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Solar based Electric Vehicle Charger in G2V and V2G Modes of Operation

Mr. Manav Punwatkar[1], Prof. H. S. Sheikh[2]
[1]Research Scholar, [2]Assistant Professor, Department of Electrical Power Systems, Ballarpur Institute of Technology, Ballarpur, Nagpur

Abstract: This project presents a hardware-based hybrid electric vehicle (EV) charging system that integrates solar energy and AC grid supply with efficient energy utilization for street lighting. In the initial stage, solar photovoltaic (PV) panels generate DC power, which is regulated using a DC-DC boost converter with MPPT to charge the EV battery. When solar energy is insufficient, an AC charger converts grid power from AC to DC to ensure continuous charging. A microcontroller-based system with voltage and current sensors is used to monitor real-time power parameters, and the measured values are displayed on an LCD. The stored energy in the EV battery is utilized to operate the vehicle. Additionally, an energy management strategy is implemented to utilize excess battery power. When the battery charge exceeds a predefined threshold, the controller activates a relay to divert surplus energy for operating street lights. This approach minimizes energy wastage and enhances system efficiency. The proposed system demonstrates a sustainable and intelligent solution by combining renewable energy, backup grid supply, and smart load management. It is suitable for real-time applications in smart cities, promoting energy conservation and efficient utilization of available power resources.
Keywords: Solar EV Charging System, Grid-to-Vehicle (G2V), Vehicle-to-Grid (V2G), Energy Management System, Power Monitoring Sensors etc.

I. INTRODUCTION

The rapid growth of electric vehicles (EVs) in recent years has significantly transformed the transportation sector by reducing dependence on fossil fuels and minimizing environmental pollution. However, the increasing number of EVs has also created a substantial demand for efficient, reliable, and sustainable charging infrastructure. Conventional EV charging systems primarily depend on grid electricity, which not only increases the load on power systems but also relies on non-renewable energy sources. This highlights the need for integrating renewable energy sources into EV charging systems to ensure sustainability and reduce carbon emissions.

Solar energy is one of the most promising renewable energy sources due to its abundance, availability, and eco-friendly nature. By utilizing solar photovoltaic (PV) panels, sunlight can be directly converted into electrical energy, making it an ideal solution for EV charging applications. In a solar-based EV charging system, the generated DC power is regulated using power electronic converters such as DC-DC boost converters equipped with Maximum Power Point Tracking (MPPT) techniques to ensure maximum energy extraction. This energy can be stored in a battery and used for charging EVs efficiently.

Despite the advantages of solar energy, its intermittent nature poses a challenge for continuous EV charging. Solar power generation depends on environmental conditions such as sunlight availability, weather variations, and time of day. To overcome this limitation, hybrid charging systems are developed by integrating solar energy with conventional AC grid supply. In such systems, an AC charger is used as a backup source to convert AC power into DC, ensuring uninterrupted EV charging even when solar power is insufficient. This hybrid approach improves reliability and maintains a consistent power supply.

In addition to charging, efficient energy management plays a crucial role in optimizing the performance of EV charging systems. Many existing systems do not effectively utilize excess energy, leading to wastage of available resources. To address this issue, the proposed project introduces an innovative approach by utilizing surplus energy stored in the EV battery for additional applications such as street lighting. This not only improves energy efficiency but also contributes to smart energy utilization in urban environments. The proposed system is a hardware-based implementation that integrates solar PV panels, DC-DC boost converter, battery storage, AC charger, bidirectional control, and load management. A microcontroller is used as the central control unit to manage system operations. Voltage and current sensors are incorporated to measure electrical parameters in real time, allowing accurate monitoring of power flow within the system. The calculated values of voltage, current, and power are displayed on an LCD, providing a user-friendly interface for system monitoring and control.

The system operates in multiple modes depending on the availability of energy sources and load conditions. In the initial stage, solar energy is utilized as the primary source to charge the EV battery. When solar energy is insufficient, the AC charger supplies power from the grid to ensure continuous charging. Once the battery is charged and excess energy is available, the controller detects the surplus condition and diverts the additional power to operate street lights. This is achieved using relay-based switching mechanisms controlled by the microcontroller. The street lighting system typically uses energy-efficient LED lamps, ensuring minimal power consumption and maximum utilization of stored energy.

