controller to regulate power current. Component riders were carefully selected to match the daily energy demand and local solar accessibility. Proper protection devices and wiring activities were incorporated to boost system safety and ensure proper action.

After settling the design, the installation and gathering of the solar system were carried out. The solar panel was riding at an ideal tilt angle to maximize solar energy absorption. The battery, charge controller, and LED lamp were securely fitted on the mini high mast solar assembly. Electrical connections were finalized following standard safety rules and using components sized according to the design designs. The smart controller was automated for automatic dusk-to-dawn operation using either a light-dependent radar or a time-based sensor, while also so long as battery charge and discharge shield.

Subsequent installation, the system was operated underneath real environmental conditions for performance checking and data collection. Key limitations such as solar energy lord group, battery voltage, state of charge, and LED operating length were noted. Weather settings were also pursued to compare system performance with conservational features.

To conclude, the collected data was studied to calculate the overall efficiency of the solar high mast system. Selection and fitting decisions were evaluated based on fitting cost, maintenance necessities, and long-term energy savings compared to straight grid-based lights systems. The results obtained through this organization were used to weigh the pragmatism and success of the proposed Smart Mini Solar High Mast System.

Components

The Smart Mini Solar High Mast System contains of a solar panel, MPPT charge controller, battery, inverter, and LED spotlight. The solar panel converts daylight into electrical energy and supplies power to the MPPT charge regulator. The charge controller regulates the arraigning route, protective the battery from swindling and deep discharge.

1. **Solar Panel –** (120-Watt Solar Panel)

   The solar panel changes solar energy into electrical vigor. In this system, a 120W solar panel is used to trust the battery and supply power to the related LED lamp.

   Intention of solar panel-

   Solar panel current = 10 A

   $$I = \frac{P}{V} = \frac{120}{12}$$

   That incomes the panel can deliver near 10 amperes current daylight conditions.

2. **MPPT Charge Controller**

   The charge organizer regulates the power impending from the solar panel and supplies it to the battery. It protects the battery from cheating and deep emancipation, thereby encompassing the battery's life. MPPT (Maximum Power Point Tracking) controllers enhance charging proficiency by nonstop tracking and operating at the solar panel's determined power point. solar panel current = **10 A**.

   regulator selected = **20 A** (For safety purpose)

3. **Battery**

   The battery stores the electrical energy generated by the solar panel throughout the day. This stockpiled energy is cast-off to power the AC LED prearrangement at night. Deep-cycle batteries, such as lead-acid or lithium-ion types, are regularly employed to certify reliable and long-lasting operation.. E=V X Ah = 12 X 42

   Battery energy = 504 Wh

   That revenue battery stores 504 watt-hour energy.

4. **Inverter**

   The inverter adapts the DC power stored in the battery into the AC power required to operate the AC spot. It guarantees a stable voltage and frequency output, allowing proper and efficient lamp operation.

5. **AC Lamp (LED Light)**

   The AC lamp provides illumination for the voted area. LED lamps are chosen for their tall efficiency, low power eating, long lifespan, and undeviating light dissemination, construction them ideal for high mast lighting tenders.

   Load = 36W

Selected inverter = 100W
Since inverter rating > load rating, system mechanism in one piece

6. **GI Pole (High Mast Structure)**
The GI (Galvanized Iron) pole is used to maintenance the solar panel, LED lamp, and other system machineries at an preeminent stature. It provides powered strength and ensures wider and unvarying light supply over the required zone. The galvanization varnish protects the pole from rust, rust, and harsh weather settings, increasing its package life. The GI pole is designed to bear wind loads and provide stable preservative for the smart mini cosmological high mast igniting system.

Flow Chart:-

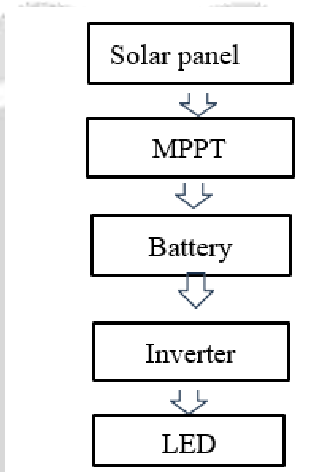

Fig 2. Flow Chart

The flow chart of the Smart Mini Solar High Mast Light Organization is shown in the above figure (Fig. 2). The solar panel produces DC power from sunlight. This power is safely accomplished by the charge controller, which protects the battery from fleecing and deep liberation. The battery is connected to the charge controller, and the productivity poisonous of the charge controller is related to an inverter. The inverter converts the DC power into AC power mandatory by the LED load. The AC output from the inverter is supplied to the LED lamp riding on the high mast pole.

