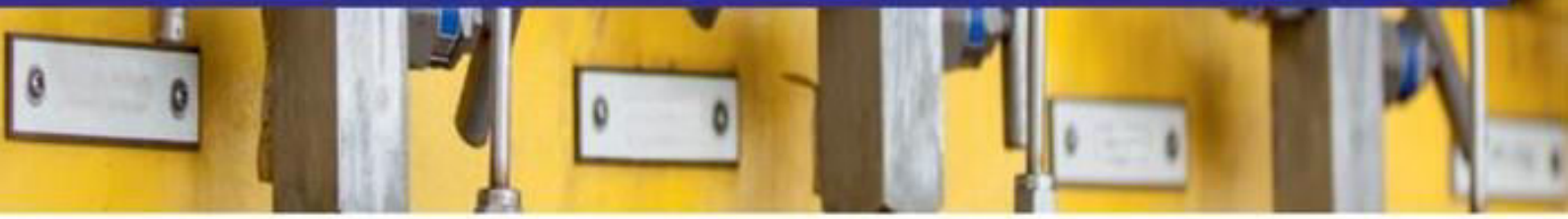
IJAREEIE

e-ISSN: 2278-8875
p-ISSN: 2320-3765

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

Volume 15, Issue 5, May 2026



INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 9.867

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE)

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 9.867 | A Monthly Peer Reviewed & Refereed Journal |

|| Volume 15, Issue 5, May 2026 ||

| DOI:10.15662/IJAREEIE.2026.1505003 |

The Smart Solar Gazebo: A Renewable Energy-Based Public Charging Hut

Abhijit A. Mahankal[1], Mrunali K. Sakharwade[2], Shiv S. Sangidwar[3], Shital N. Rode[4], Akshay B. Guthal[5], Dhanshree V. Bhende[6], Dr. Kiran M. Kimmatkar[7], Dr. Saurabh V. Lawate[8]

U.G. Student, Department of Electrical Engineering, Vidarbha Institute of Technology, Nagpur, Maharashtra, India[1,2,3,4, 5,6]

Head of Department of Electrical Engineering, Vidarbha Institute of Technology, Nagpur, Maharashtra, India[7]

Assistant Professor, Department of Electrical Engineering, Vidarbha Institute of Technology, Nagpur, Maharashtra, India[8]

ABSTRACT: "The Smart Solar Gazebo: A Renewable Energy-Based Public Charging Hut" is designed to serve as a public charging station for electronic devices such as mobile phones, laptops, and e-bikes, providing users with convenient access to sustainable energy in parks, campuses, and other public spaces. Equipped with smart features such as USB and wireless charging ports, energy monitoring sensors, LED lighting, and an IoT-based monitoring system, the gazebo ensures efficient energy utilization and real-time data accessibility. The integration of microcontrollers or IoT platforms enables remote supervision, fault detection, and performance optimization of the entire system. From an environmental perspective, "The Smart Solar Gazebo: A Renewable Energy Based Public Charging Hut" contributes significantly to reducing carbon emissions and dependence on fossil-fuel-based power sources. It promotes awareness and adoption of renewable energy technologies among the public while enhancing the aesthetic and functional value of urban infrastructure.

KEYWORDS: Photovoltaic, Maximum Power Point Tracking, Direct Current, Alternating Current, Sealed, Maintenance Free, Valve Regulated Lead Acid, State of Charge, Depth of Discharge, Human Machine Interface, Internet of Thing, Hot Dip Galvanized Iron, Reinforced Cement Concrete, Load Distribution Board, Light Emitting Diode, Galvanized Iron, Miniature Circuit Breaker, Residual Current Circuit Breaker, Surge Protection Device, Ultraviolet, IS Cognitive Radio, Spectrum Sensing, Efficient Communication, System Security.