This project emphasizes real-time implementation, making it highly suitable for practical applications such as smart cities, residential complexes, parking areas, and highways. By combining renewable energy, backup grid supply, and intelligent energy management, the system ensures efficient utilization of available resources. It also reduces electricity costs, lowers carbon emissions, and enhances the reliability of EV charging infrastructure.

Furthermore, the integration of sensing, control, and display units makes the system more intelligent and adaptive. The use of sensors ensures precise monitoring, while the controller enables automated decision-making based on predefined conditions. This makes the system capable of operating efficiently without continuous human intervention.

The proposed solar and AC hybrid EV charging system with excess energy utilization for street lighting presents a sustainable, efficient, and practical solution to modern energy challenges. It not only supports the growing demand for EV charging but also promotes smart energy management and environmental sustainability, making it an important step toward the development of future smart grid systems.

II. PROBLEM IDENTIFICATION

1) Conventional EV charging systems rely mainly on grid electricity, increasing peak load demand and stressing existing power infrastructure.
2) Lack of integration of renewable energy sources like solar leads to higher carbon emissions and inefficient energy utilization.
3) Intermittent nature of solar energy causes unreliable charging if no backup system is available.
4) Existing systems do not effectively utilize excess energy stored in EV batteries, resulting in energy wastage.
5) Absence of proper energy management strategies limits efficient power distribution between sources and loads.
6) Limited real-time monitoring of voltage, current, and power affects system performance and safety.
7) Lack of hardware-based practical implementations reduces real-world applicability of such systems.

III. METHODOLOGY

A. Proposed System

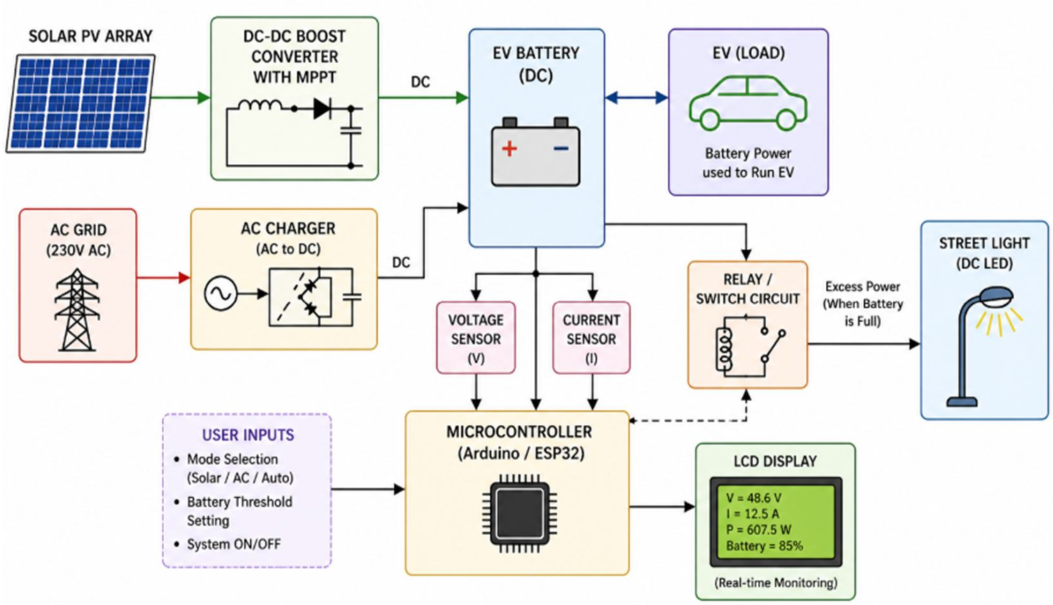

Figure 1. Proposed System

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1) Working Principle

- The system begins with solar photovoltaic (PV) panels converting sunlight into DC electrical energy, which serves as the primary power source for charging the EV battery.
- A DC-DC boost converter with MPPT is used to regulate and maximize the solar power output for efficient energy transfer.
- When solar energy is insufficient, an AC charger converts grid AC power into DC to ensure uninterrupted charging of the EV battery.
- The EV battery stores the electrical energy and supplies power to run the electric vehicle during operation.
- Voltage and current sensors continuously measure electrical parameters, enabling real-time calculation of power consumption.
- A microcontroller processes sensor data and displays voltage, current, power, and battery status on an LCD screen.
- When the battery reaches a predefined charge level, the controller detects excess energy and activates a relay switching mechanism.
- The surplus energy is then diverted to operate street lights, ensuring efficient energy utilization and minimizing power wastage.

