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**Research Paper**

# HYBRID DUAL BATTERY SOLAR ELECTRIC VEHICLE SYSTEM (SEV)

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## ABSTRACT

The design and implementation of a Hybrid Solar-Powered Electric Vehicle (SEV) system with a dual-battery management mechanism. The system integrates solar energy harvesting, intelligent battery switching, and ESP32-based control to enhance efficiency, reliability, and sustainability. The primary battery powers the vehicle while the secondary battery is charged using solar energy. An intelligent control algorithm continuously monitors battery voltages and automatically switches between batteries based on charge levels. The system includes real-time voltage monitoring using sensors, relay-based battery selection, motor control through an L298N driver, and LCD display for status indication. Additionally, IoT-based monitoring is enabled using Blynk through ESP32 Wi-Fi capability. This approach reduces dependency on grid charging, minimizes downtime, and improves overall battery lifespan. The project demonstrates a practical and eco-friendly solution for sustainable transportation using renewable energy sources.

## 1.1 **INTRODUCTION:**

### Background & Motivation

The global transportation sector is one of the largest contributors to greenhouse gas emissions and fossil fuel consumption. The urgent need to reduce carbon footprints and mitigate climate change has accelerated the adoption of electric vehicles (EVs) as a cleaner alternative to internal combustion engine vehicles. However, conventional EVs rely predominantly on grid electricity for charging, which may still be generated from non-renewable sources, limiting their environmental benefits.

Solar-powered vehicles offer a compelling solution by harnessing renewable solar energy directly on-board. The integration of photovoltaic (PV) panels with battery energy storage systems enables vehicles to self-charge during operation, reducing or even eliminating dependency on grid infrastructure. This is particularly significant for remote areas where charging stations may be unavailable or unreliable.

**1.2 The primary objectives of this project are:**

1. Design a hybrid solar-electric vehicle with dual-battery energy management
2. Implement automatic battery switching based on real-time voltage monitoring
3. Integrate IoT-based monitoring for remote system observation using Blynk
4. Develop low-voltage protection mechanisms to prevent battery damage
5. Validate system performance through hardware testing and result analysis.

**1.3 Scope of the study:**

This project focuses on a prototype-scale Hybrid Dual Battery Solar Electric Vehicle. The scope includes hardware design, firmware development, IoT integration, and performance evaluation. While the prototype operates at a small scale, the design principles are scalable to full-sized EVs. The project does not cover large-scale manufacturing or road-legal certification but serves as a proof-of-concept for the proposed energy management strategy.

**1.4 Limitations of study:**

- The prototype operates at a small scale and does not represent the full complexity of a road-legal EV
- Solar panel power output is limited by the panel size mounted on the prototype chassis
- The 10V threshold may require calibration for different battery types and aging profiles
- Blynk free tier imposes limitations on data frequency and dashboard widgets
- The L298N driver is suitable for the DC motor in this prototype but would need to be scaled for larger EV applications
- No battery state-of-charge (SoC) estimation algorithm is implemented; switching is purely voltage-based

**1.5 Review of Literature :**

**Solar-Powered Electric Vehicles**

Research into solar-powered vehicles dates back several decades. Early work focused primarily on racing prototypes such as the World Solar Challenge vehicles, which demonstrated the feasibility of solar propulsion over long distances. More recent studies have shifted toward practical, urban-use solar EVs. Studies by Tina et al. (2020) and

Chauhan & Saini (2019) highlight the significant potential of integrating PV panels with EVs to extend driving range and reduce grid dependency.

**Dual Battery Systems in EVs**

Dual battery systems have been widely studied in the context of improving EV reliability and range. Research by Hannan et al. (2017) demonstrates that hybrid energy storage systems combining two battery banks can improve energy throughput and system reliability by distributing the discharge load. Studies on hybrid energy storage systems (HESS) show that intelligent switching between battery packs can extend overall battery lifespan by preventing individual cells from deep discharge.Relay-based automatic switching, as explored in this project, provides a cost-effective and reliable method for battery selection. More advanced approaches use bidirectional DC-DC converters, but these add complexity and cost that may not be justified at the prototype level.

**ESP32-Based Control Systems**

The ESP32 microcontroller, developed by Espressif Systems, has emerged as a popular choice for embedded IoT applications due to its dual-core processor, built-in Wi-Fi and Bluetooth, and rich peripheral support including high-resolution ADCs. Research by Kumar et al. (2021) demonstrates the suitability of ESP32 for real-time battery monitoring and control in energy management systems.

**1.6 Research Methodology:**

## Synthesis of Research Gaps

The comprehensive literature review presented in Chapter 2 and the implementation experience detailed in Chapter 4 together reveal a landscape of research opportunities that have not been adequately addressed in existing work. This chapter provides a structured taxonomy of identified research gaps, the specific problems they engender in real-world SEV deployment, and the methodological approaches proposed to address them in future research.

