"Design and Implementation of a Solar System Using DC Lighting for Energy Efficiency"

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Abstract- ALL product manufacturing units need to have a faulty product detection and separation system in order to maintain product quality and maintain to good reputation so here we demonstration such a system using a solar system by using DC lightning. We Proposed design and solar faulty product is different and thus has a different mechanism A DC lightning strike in a solar photovoltaic (PV) system can induce extremely high voltages and currents, potentially damaging the system's components like PV panels, inverters, and DC cables. These damages can result from over voltage, excessive currents, or arcing due to lightning strikes.

Keywords- SC Solar cell Solar System two or more system and connect together, DC (Direct Current), SRA solar panel ampere.

I. Introduction:

Photovoltaic (PV) solar systems generate direct current (DC) electricity from sunlight and serve as a sustainable energy source. However, their outdoor placement makes them vulnerable to lightning strikes, which can damage critical components like modules and inverters. To mitigate these risks, implementing a robust Lightning Protection System (LPS)—including lightning rods and grounding—is essential. The generated DC can be stored in batteries or converted to alternating current (AC) via inverters for powering standard appliances, making protection vital for safe and continuous operation.

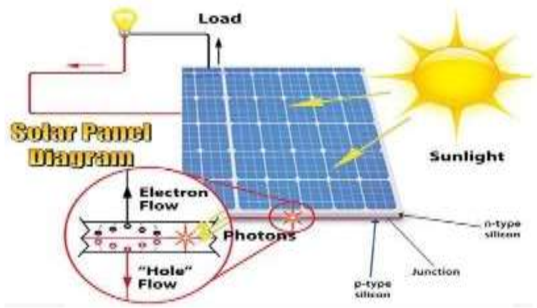

Fig: Conversion of light energy to electrical

In solar photovoltaic (PV) systems, DC lightning protection refers to safeguarding the direct current (DC) side—where high voltages are generated—against lightning-induced surges. Although there's no standard abbreviation for such systems, related terms include PV (Photovoltaic), SHS (Solar Home System), DC-DC (Direct Current converters), and SP (Surge Protection). Effective protection is critical to prevent damage to panels, inverters, and other components.

II. Methodology:

1. Solar panel collects sunlight and generates DC.
2. Charge controller sends power to charge the battery.
3. At night, the battery powers LED lights directly via DC wiring.
4. The system avoids AC/DC or DC/AC conversions, improving efficiency.

HARDWARE DEVICES:

- **Charge controller-** to prevent over-charging which is detrimental to the health of the battery.
- **Voltage regulator-** for regulating a constant 5V DC power supply.
- **Inverter-** for converting DC to AC power supply circuit is connected across the solar cell; the excited electrons will flow through the external circuit to recombine with the holes in the p- region as shown in.
- **Battery indicator-** to allow user to have an idea the amount voltage left inside the battery bank.
- A **storage box-** to contain all the electronic circuits to prevent damage to components as well as the danger to personnel using it since high AC voltage is present.

Table I provides the overall system specification of the portable power supply-

TABLE I.SPECIFICATION OF PORTABLE SOLAR POWER SUPPLY:

Descriptions	Specifications
Input voltage solar panel	12Volt–21 Volt
Inverter output voltage(AC operations)	220-230VAC
Voltage regulator output voltage(DC operations)	5Volt
Battery bank	12Volt
Charge controller	Abletocharge12 Volt rechargeable battery
Battery meter	Display arrange of Voltage using LEDs

B. Hardware Design Theory and Calculations:

Before proceeding with hardware implementation, basic electrical calculations were performed using Ohm's Law (V = IR) to estimate power requirements and component sizing.

TABLE II. POWER CONSUMPTION FOR SELECTED HARDWAREDEVICES:

Description	Rating (Watts)	Usage (hours)	Consumption (Watt hours)	Quantity
Solar Panel	30	-	-	1
Battery	12Volt 40AH	-	-	2

Key components and ratings:

Solar Panel: 50 W × 2 units = 100 W, Current =2.8A

Charge Controller: 10 A (DC max)

Battery: 12 V, 14 Ah × 2 = 144Wh

Inverter Output: 200 W max (AC), USB Output = 5 V, 6.2 A = 27 W (4 ports)

1) Battery Charging Time:

Solar Voltage = 12 V, Solar Current = 2.8 A × 2 = 5.6 A

Charging Time = Battery Capacity / Charging Current

= 144 WH / (12 V × 5.6 A) ≈ 2.5 hours

2) Load Calculation:
Inverter Efficiency Loss = 10%
Net Available Power = 200 W − 10% = 180 W
Inverter Runtime = Battery Capacity / Load
= 144 WH / 180 W ≈ 0.8 hours
Example Load:
a) Laptop Charger = 60 W
b) 4 DC Bulbs = 12 W × 4 = 48 W
c) Total Load = 108 W
d) Runtime = 144 WH / 108 W ≈ 1.33 hours.