I. INTRODUCTION

The Smart Solar Gazebo is an innovative, self-sustaining structure designed to harness solar energy for public utility applications such as device charging, lighting, and power supply for small loads. It integrates renewable energy generation, efficient power management, and safety systems to promote sustainable and green public infrastructure. This system not only demonstrates the practicality of renewable energy but also encourages the development of eco-friendly community spaces in campuses, parks, and public zones.

In this research paper proposes replicable framework for future sustainable infrastructure projects, combining technical innovation with practical utility. As communities worldwide seek to reduce their environmental impact and enhance public amenities, the Smart Solar Gazebo provides a comprehensive solution that balances performance, sustainability, and user needs. Its successful implementation paves the way for broader adoption of renewable energy technologies in public spaces, contributing to the global transition toward cleaner, smarter cities. This initiative not only addresses immediate energy needs but also serves as an educational platform and catalyst for further innovation in sustainable urban development. The lessons learned and technologies demonstrated will inform future projects, accelerating the integration of renewable energy solutions into everyday public infrastructure.

II. SYSTEM MODEL AND ASSUMPTIONS

The Smart Solar Gazebo: A Renewable Energy-Based Public Charging Hut is an innovative and eco-friendly engineering project designed to harness solar energy for public utility purposes. The project aims to develop a self-sustaining solar-powered gazebo that provides charging facilities for mobile phones, laptops, and other portable electronic devices in public areas such as parks, campuses, bus stops, and community centers.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 9.867 | A Monthly Peer Reviewed & Refereed Journal |

|| Volume 15, Issue 5, May 2026 ||

| DOI:10.15662/IJAREEIE.2026.1505003 |

In today's world, there is a continuous rise in the demand for energy, along with a growing awareness of environmental protection and sustainable development. The increasing use of electronic gadgets in everyday life often creates the need for accessible charging facilities in outdoor areas. Conventional grid-based charging systems are limited by their dependence on non-renewable energy and infrastructure availability. The Smart Solar Gazebo addresses these issues by using renewable solar energy to generate electricity, thereby offering an independent, green, and sustainable solution for public energy needs.

The research paper & project utilizes solar photovoltaic (PV) panels to convert sunlight into electrical energy, which is then stored in a battery bank through a charge controller with MPPT (Maximum Power Point Tracking) technology to ensure maximum efficiency. A solar hybrid inverter is used to convert the stored DC power into AC power for charging different electronic devices. The system also includes LED lighting, allowing the gazebo to function during nighttime and low-light conditions.

The gazebo's structural frame is fabricated using Hot-Dip Galvanized Iron (HDGI) pipes, which provide durability, corrosion resistance, and the mechanical strength required for outdoor installations. It includes safety mechanisms such as proper earthing, lightning arrestors, and circuit protection devices to ensure user and system safety.
This smart charging hut not only provides a convenient charging point for the public but also demonstrates the practical implementation of renewable energy in public infrastructure. It helps promote awareness about clean energy usage and contributes to reducing carbon emissions by minimizing dependence on conventional grid electricity. This Figure 2.1 shows the installation phase of the Smart Solar Gazebo, including:

- Mounting of the gazebo structure
- Installation of solar PV panels
- Electrical wiring and fittings
- Integration of lighting and charging system components.

Figure 2.1 shows the installation phase of the Smart Solar Gazebo

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 9.867 | A Monthly Peer Reviewed & Refereed Journal |

|| Volume 15, Issue 5, May 2026 ||

| DOI:10.15662/IJAREEIE.2026.1505003 |

III. INTRODUCTION TO SOLAR HYBRID INVERTER

A solar hybrid inverter is a multifunctional device that integrates solar energy conversion, energy storage, and grid interconnection into a single system. It combines the functionalities of a solar inverter and a battery inverter, enabling simultaneous management of solar panels, batteries, and utility power. In the Smart Solar Gazebo, the hybrid inverter serves as the central energy controller that:

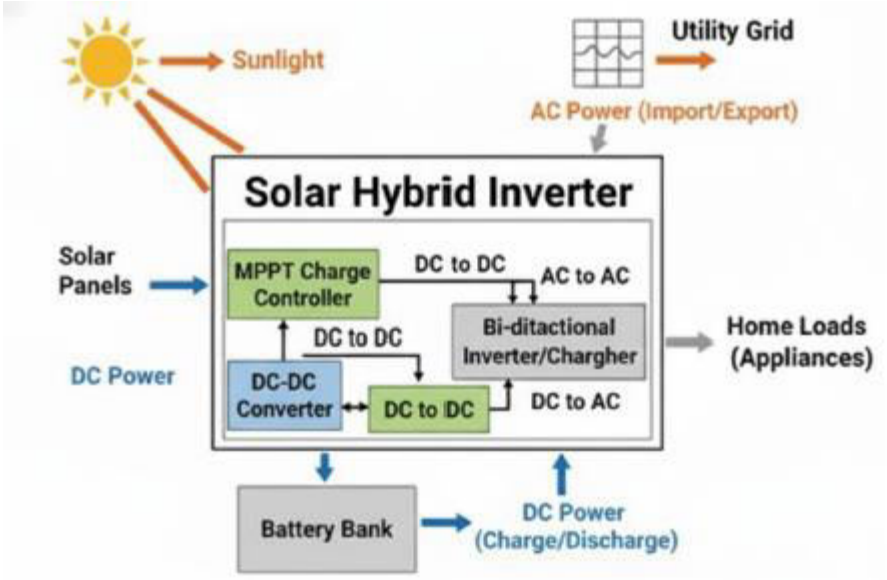


Figure 3.1: Introduction to Solar Hybrid Inverter

Converts DC power from solar panels into usable AC power,, Stores excess energy in the battery bank, and, Manages energy flow between the solar array, battery, and connected loads. This system ensures uninterrupted power supply for public charging stations, even during periods of low sunlight or grid failure.

- Photovoltaic Principle and Energy Conversion Mechanics Solar energy conversion is primarily achieved through the photovoltaic (PV) effect, a process where sunlight (photons) incident on a semiconductor material generates electricity.

110W Monocrystalline Panel Specifications and Performance Characteristics

Table: 3.1 110W Monocrystalline Panel Specifications and Performance Characteristics.

Parameter	Specification
Rated Power (Pmax)	110 W
Open Circuit Voltage (Voc)	22.5 V
Short Circuit Current (Isc)	6.2 A
Maximum Power Voltage (Vmp)	18.0 V
Maximum Power Current (Imp)	6.1 A
Module Efficiency	19–21%
Cell Type	Monocrystalline Silicon
Operating Temperature	-40°C to +85°C
Frame Material	Anodized Aluminum Alloy
Weight	~8 kg
Dimensions	1000 mm × 540 mm × 30 mm

The Smart Solar Gazebo employs 110W monocrystalline solar panels, known for their high efficiency and superior low-light performance. Monocrystalline panels are manufactured from a single crystal structure, providing excellent energy conversion rates and long service life.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 9.867 | A Monthly Peer Reviewed & Refereed Journal |

|| Volume 15, Issue 5, May 2026 ||

| DOI:10.15662/IJAREEIE.2026.1505003 |

IV. COMPONENT INTEGRATION AND PERIPHERALS

The integration of components and peripheral devices is essential for ensuring the smooth operation, safety, and user convenience of the Smart Solar Gazebo system. This chapter focuses on the interconnection hardware, lighting systems, and public charging modules that enhance the system's efficiency and usability. MC4 Connectors and System Interconnectivity. MC4 connectors are essential components in solar PV systems, designed to establish safe, efficient, and weatherproof connections between photovoltaic (PV) panels, inverters, and charge controllers. These connectors facilitate quick coupling and uncoupling of solar DC circuits while ensuring minimal contact resistance and long-term reliability in outdoor conditions.