All gears are securely mounted on the stimulated iron (GI) high mast building with proper wiring, protection devices, and earthlings to ensure safe and dependable operation.

The section connections inside the Smart Mini Solar High Mast Light System are calculated to guarantee efficient group, storage, conversion, and smart application of solar energy. The solar panel is connected to an MPPT (Maximum Power Point Tracking) charge controller consuming accurately rated DC restraints. The charge controller adjusts the voltage and current generated by the solar panel, guaranteeing safe battery charging by avoiding overcharging and deep emancipation.

The battery, helping as the main oomph storage unit, is connected to the output terminals of the charge controller. Electrical energy stored in the battery through the evening is complete to the inverter during evening operation. The inverter adapts the stored DC power from the battery hooked on AC power looked-for to operate the LED lighting load. The AC output of the inverter is then allied to the LED lamp.

Performance Analysis of Smart Mini Solar High Mast System

System act was evaluated during actual act to weigh energy usage, battery charging comportment, lighting efficiency, and overall system trustworthiness. The performance mainly be subject to on solar energy generation, battery charge-discharge crescendos, lighting act, and the effectiveness of the smart control structures.

In the afternoon, the solar photovoltaic panel efficiently renewed solar energy into electrical power, charging the battery over the charge supervisor. The charge controller confirmed stable charging by modifiable voltage and current, defending the battery and encompassing its life. The battery effectively stored necessary energy to support constant hours of darkness lighting.

At night, the Light Reliant on Resistor (LDR) exactly identified reduced ambient light and repeatedly switched

the lighting system ON. Furthermore, a Passive Electromagnetic (PIR) sensor sensed human task in the district, stimulating a high-brightness mode when motion was contemporary. In the nonattendance of motion, the system worked in a dim mode, suggestively tumbling power feeding and improving vigor efficiency.

The LED lamp distributed unbroken and acceptable illumination over the designated area while overriding low power. The inverter providing a stable AC output to the lamp without visible fluctuations. Total, the smart control features improved energy use, abated battery discharge, and ensured reliable brightness throughout the night.

Study indicates that the Smart Mini Solar High Mast Lighting Classification operates proficiently with minimal repairs, reduced energy depletion, and heightened reliability. These assets make the system well-suited for outdoor light applications such as streets, room areas, campuses, and rural positions.

Design Calculations of Smart Mini Solar High Mast System

The design of the Smart Mini Solar High Mast Lighting System is grounded on the daily power necessities of the lights consignment and the existing solar energy. Key calculations include shaping the LED load demand, battery capacity, solar panel rating, inverter selection, and apposite pole height.

1. LED Load Calculation

The power of the LED lamp rummage-sale in the system is 36 W. The lamp functions for 12 hours during nocturnal time.

Daily energy compulsory by the lamp is:

$36*12 = 432$

Therefore, the calculated daily energy requirement for the lighting load is 432 Wh/day.

2. Battery Sizing

The system operates at a voltage of 12 V with a daily energy requirement of 432 Wh. The battery capacity is calculated as follows:

Battery Capacity (Ah) = Daily Energy Requirement (Wh) ÷ System Voltage (V)
Battery Capacity = 432 Wh ÷ 12 V = 36 Ah

Consequently, the basic battery capacity vital to meet the daily energy demand is 36 Ah.

To account for battery losses and safe discharge margin, extra capacity is considered. Therefore, 12V 42Ah Lead Acid Battery is selected for the system.

This battery provides sufficient backup for night operation.

3. Solar Panel Sizing

Average effective solar charging time is considered as 5 hours per day. Required solar panel power is:

$$432/5=86.4$$

Thus, minimum required panel rating is 86.4 W.