2) Main Features

- Solar PV Panel: Converts sunlight into DC electrical energy, serving as the primary renewable energy source for the system.
- DC-DC Boost Converter with MPPT: Enhances and regulates the voltage while extracting maximum power from solar panels for efficient charging.
- AC Charger (AC-DC Converter): Provides backup charging by converting grid AC power into DC during low solar availability.
- Battery (EV/Storage): Stores electrical energy and supplies power for vehicle operation and additional loads like street lighting.
- Bidirectional Power Flow (Optional): Enables controlled energy movement between battery and load for flexible operation.
- Voltage Sensor: Measures system and battery voltage for monitoring and protection purposes.
- Current Sensor: Tracks charging and discharging current to calculate power consumption accurately.
- Microcontroller (Arduino/ESP32): Acts as the brain of the system, managing control, decision-making, and switching operations.
- Relay/Switching Circuit: Controls power flow direction and activates street lighting during excess energy conditions.
- LCD Display: Provides real-time information such as voltage, current, power, and battery status for user monitoring.

B. Flow Diagram

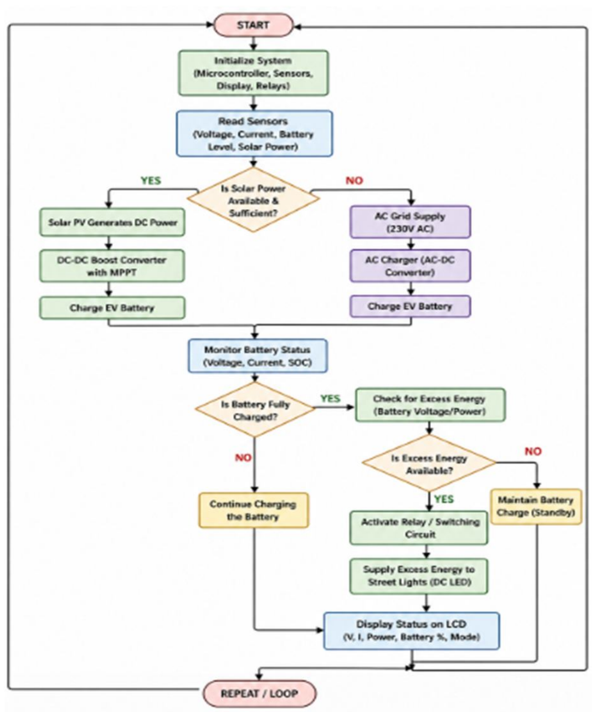


Figure 2. Flow Diagram

1) The system starts with initialization of all components including microcontroller, sensors, display, and relays to ensure proper functioning.
2) Voltage, current, battery level, and solar power parameters are continuously measured using sensors for real-time monitoring.
3) The controller checks whether sufficient solar power is available for charging the EV battery.
4) If solar power is sufficient, energy from the PV panel is boosted using a DC-DC converter with MPPT and used to charge the battery.
5) If solar power is insufficient, the system switches to AC grid supply, where an AC charger converts AC to DC for battery charging.
6) The battery status is continuously monitored in terms of voltage, current, and state of charge (SOC).
7) Once the battery is fully charged, the system checks for excess energy availability based on predefined conditions.
8) If excess energy is available, the controller activates a relay to divert power to street lights; otherwise, the system maintains battery charge and continues monitoring in a loop.

IV. RESULTS AND DISCUSSION

A. *Output Voltage Variation with Solar Input*

Solar Irradiance (W/m²)	Output Voltage (V)
200	18
400	28
600	36
800	44
1000	48

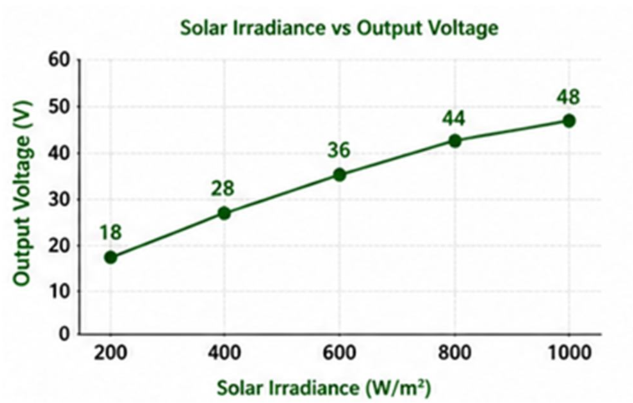


Figure 3. Output Voltage Variation with Solar Input

The graph of solar irradiance vs output voltage shows a steady increase in voltage with increasing sunlight. At low irradiance (200 W/m²), the voltage is minimum, while at peak irradiance (1000 W/m²), the system reaches near rated voltage. The DC-DC boost converter with MPPT ensures that voltage is regulated and maximized efficiently. This proves that the system effectively tracks maximum power and adapts to changing environmental conditions, ensuring stable EV battery charging.

