

# Solar Powered EV Charging System

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**Abstract:** *The increasing adoption of Electric Vehicles (EVs) has introduced new challenges to existing power systems, particularly in terms of load demand and grid stability [5], [6]. When EV charging relies on conventional electricity generated from fossil fuels, the environmental advantages of electric mobility are significantly reduced. To overcome these issues, this paper presents a solar photovoltaic (PV)-based EV charging system integrated with a Battery Energy Storage System (BESS). The proposed architecture uses a DC-DC boost converter with Maximum Power Point Tracking (MPPT) to efficiently extract solar energy, along with a bidirectional converter to manage energy flow between the battery and load. Simulation results indicate that the battery storage system effectively compensates for solar power fluctuations, maintaining a stable DC output and enabling continuous EV charging during peak sunlight conditions without grid support.*

**Keywords:** IoT, Underground Tunnel, Worker Safety, ESP8266 Node MCU, Gas Detection, Smart Monitoring System,

## I. INTRODUCTION

The transportation sector is rapidly transitioning from internal combustion engine vehicles to Electric Vehicles (EVs) to reduce greenhouse gas emissions and promote cleaner mobility solutions [5], [6]. However, large-scale EV integration introduces challenges such as increased peak load demand, transformer overloading, and voltage fluctuations in existing electrical networks [7], [8].

If EV charging depends on non-renewable energy sources, the environmental benefits of electric mobility are significantly diminished [6], [7]. This has led to growing interest in integrating renewable energy systems, especially solar photovoltaic (PV) technology, into EV charging infrastructure [9], [11].

Although solar energy is clean and widely available, its intermittent nature due to weather variations makes it unreliable for continuous power supply without energy storage support [10], [15]. Battery Energy Storage Systems (BESS) help overcome this limitation by storing excess energy and supplying it when solar generation is insufficient [10], [16].

Recent studies show that power electronic converters and intelligent control techniques significantly improve the performance of renewable-based charging systems [11], [15]. Embedded control strategies further enhance system efficiency by enabling real-time energy management and regulation [12], [13][16-173]

## II. PROBLEM STATEMENT

The increasing number of Electric Vehicles is creating significant stress on conventional power distribution networks, resulting in peak demand issues and reduced system reliability [5], [7]. Additionally, charging EVs using electricity generated from fossil fuels reduces the environmental advantages of electric transportation [6], [8].



Although solar PV systems offer a renewable alternative, their output is highly dependent on environmental conditions, making them unsuitable for standalone operation without storage support [9], [10]. Many existing systems lack intelligent control mechanisms to coordinate solar generation, battery storage, and load demand effectively [11], [15].

Therefore, there is a need for an autonomous solar-powered EV charging system that integrates energy storage and embedded control to ensure stable and efficient operation [10], [16].

### III. DESIGN AND ANALYSIS OF THE PROJECT

The proposed work presents a Smart Battery Management System (BMS) integrated with a solar-powered Electric Vehicle (EV) charging prototype. The main objective of the system is to continuously monitor, regulate, and safeguard the battery during both charging and discharging processes to ensure safe and efficient operation.

The developed prototype consists of key components such as a solar panel, solar charge controller, 12V rechargeable battery, Arduino UNO microcontroller, relay module, voltage sensing circuit, OLED display, buzzer alarm system, and an EV charging output interface.

In this system, the Arduino UNO acts as the central control unit. It continuously tracks the battery voltage level and accordingly operates the relay to control the charging process based on predefined conditions. The OLED display provides real-time updates regarding battery status, charging condition, and system operation.

#### System Analysis

- Input Voltage: 12V DC
- Battery Capacity: 2Ah
- Solar Panel Rating: 10W
- Relay Operating Voltage: 5V
- Arduino Operating Voltage: 5V

#### A. Battery Voltage Monitoring Equation

The voltage divider equation used for battery sensing:

$$V_{out} = V_{in} \times \frac{R_2}{R_1 + R_2}$$

#### Where:

- $V_{in}$  = Battery voltage
- $V_{out}$  = Arduino analog input voltage
- $R_1, R_2$  = Voltage divider resistors

#### B. Objectives of the Project

The major objectives of the project are:

1. To develop a smart battery monitoring system.
2. To protect battery from overcharging and deep discharge.
3. To control EV charging automatically using relay.