Selection of Solar Panel: With the consistent improvement in technology development, there are many solar panels readily available on the market. It is important to choose a solar panel which is able to meet the objectives and goals of this project.

Fig: Solar Panel

For the selection of solar panel, we look at the three important factors.

B. Battery Selection-

A 12 V, 14Ah sealed lead-acid battery was selected for this system due to its suitability for solar applications, reliable performance, and ease of maintenance. The 14 Ah rating indicates the battery can deliver 14 A for 1 hour or 1 A for 14 hours, depending on the load. Exide batteries are chosen for their durability, high cranking power, improved charge retention, and resistance to vibration making them ideal for both solar and automotive use.

Fig: Exide Battery

Advantages of sealed lead-acid batteries include:
-Maintenance-free operation.
-Environment-friendly, with absorbed gas emissions.
-Spill-proof and safe, allowing for flexible and portable installation.

Charge Controller Design-

A charge controller (also known as a charge regulator) is an essential component in solar power systems or battery-based power systems. Its main job is to regulate the voltage and current coming from the power source (like solar panels) to the battery, preventing overcharging and over discharging, which can damage the battery.

Fig. Charge Controller

- The controller performs key functions: Battery Protection: Prevents overcharging and deep discharge.
- Voltage & Current Regulation: Maintains safe battery operating parameters.
- System Monitoring (optional): Provides system status and energy flow data.

Circuit Components:
8 transistors, 8 resistors, 2 variable resistors, and 1center-taptransformer. Q1 & Q2 operate as a stable multi vibrator generating a 50 Hz AC signal via variable resistors . Complementary outputs from Q1 and Q2 drive Q3 & Q4, initiating the PNP Darlington driver stage (Q3–Q6) to amplify current. Q7 & Q8 (2N3055

power transistors) form the final push-pull output stage to derive the transformer

This configuration ensures efficient charge control, enhances battery lifespan, and provides a stable power interface in DC solar lighting systems.

Single-Phase Rectifier-Rectification is the process of converting an AC voltage into a DC voltage using power electronic devices such as diodes, thyristors, or transistors. Single-phase rectifiers are fundamental components in AC-DC power conversion systems and are commonly implemented in half-wave or full-wave configurations.

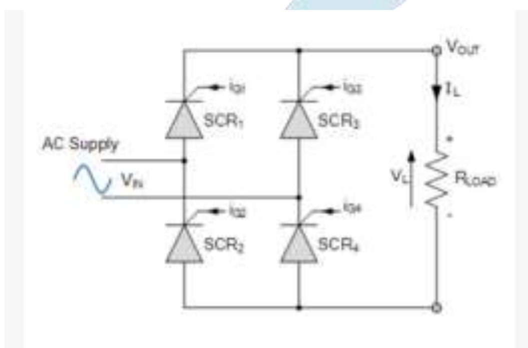

Fig. Single-Phase Rectifier

In these systems, semiconductor diodes are typically used due to their ability to conduct in the forward direction and block in the reverse, enabling the conversion of an oscillating AC input into a unidirectional DC output. Rectifiers may be uncontrolled, using only diodes, or controlled, using thyristors or transistors to regulate output voltage and current.

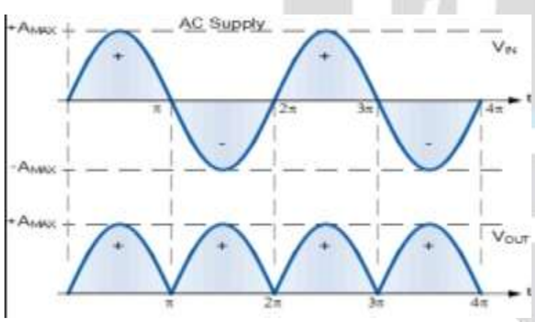

Fig. Single-Phase Waveform

This rectification process is essential in providing a stable DC supply from a single-phase AC source, serving as a core function in various power electronics applications.

Hardware Testing and Results

Prior to final assembly, all circuit designs were first tested on a breadboard to verify functionality. After successful validation, components were soldered onto the PCB for full system integration.