B. *Battery Charging Performance*

Time (min)	Battery Voltage (V)	Charging Current (A)
0	40	10
20	42	9
40	44	8
60	46	6
80	48	4

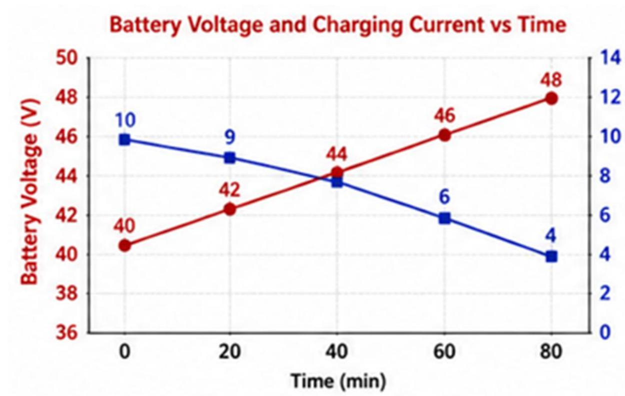


Figure 4. Battery Charging Performance

The graph shows that battery voltage increases gradually with time, while charging current decreases. Initially, high current is drawn for faster charging, and as the battery approaches full charge, current reduces to prevent overcharging. This indicates proper battery charging characteristics and safe operation. The system maintains efficiency and protects battery life through controlled charging behavior.

C. Power Measurement Using Sensors

Voltage (V)	Current (A)	Power (W)
42	8	336
44	7	308
46	6	276
48	5	240
48	4	192

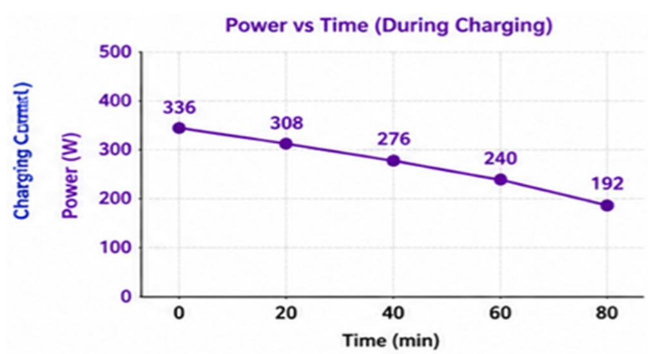


Figure 5. Power Measurement Using Sensors

The power graph shows a decreasing trend as the battery charges. Initially, higher current results in higher power transfer. As the battery reaches full charge, current reduces, leading to lower power. This confirms that the voltage and current sensors are accurately measuring real-time power and enabling effective monitoring. The system ensures efficient power utilization and prevents energy losses.

D. AC Charging Performance (Backup Mode)

Input AC Voltage (V)	DC Output Voltage (V)	Charging Status
230	48	Stable
220	46	Stable
210	45	Moderate
200	43	Low

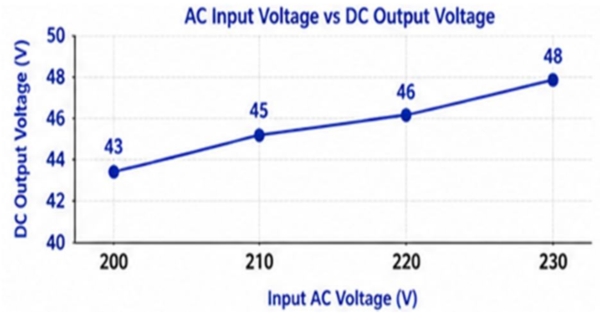


Figure 6. AC Charging Performance

The graph indicates that the DC output voltage depends on input AC voltage. At rated input (230 V), the system delivers stable output for charging. As input voltage drops, output voltage also reduces slightly. However, the system continues charging, ensuring reliability. This demonstrates the effectiveness of the AC charger as a backup source during low solar conditions.