Considering charging losses and weather variation, a 120-Watt Solar Panel is selected.

This gives reliable charging performance.

4. Inverter Selection

The inverter rating must be higher than the connected load. Since lamp load = 36 W, inverter rating selected is:

$100 > 36$

Therefore, 100W Power Inverter is selected for safe operation.

5. MPPT Controller Selection

Solar panel current:

$$120/12=10$$

Solar current = 10 A

Hence, MPPT Solar Charge Controller is selected for safe charging control.

Comparative Case Study

In this plan, the Smart Mini Solar High Mast System is compared with a conventional street lighting system. Conventional street lights operate directly on grid electricity, resulting in higher electricity consumption and increased monthly operating costs. Additionally, these systems typically fail during power outages due to the absence of energy storage. In contrast, the proposed system utilizes solar energy as its primary power source via a 120-Watt solar panel, significantly reducing grid electricity consumption and promoting energy savings. Electrical energy generated during the daytime is stored in a lead-acid battery, enabling uninterrupted lamp operation at night.

An MPPT (Maximum Power Point Tracking) solar charge controller is employed to enhance charging efficiency and protect the battery from overcharging. The stored DC power is converted to AC power by a 100W inverter to meet the lamp's requirements.

The lighting load consists of an LED street light, which offers higher efficiency and better illumination compared to traditional lamps while consuming less power. The daily energy requirement of the lamp is calculated as:

Battery capacity (Ah) × System voltage (V) = 36 Ah × 12 V = 432 Wh per day.

By relying primarily on solar energy, the proposed system drastically reduces dependence on grid power, making it more economical, energy-efficient, and suitable for outdoor lighting applications.

Solar Output Vs Time

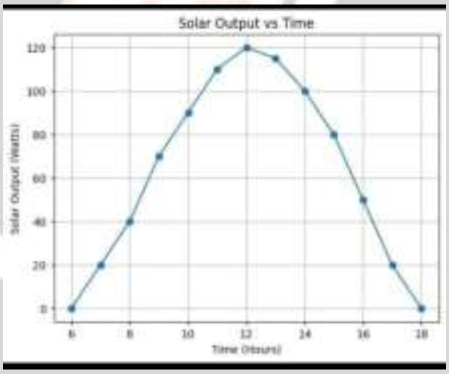

Fig.3 Solar Output Vs Time

Battery Voltage Vs Time

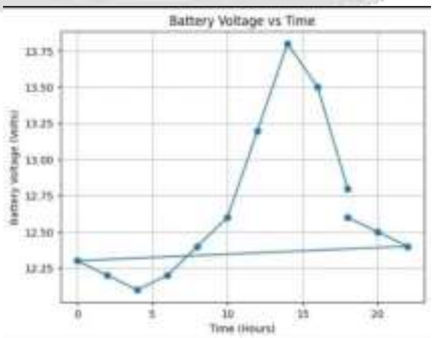

Fig 4. Battery Voltage Vs Time

CONCLUSION

The Keen Mini Solar High Mast System was established to enable actual use of renewable energy for outdoor lighting by assimilating a solar panel, battery storage, inverter, and smart control organization. This design ensures consistent, nonstop lighting without requirement on conformist grid power. The enclosure of smart control fundamentals such as Light Dependent Resistors (LDR) and time-based feelers qualifies programmed load operation and brilliance adjustment, falling energy wastage and pleasing to the eye overall system adeptness.

Design cunnings confirmed the apt selection of system gears, while performance analysis demonstrated efficient energy generation, stable battery charging, and sufficient lighting output under varying environmental conditions. Efficiency and autonomy evaluations indicated that the system can operate for more than one day without solar input, making it well-suited for areas with frequent power outages or limited grid access.

Furthermore, the use of energy-efficient LED luminaires and a corrosion-resistant galvanized iron (GI) high mast pole contributes to long service life and low maintenance requirements. The proposed system significantly reduces electricity costs and minimizes carbon emissions, thereby supporting environmental sustainability.

Overall, the Smart Mini Solar High Mast Lighting System provides a practical, economical, and eco-friendly solution for modern outdoor lighting needs, with strong potential for large-scale deployment in urban, semi-urban, and rural infrastructure projects.

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