1. **Solar Panel Testing:**
   Under direct sunlight, the solar panel produced an output voltage of approximately 19.9V, closely matching the design specification outlined in Table I (rated at ~20V), This confirmed the panel's performance and allowed progression to subsequent hardware testing.

Fig: Setup solar system while using DC lightning

All components, including the charge controller and battery system, were systematically tested under controlled conditions to ensure operational

reliability and adherence to design parameters. **Note:** The term "DC lightning" is a misnomer; testing for lightning resilience typically involves surge protection analysis rather than direct exposure to high-voltage transients.

2.SurgeProtection

Solar systems, especially in areas prone to lightning, are often equipped with surge protection devices (SPDs) to shield the system from voltage spikes caused by lightning strikes. Testing these surge protectors can simulate how the system responds to high voltage surges, ensuring that components like inverter sand batteries are protected.

3. Electromagnetic Interference (EMI) Testing and Plasma Propulsion Technologies-
Lightning-induced electromagnetic interference (EMI) can challenge the robustness of solar systems. In futuristic scenarios, DC lightning could serve as a high-voltage energy source for long-distance power or data transmission, particularly in space applications. This would require advanced technologies to generate and control powerful electrical discharges,

potentially enabling communication and power transfer across space stations or interplanetary systems. A DC lightning-based methodology could also be applied in plasma propulsion systems. In such systems, plasma—often utilized for propulsion or energy generation—must be resilient to high-frequency electrical noise, ensuring stable performance in space environments.

DC Voltage Surge and Physical Lightning Strike Simulation Testing

4. DC Voltage Surge Testing: To evaluate the resilience of components such as inverters and battery banks, controlled high DC voltage surges (simulating nearby lightning strikes) are used to assess their ability to withstand unexpected voltage spikes.

5. Physical Lightning Strike Simulation: Advanced testing systems, such as Tesla coils, simulate lightning strike effects on electrical systems to ensure durability under extreme conditions. This approach is typically reserved for robust equipment, as it may cause significant damage if applied to entire solar systems.

Drawbacks of Using DC Lighting in Solar Systems:
The use of DC lighting in solar systems presents several challenges:

1. **Inefficient Long-Distance Transmission**: DC is less efficient for long-distance transmission compared to AC. Solar panels generate DC, which must be converted to AC for long-distance transport or household appliance use, leading to energy losses.

Incompatibility with Grid Power:
Most power grids operate on AC, requiring DC-powered systems (e.g., solar panels) to convert DC to AC via inverters. Using DC lighting would necessitate additional converters for grid and appliance compatibility.

2. **Limited Range of Lighting Fixtures**: DC lighting is less common for residential and commercial use, limiting fixture options and availability. Specialized DC fixtures are often more expensive and less accessible.

Maintenance Complexity: DC systems, including inverters and batteries, may require more frequent maintenance due to their specialized components, adding complexity and potential wear.

While DC lighting in solar systems can be efficient for direct use, it introduces challenges in broader applications, especially for grid integration.

Proposed Solution: Solar-Wind Hybrid System
A solar-wind hybrid system is proposed to supply electricity to laboratories in hilly and remote areas where wind energy is abundant. This system is cost-effective and efficient for generating electrical energy, providing a reliable solution for off-grid applications.

CONCLUSION:
This paper presents the implementation of a solar system for DC lighting, focusing on its efficiency and cost-effectiveness for off-grid applications. The use of DC lighting directly powered by solar panels eliminates the need for AC conversion, reducing energy losses and system complexity. The system offers sustainability by utilizing renewable solar energy, making it an ideal solution for remote areas lacking grid infrastructure. The system is also low maintenance, ensuring reliability and longevity. Overall, the integration of solar energy with DC lighting provides a reliable, eco-friendly, and cost-effective solution for off-grid lighting, with potential for widespread adoption in energy-deficient regions.

Scope
The proposed solar-wind hybrid system offers a reliable energy solution by leveraging both solar and wind resources, which vary throughout the day and across seasons. During the day, solar energy is abundant, while in the evening or during winter/rainy seasons, wind energy is more readily available. This hybrid approach ensures a continuous and reliable energy supply year-round. Incorporating DC lighting into the system adds complexity, especially in ensuring compatibility with battery storage (such as lithium-ion batteries), which may increase system costs. However, this integration enhances efficiency and reduces dependency on conventional energy source.
As energy demand rises due to population growth and technological advancements, the need for sustainable energy solutions becomes critical. Traditional energy sources are limited, polluting, and depleting, while renewable energy offers a cleaner, more sustainable alternative to

meet growing energy needs and protect the environment.

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