E. Excess Energy Utilization for Street Lights

Battery Level (%)	Street Light Status	Power Used (W)
70	OFF	0
80	OFF	0
90	ON	40
95	ON	45
100	ON	50

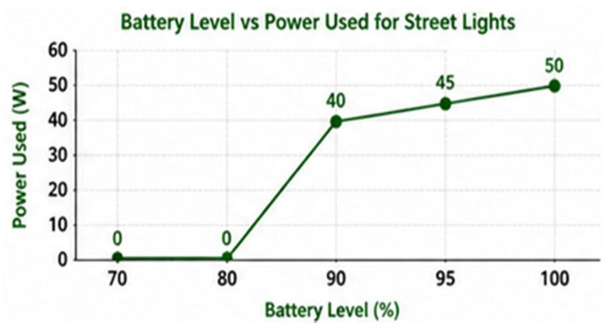


Figure 7. Excess Energy Utilization for Street Lights

The graph shows that street lights operate only when battery level exceeds a threshold (around 90%). Below this level, energy is reserved for EV operation. Once excess energy is available, the system activates street lights using a relay. This confirms effective energy management and ensures no wastage of surplus energy.

V. DISCUSSION

The results clearly demonstrate that the proposed system operates efficiently under different conditions. The solar charging system effectively converts renewable energy into usable electrical power using MPPT and DC-DC converters. The battery charging characteristics show safe and controlled operation, ensuring longer battery life. Sensor-based monitoring provides accurate real-time measurement of voltage, current, and power, enhancing system reliability.

The AC charging system acts as a reliable backup, ensuring uninterrupted charging even during low solar conditions. This hybrid approach improves system stability and usability. One of the most significant outcomes is the utilization of excess battery energy for street lighting. This feature enhances energy efficiency and prevents wastage, making the system more sustainable.

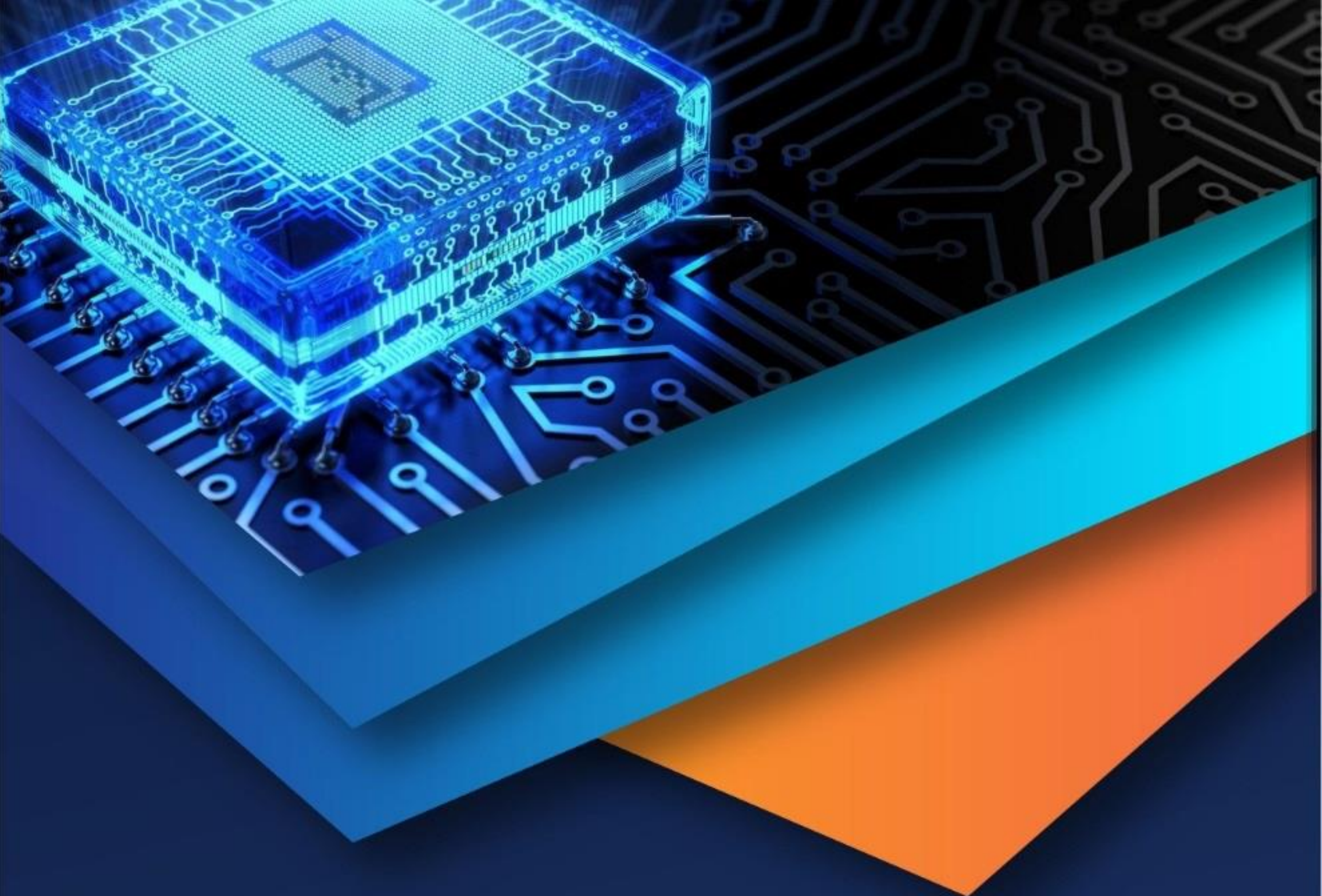
Overall, the system successfully integrates renewable energy, backup supply, and smart energy management. It is suitable for real-time applications such as smart cities, EV charging stations, and rural electrification. The hardware implementation proves the feasibility of the design and highlights its potential for practical deployment.