LED Luminary and Photocell Integration :-ED luminaires are the primary lighting components of the Smart Solar Gazebo, providing efficient, durable, and eco-friendly illumination. Their integration with a photocell sensor (light-dependent resistor) enables automatic control of the lighting system based on ambient light conditions, ensuring energy efficiency and user convenience. During daylight, the photocell sensor detects sufficient illumination and automatically switches OFF the LED lights. As the ambient light level drops at dusk, the sensor activates the luminaires, providing seamless, hands-free operation. Integration Process:

- ✓ All wiring between the luminaires and photocell is routed through PVC conduits to protect against environmental exposure.
- ✓ Each luminary circuit is protected by an individual Miniature Circuit Breaker (MCB) located within the Load Distribution Board (LDB).
- ✓ The photocell output is connected to a relay or inverter control input that governs the ON/OFF status of the lighting circuit.
- ✓ Regular testing ensures reliable sensor performance and consistent light operation.
- ✓

Charging Points (USB, Type-C, AC Outlets)

- ❖ The Smart Solar Gazebo is equipped with a variety of public charging points designed to accommodate different types of portable electronic devices such as smartphones, tablets, laptops, and other small appliances. These charging interfaces increase public usability and highlight the practical application of renewable energy in community spaces.
- ❖ The integration of multiple charging standards, USB, Type-C, and AC outlets, ensures universal compatibility and efficient power delivery from the solar power system via the inverter.

Charging Options:

- ■ USB-Ports: Provide a 5 V DC output at 2.1 A, suitable for charging mobile phones, Bluetooth devices, and small gadgets directly from the DC bus.
- ■ Type-C Fast Chargers: Equipped with Power Delivery (PD) and Quick Charge (QC) protocols, offering up to 20 W output for rapid charging of compatible smartphones, tablets, and accessories.
- ■ AC-Outlets: Deliver 230 V, 50 Hz AC power directly from the solar inverter, allowing users to charge laptops or operate small appliances within the gazebo.

V. RESULT AND DISCUSSION

In the fig 5.1, it shows the The Smart Solar Gazebo: A Renewable Energy- Based Public Charging Hut.", reserach paper and results. The implementation of **"The Smart Solar Gazebo – A Renewable Energy-Based Public Charging Hut"** has successfully demonstrated the integration of clean energy technology into a functional and public-friendly infrastructure. The project results confirm the system's technical reliability, structural stability, and practical usability for everyday community applications.

1. System Performance Results

- The 110W monocrystalline solar panels consistently generated stable DC power under varying sunlight conditions.
- MPPT-based hybrid inverter operation increased energy harvesting efficiency by **15– 25%**, ensuring optimal charging performance throughout the day.
- The SMF battery storage maintained uninterrupted power supply during evenings and cloudy weather, enabling reliable public device charging.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 9.867 | A Monthly Peer Reviewed & Refereed Journal |

|| Volume 15, Issue 5, May 2026 ||

| DOI:10.15662/IJAREEIE.2026.1505003 |

2. Structural Results

- HDGI structural framework passed load verification tests, showing:
  - Maximum deflection of 6.5 mm, well within allowable standards.
  - No foundation uplift under simulated wind speeds up to 150 km/h.
  - Safety factor greater than 2.0, confirming the overall strength and durability of the gazebo structure.

3. Electrical Safety and Protection Results

- Earthing resistance was successfully maintained below **5 Ω**, ensuring safe fault-current dissipation.
- Lightning arrestor and surge protection devices (SPDs) effectively safeguarded the system from overvoltage conditions.

Figure.5.1. Real Time implementaion of The Smart Solar Gazebo: A Renewable Energy- Based Public Charging Hut.", with electronics components charging

4. Maintenance and Reliability Results

- Preventive maintenance activities confirmed stable system performance with no major operational issues.
- Panel cleanliness and wiring inspections showed minimal degradation after installation.
- Battery health remained within safe operational limits, supporting optimal charging and discharging cycles.