4. To utilize renewable solar energy for charging.
5. To display real-time battery information.
6. To reduce energy wastage.
7. To provide low-cost and eco-friendly charging solution.
8. To improve battery life and charging efficiency.

**C. Layout of Project Main Sections of Layout**

- Solar Energy Generation Unit
- Battery Charging Unit
- Battery Storage Unit
- Battery Monitoring Unit
- Relay Control Unit
- User Interface Unit
- EV Charging Output Unit

**Power Flow**

Solar Panel → Charge Controller → Battery → Relay → EV Charging Port

**Control Flow**

Arduino UNO → Relay + OLED + Buzzer

**D. Block Diagram**

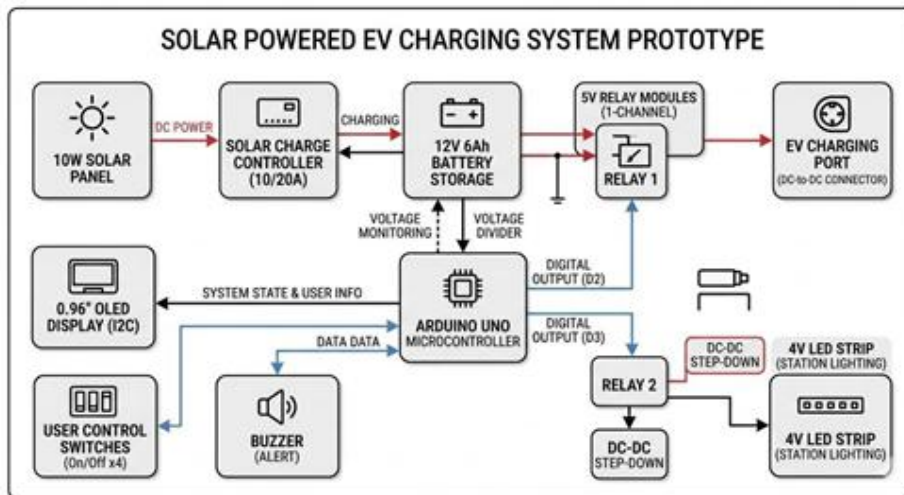


Figure: Block Diagram

**IV. IMPLEMENTATION AND WORKING OF PROJECT**

**1) Step 1: Solar Energy Generation**

The solar panel converts sunlight into DC electrical energy, which is then supplied to the charge controller for further processing.



### **2) Step 2: Battery Charging Process**

The charge controller regulates the incoming solar power and ensures safe charging of the 12V battery by preventing overcharging and maintaining charging stability.

### **3) Step 3: Voltage Monitoring**

The Arduino microcontroller measures the battery voltage using its analog input pins through a voltage divider circuit for accurate voltage sensing.

### **4) Step 4: Relay Operation Control**

Based on the monitored battery voltage:

- When the voltage is within the safe operating range, the relay is activated and the EV charging port is enabled.
- When the voltage drops below the threshold level, the relay is deactivated, and the charging output is disconnected to protect the battery.

### **5) Step 5: Display and Alert System**

The OLED display continuously shows key system parameters such as battery voltage, charging status, and relay condition. Additionally, the buzzer is triggered in case of abnormal conditions such as:

- Low battery voltage
- System fault conditions
- Over-discharge scenarios

## **V. CONCLUSION**

The study demonstrates that integrating solar PV systems with battery energy storage provides a reliable and sustainable solution for EV charging applications. The use of MPPT techniques improves solar energy utilization, while the battery system ensures stable power delivery under varying environmental conditions. Future improvements may include bidirectional energy flow (Vehicle-to-Grid capability) and advanced intelligent control algorithms to enhance system flexibility and efficiency.

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