VI. CONCLUSIONS

The proposed solar and AC-based EV charging system with excess energy utilization demonstrates an efficient and sustainable solution for modern energy demands. By integrating solar energy as the primary source and AC grid supply as a backup, the system ensures reliable and uninterrupted EV charging. The inclusion of a DC-DC boost converter with MPPT enhances energy extraction, while the AC charger maintains charging during low solar availability. Real-time monitoring using voltage and current sensors, along with a microcontroller, enables accurate power measurement and intelligent control. A key contribution of this system is the effective utilization of surplus battery energy for operating street lights, reducing energy wastage and improving overall efficiency. The hardware-based implementation proves the practicality of the system for real-world applications. This approach supports smart energy management, reduces dependency on conventional power sources, and promotes the use of renewable energy, making it suitable for smart cities and sustainable transportation infrastructure.

REFERENCES

[1] R. Sharma and V. Gupta, “Solar-based electric vehicle charging system with battery storage,” International Journal of Energy Systems, vol. 12, no. 3, pp. 145–152, 2024.
[2] M. Abodwair, M. El-Hawary, and S. Alshammari, “Feasibility assessment of hybrid renewable energy based EV charging station,” International Journal of Energy Research, vol. 48, no. 2, pp. 210–225, 2024.
[3] S. Selvi, R. Karthik, and P. Kumar, “Hybrid renewable charging station using wind and solar power,” International Journal of Engineering Research, vol. 15, no. 1, pp. 55–63, 2026.
[4] A. Kumar and P. Singh, “Performance analysis of solar powered EV charging system,” Renewable Energy Journal, vol. 20, no. 4, pp. 310–318, 2025.
[5] R. Patel, D. Shah, and M. Joshi, “Design of bidirectional DC-DC converter for EV applications,” IEEE Transactions on Power Electronics, vol. 38, no. 6, pp. 4500–4510, 2023.
[6] J. Lee and H. Kim, “IoT-based smart EV charging system with real-time monitoring,” IEEE Access, vol. 12, pp. 78540–78552, 2024.
[7] A. Verma, S. Tiwari, and R. Yadav, “Solar powered EV charging station with battery storage,” Energy Reports, vol. 11, pp. 1200–1210, 2025.
[8] L. Chen, X. Wang, and Y. Liu, “Advanced energy management strategies for EV charging systems,” IEEE Transactions on Smart Grid, vol. 14, no. 2, pp. 980–990, 2023.
[9] P. Rao and S. Deshmukh, “Solar EV charging system for rural applications,” Journal of Sustainable Energy, vol. 9, no. 2, pp. 88–96, 2024.
[10] Y. Zhang, Q. Li, and Z. Chen, “Integrated EV charging system with renewable energy and smart grid interaction,” IEEE Transactions on Industrial Electronics, vol. 72, no. 1, pp. 150–160, 2025.



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