5. User Functional Results

- LED lighting operated automatically via photocell integration, reducing energy wastage.
- Public charging points (USB, Type-C, and AC outlet) provided accessible and efficient power for multiple devices simultaneously.

VI. CONCLUSION

The Smart Solar Gazebo successfully demonstrates the practical implementation of renewable energy technology in public infrastructure, serving as a model for sustainable community development. Key achievements include: Technical Excellence, Environmental Impact, Significant reduction in carbon footprint through clean energy generation, Social

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 9.867 | A Monthly Peer Reviewed & Refereed Journal |

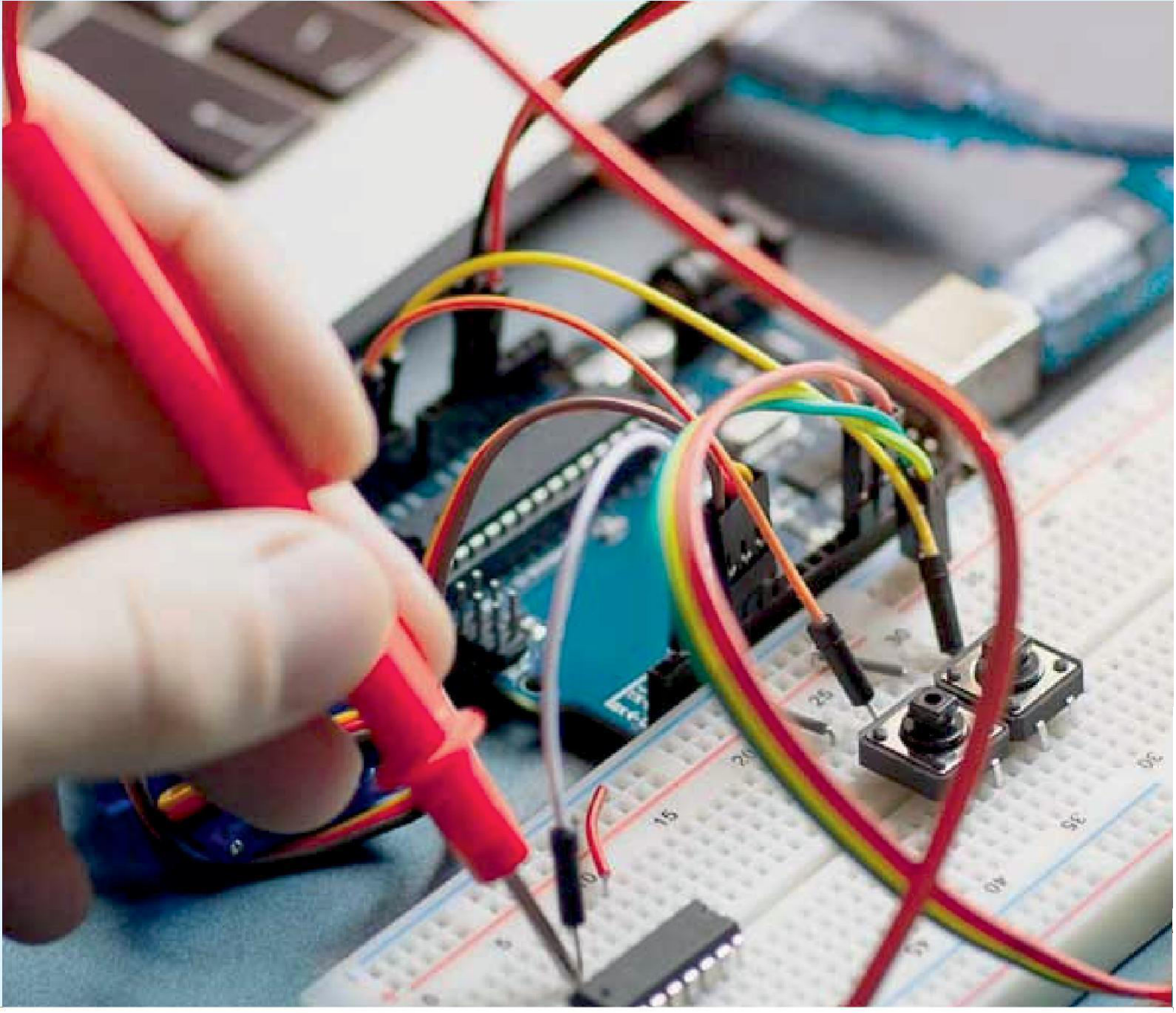
|| Volume 15, Issue 5, May 2026 ||

| DOI:10.15662/IJAREEIE.2026.1505003 |

Value, Provision of essential services (charging, lighting) to community members, Economic Viability, Potential for revenue generation through advertising or service fees

REFERENCES

[1] SolarPower Europe, Global Market Outlook for Solar Power 2025–2029. Brussels, Belgium, 2025.
[2] National Renewable Energy Laboratory (NREL), PV System Design, Wiring and Safety Compliance – 2025 Update. Golden, CO, USA, 2025.
[3] Safety of Power Converters for Use in Photovoltaic Systems, International Electrotechnical Commission (IEC) Standard IEC 62109-1/2:2025, 2025.
[4] 110W Monocrystalline Solar Panel Datasheet. Manufacturer Technical Specifications, Tech. Rep., 2025.
[5] Hybrid Solar Inverter Datasheet. Manufacturer Technical Specifications, Tech. Rep., 2025.
[6] SMF/VRLA Battery Datasheet. Manufacturer Technical Specifications, Tech. Rep., 2025.
[7] DC Surge Protective Devices – New Requirements, International Electrotechnical Commission (IEC) Standard IEC 63027:2024, 2024.