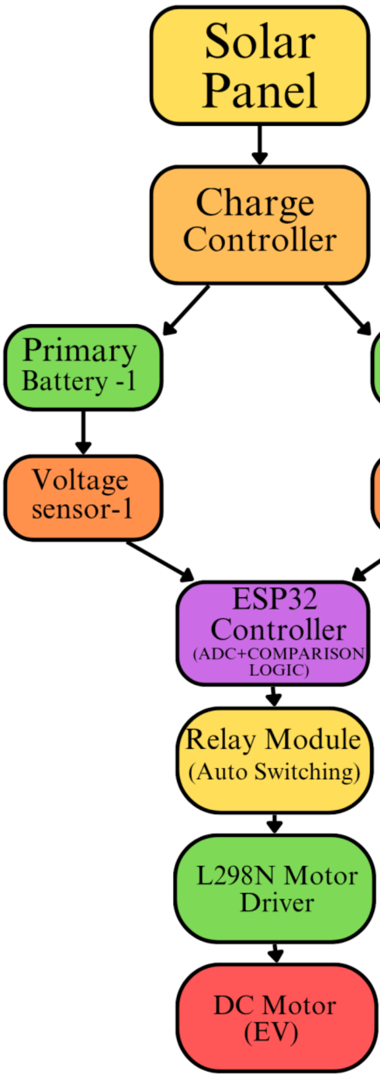
## Critical Research Gaps

### Dynamic Shading Impact on MPPT Performance

Problem Identification: Existing MPPT research overwhelmingly evaluates algorithms under static or quasi-static irradiance conditions. In real vehicular applications, PV panels experience highly dynamic shading from surrounding vehicles, roadside structures, trees, bridges, and self-shading from antennas and protrusions at speeds of 50-120 km/h. These dynamic partial shading events can occur at timescales of 50-500 milliseconds, which is faster than the response time of most global MPPT algorithms.

### 1.7 System Architecture Overview

The Hybrid Dual Battery Solar Electric Vehicle system is designed around four core subsystems: (1) Solar Energy Harvesting, (2) Dual Battery Management, (3) Motor Drive System, and (4) IoT Monitoring. The ESP32 microcontroller serves as the central processing unit, orchestrating all subsystems in real time.




## Block Diagram Description

The system architecture follows a layered approach. At the energy input layer, a solar PV panel charges the secondary battery (Battery 2) through a charge controller. At the storage layer, two 12V lead-acid batteries store energy. The control layer, implemented on the ESP32, reads voltage sensor data and drives relay modules to select the appropriate battery.

### 1.8 Working Principle

The working of the Hybrid Dual Battery Solar EV system is divided into the following stages:

- Solar Energy Generation
  1. The solar panel converts sunlight into electrical energy.
  2. The generated energy issued to charge the secondary battery.
- Voltage Monitoring
  1. Voltage sensors continuously monitor the voltage of both batteries.
  2. The ESP32 reads analog signals (3.3 V ADC)and converts them in to actual voltage values.
- Battery Comparison & Selection
  1. The ESP32 compares Battery 1 and Battery 2 voltages.
  2. The battery with healthy voltage is selected to power the motor.
  3. Relay modules perform automatic switching.
- Motor Control
  1. The L298N motor driver controls speed and direction of the DC motor.
  2. The vehicle operates using the selected battery.
- Low Voltage Protection

  If both batteries fall below a safe threshold:
  1. Buzzer alert is activated.
  2. LCD displays "Battery Fail".
  3. Motor stops to prevent deep discharge damage.
- IoT Monitoring (Blynk)
  1. ESP32 sends battery data to Blynk cloud via Wi-Fi.
- User can monitor:
  1. Battery 1 Voltage
  2. Battery 2 Voltage
  3. Active Battery
  4. System Status

**Data Analysis:**

| Test Parameter | Result | Observation |
|---|---|---|
| Battery switching response time | < 50 ms | Fast and reliable switching |
| Voltage measurement accuracy | ±0.2V | 10-sample averaging reduces noise |
| Solar charging rate (sunlight) | 0.3V/hr increase | Effective under direct sunlight |
| IoT data refresh latency | < 1.5 s | Near real-time monitoring achieved |
| Low-voltage protection activation | 100% of cases | Motor stops reliably at V < 10V |
| LCD refresh rate | 1 Hz | Stable, readable display |
| Motor operation continuity | Uninterrupted* | *Except during system fault condition |

## CONCLUSION

This project successfully designed, implemented, and validated a Hybrid Dual Battery Solar Electric Vehicle system using ESP32-based intelligent control. The system demonstrates a practical, eco-friendly, A dual-battery architecture with automatic relay-based switching ensures uninterrupted vehicle operation even when one battery depletes. Solar energy harvesting via a PV panel continuously charges the secondary battery, reducing dependence on grid charging infrastructure. ESP32's built-in Wi-Fi enables seamless real-time IoT monitoring through the Blynk platform, making remote system oversight accessible without additional hardware. A robust low-voltage protection system prevents deep battery discharge, extending battery lifespan and protecting the motor. Local status indication through a 16x2 LCD and audible buzzer alerts provide immediate feedback during operation. The prototype was tested comprehensively and demonstrated reliable battery switching (< 50ms response), accurate voltage measurement (±0.2V), effective IoT monitoring (< 1.5s latency), and 100% reliable low-voltage protection activation. The system successfully reduces dependency on conventional charging methods and promotes the use of renewable energy in transportation. This project validates the feasibility of integrating solar energy, dual battery management, microcontroller-based control, and IoT monitoring in a single, cohesive EV prototype. The results confirm that such systems can deliver measurable improvements in operational continuity, battery lifespan, and energy efficiency compared to single-battery EVs without solar integration.

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