



## DESIGN AND IMPLEMENTATION OF A HYBRID SOLAR-GRID ELECTRIC VEHICLE CHARGING SYSTEM

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### Abstract:

The rapid adoption of Electric Vehicles (EVs) is essential for reducing carbon emissions, yet it places significant strain on existing electrical grids. This paper presents the design and implementation of a hybrid charging system that integrates solar photovoltaic (PV) energy with the conventional power grid. To maximize energy harvesting, a Maximum Power Point Tracking (MPPT) controller is employed. The system is designed to prioritize solar energy, switching automatically to grid power during periods of low irradiance or nighttime. Experimental results and simulations indicate that the hybrid approach ensures uninterrupted charging, reduces dependency on fossil-fuel-based electricity, and improves overall system efficiency. The project demonstrates the feasibility of sustainable EV infrastructure for both urban and rural applications.

**Keywords:** Electric Vehicles, Solar Photovoltaic, Hybrid Charging, MPPT, Renewable Energy, Power Grid

## 1. INTRODUCTION

The global energy landscape is undergoing a critical shift due to the rapid growth of the population and industrialization. Conventional energy sources, including coal and natural gas, have long been the primary drivers of transportation and electricity. However, these fossil fuels are finite and contribute significantly to environmental degradation through the release of greenhouse gases like CO<sub>2</sub> and methane. Consequently, the development of clean, sustainable energy sources is more urgent than ever.

Electric Vehicles (EVs) have emerged as a promising solution to minimize environmental pollution. Unlike internal combustion engines, EVs utilize electric motors powered by rechargeable batteries. While governments worldwide are promoting EV adoption through subsidies and infrastructure development, a major challenge remains: the dependency of charging stations on the electrical grid. In many regions, grid electricity is still generated from fossil fuels, which offsets the environmental benefits of EVs. Furthermore, the rising number of EVs can lead to energy demand fluctuations and potential grid instability.

To address these issues, this research proposes a hybrid solar-grid charging system. Solar energy is one of the most abundant resources on Earth. By integrating solar PV panels with an MPPT-based charge controller and a grid backup, the system provides a reliable, cost-effective, and "green" charging solution.

## 2. LITERATURE SURVEY

The development of EV technology dates back to the 19th century, but recent advancements in power electronics and renewable integration have renewed interest in the field.

Vendoti et al. (2025) proposed a hybrid system integrating PV, fuel cells, and energy storage, utilizing an Adaptive Neuro-Fuzzy Inference System (ANFIS) for MPPT. Their research highlighted that intelligent algorithms significantly improve extraction efficiency under varying irradiance. Similarly, Singla et al. (2024) designed a 4 kW solar-based hybrid station, demonstrating that such architectures reduce the load on the electrical grid during peak periods.

Research by Gopalasami et al. (2024) introduced multiport converters, allowing for simultaneous interaction between solar PV, batteries, and the utility grid. Their findings suggest that bidirectional power flow (Vehicle-to-Grid or V2G) can further support grid stability. Additionally, Alrubaie et al. (2023) conducted a comprehensive review emphasizing that while initial installation costs are high, the long-term economic and environmental benefits of solar-integrated stations are substantial.

Despite these advancements, a literature gap exists regarding simplified, cost-effective hybrid implementations for small-scale prototypes and the optimization of panel inclination for vehicle-mounted applications.

### 3. METHODOLOGY AND SYSTEM ARCHITECTURE

The proposed system follows a modular architecture designed for high efficiency and reliability.

#### A. System Overview

The system integrates solar PV panels, an MPPT charge controller, a Battery Management System (BMS), DC-DC converters, and a grid interface. The primary objective is to maintain a continuous DC bus for battery charging regardless of solar availability.

#### B. Subsystems

- Solar Power Generation:** Utilizes approximately 40 solar panels. These panels are installed at an optimized inclination angle based on geographical latitude to maximize solar radiation absorption throughout the year.
- MPPT Charge Controller:** A crucial component that monitors the voltage and current of the PV array to find the Maximum Power Point (MPP). It adjusts the duty cycle of the DC-DC converter to ensure the panels operate at peak efficiency, potentially increasing energy harvesting by up to 30%.
- Grid Power Supply:** Acts as a secondary source. An AC-DC rectifier converts grid power into a regulated DC voltage suitable for battery charging when solar output is insufficient.
- Battery Management System (BMS):** Monitors battery health, prevents overcharging/deep discharging, and ensures cell balancing for the Lithium-ion battery pack.

#### C. Control Strategy

The system operates in three distinct modes:

- Solar Mode:** Used during peak sunlight; solar energy provides 100% of the charging current.
- Grid Mode:** Used at night or during heavy rain; the system switches entirely to the grid.
- Hybrid Mode:** During partial shading, both solar and grid sources contribute simultaneously to maintain the required charging rate.

### 4. DESIGN AND IMPLEMENTATION

#### A. Hardware Selection

The implementation required high-grade mechanical and electrical components. The Bill of Materials (BOM) includes 40 solar panels, an MPPT controller, a DC-DC boost converter, a Lithium-ion battery, and a structural mounting frame.

## B. Manufacturing Processes

The fabrication of the physical structure involved several mechanical stages:

1. **Cutting:** Steel rods and sheets were cut to precise dimensions using angle grinders to ensure structural integrity.
2. **Welding:** Arc welding was utilized to assemble the main frame, providing a rigid base for the panels.
3. **Grinding & Drilling:** Surfaces were smoothed to prevent corrosion, and holes were drilled for the secure mounting of electrical enclosures and PV panels.

## C. Electrical Installation

Wiring was performed using copper conductors with high-grade insulation. Color coding was strictly followed to distinguish between positive, negative, and ground connections. Switches were installed on a central control panel to allow the operator to isolate subsystems during maintenance.

## 5. ADVANTAGES AND DISADVANTAGES

### A. Advantages

- **Environmental Sustainability:** Significant reduction in carbon footprint by utilizing renewable energy.
- **Cost Efficiency:** While the initial investment is high, the elimination of per-unit electricity costs during the day results in long-term savings.
- **Grid Support:** Reduces the "peak hour" stress on the local distribution transformer.
- **Reliability:** The hybrid nature ensures that the vehicle is never left without a charge, even during a grid failure or cloudy weather.

### B. Disadvantages

- **Initial Cost:** The high price of PV panels and Lithium-ion batteries remains a barrier.
- **Space Requirements:** A large surface area is required to mount enough panels to generate sufficient wattage for fast charging.
- **Weather Dependency:** Performance is directly linked to climatic conditions.

## 6. CONCLUSION AND FUTURE SCOPE

This project successfully demonstrates the design and implementation of a hybrid solar-grid EV charging system. By combining renewable energy with a reliable grid backup and utilizing MPPT technology, the system achieves high efficiency and uninterrupted operation. The integration of a BMS ensures the safety and longevity of the EV battery.

### Future Scope

Future developments will focus on:

1. **IoT Integration:** Implementing smart monitoring systems to allow users to track charging status and solar generation via mobile applications.
2. **Solar Tracking:** Incorporating dual-axis tracking mechanisms to automatically adjust panel angles, further increasing energy yield.

3. **V2G Technology:** Enabling bidirectional energy flow so that EVs can supply power back to the home or grid during emergencies.
4. **Advanced Materials:** Utilizing solid-state batteries and high-efficiency monocrystalline panels to reduce the overall system footprint.

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