[8] PV Hazard Control, UL (Underwriters Laboratories) Standard UL 3741:2024, 2024.
[9] Schneider Electric, Solar Inverter Installation & Maintenance Manual. Rueil-Malmaison, France, 2024.
[10] Eaton Corporation, Circuit Protection for Solar PV Systems: User Guide. Dublin, Ireland, 2024.
[11] International Energy Agency (IEA) PVPS, Task 13: Performance and Reliability of Photovoltaic Systems. Paris, France, 2023.
[12] National Renewable Energy Laboratory (NREL), Solar Photovoltaic System Installation Guidelines – 2023 Edition. Golden, CO, USA, 2023.
[13] SolarPower Europe, Best Practices Handbook for Solar PV Installation & Operation. Brussels, Belgium, 2022.
[14] Inverters, Converters, Controllers for Distributed Energy Resources, UL (Underwriters Laboratories) Standard UL 1741:2022, 2022.
[15] National Renewable Energy Laboratory (NREL), Solar Photovoltaic System Installation Manual. Golden, CO, USA, 2021.
[16] M. Rahman and A. Khan, “Design and performance analysis of hybrid solar inverter systems,” J. Energy Storage, vol. 28, p. 101225, 2020.
[17] Protection Against Lightning, International Electrotechnical Commission (IEC) Standard IEC 62305:2020, 2020.
[18] M. A. Green, “Solar cell efficiency tables (version 55),” Prog. Photovolt: Res. Appl., vol. 27, no. 1, pp. 3–12, 2019.
[19] Surge Protective Devices, International Electrotechnical Commission (IEC) Standard IEC 61643 Series, 2019.



INNO SPACE
SJIF Scientific Journal Impact Factor

doi cross ref

ISSN INTERNATIONAL STANDARD SERIAL NUMBER INDIA

निस्केयर NISCAIR

International Journal of Advanced Research

in Electrical, Electronics and Instrumentation Engineering

9940 572 462 6381 907 438 ijareeie@gmail.com

Scan to save the contact details