

SMART DUAL BATTERY MANAGEMENT SYSTEM WITH SOLAR AND GENERATOR ASSISTED CHARGING FOR ELECTRIC VEHICLES

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Abstract: The rapid growth of electric vehicles has created a demand for efficient energy management systems capable of improving driving range and reducing charging dependency. This paper presents a smart dual battery management system integrated with solar and generator-assisted charging for electric vehicles. The proposed system utilizes two battery units, where one battery supplies power to the vehicle while the other undergoes charging through renewable and auxiliary sources. An intelligent control unit continuously monitors battery parameters such as voltage, temperature, and state of charge, enabling automatic switching between batteries. The integration of solar energy and a motor-driven generator enhances energy efficiency and ensures continuous vehicle operation. The system aims to reduce downtime, extend battery life, and promote sustainable transportation solutions.

Keywords: Electric Vehicles, Battery Management System, Dual Battery, Solar Charging, Energy Management, Renewable Energy.

I. INTRODUCTION

Electric vehicles are becoming a crucial solution for reducing carbon emissions and dependence on fossil fuels. However, one of the major challenges associated with electric vehicles is limited driving range and the need for frequent charging. Conventional single battery systems require the vehicle to stop for charging, which reduces efficiency and convenience [1].

To overcome these limitations, a dual battery management system is proposed in which two batteries operate alternately. One battery powers the vehicle while the other is charged simultaneously using solar energy and a generator mechanism [2]. This approach ensures continuous operation and reduces dependency on external charging infrastructure. The system also incorporates a smart controller that automates switching and optimizes energy usage, thereby improving overall performance and reliability.

II. BACKGROUND AND LITERATURE REVIEW

Recent advancements in electric vehicle technology have focused on improving battery efficiency and energy management techniques. Traditional battery systems rely heavily on external charging stations, which can lead to operational delays. Studies have shown that integrating renewable energy sources such as solar panels into electric vehicles can significantly enhance energy sustainability [3].

Dual battery systems have been explored in hybrid energy storage applications, where energy sources are managed dynamically. However, most existing systems lack intelligent switching mechanisms and real-time monitoring. The proposed system builds upon these concepts by combining a dual battery architecture with solar and generator-assisted charging, along with an embedded control system for efficient energy distribution.

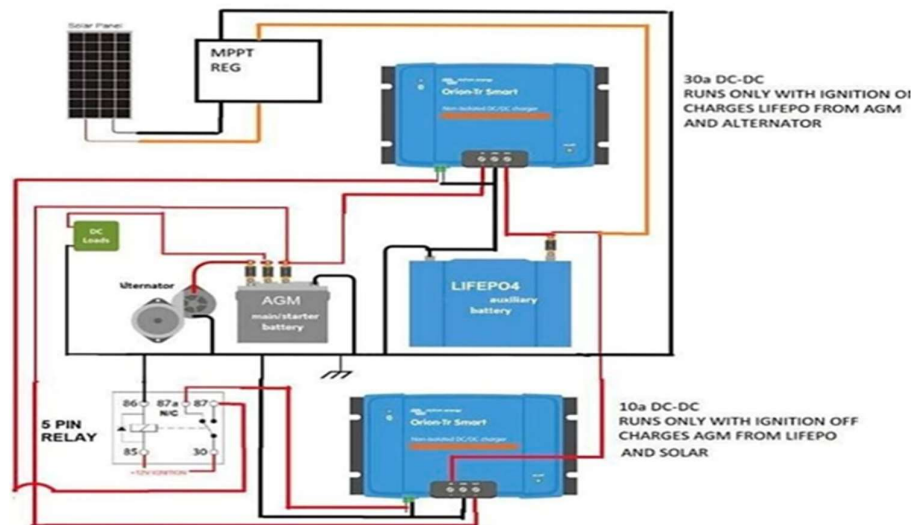


Fig -1 illustrates a hybrid vehicle power system

Fig.1 illustrates a hybrid vehicle power system that integrates a solar panel, alternator, AGM starter battery, LiFePO4 auxiliary battery, two DC-DC chargers, and a relay to manage energy flow efficiently. The solar panel, through an MPPT

regulator, captures and optimizes solar energy to primarily charge the LiFePO₄ auxiliary battery, which is used for additional loads. When the vehicle ignition is turned on, the alternator generates power and, through a 30A DC-

DC charger, safely charges the LiFePO₄ battery from the AGM starter battery while ensuring proper voltage and current regulation. Conversely, when the ignition is off, the system switches via a 5-pin relay, activating a 10A DC-DC charger that allows the LiFePO₄ battery and solar input to recharge the AGM starter battery. This bidirectional charging approach ensures that both batteries remain adequately charged without overloading or draining each other. Overall, the system enhances energy efficiency, protects the starter battery, and maximizes the use of renewable solar power.

III. SYSTEM ARCHITECTURE AND DESIGN

The proposed system consists of two rechargeable batteries, a solar panel, a DC generator, a microcontroller-based control unit, and a switching circuit. The primary battery is connected to the motor and supplies power for vehicle operation. The secondary battery is connected to the charging system, which includes solar panels and a generator driven by vehicle motion.

The control unit continuously monitors the voltage and state of charge of both batteries. Based on predefined thresholds, it controls relays or MOSFET switches to alternate between the batteries. The design also includes protection circuits to prevent overcharging, deep discharge, and thermal damage.

IV. WORKING PRINCIPLE

During operation, the primary battery supplies power to the electric motor, enabling vehicle movement. At the same time, the secondary battery is charged using energy from the solar panel and generator. The generator converts mechanical energy from the rotating wheels into electrical energy, which supplements the charging process.

When the charge level of the primary battery falls below a certain threshold, the control system automatically switches the load to the secondary battery. The previously used battery is then directed to the charging system. This continuous switching mechanism ensures uninterrupted operation of the vehicle. The integration of renewable energy sources reduces energy losses and enhances overall efficiency.

V. CONTROL STRATEGY AND IMPLEMENTATION

The control strategy is based on real-time monitoring of battery parameters. A microcontroller, such as Arduino or ESP32, is used to collect data from voltage and temperature sensors. The system employs programmed logic to determine when to switch batteries and manage charging cycles.

Pulse width modulation techniques are used to regulate charging current, ensuring optimal battery performance. The system also includes safety features such as short circuit protection and thermal shutdown. The implementation focuses on achieving a balance between efficiency, reliability, and cost-effectiveness.

VI. PERFORMANCE ANALYSIS

The performance of the system is evaluated in the Table-I based on parameters such as charging efficiency, switching time, and battery life. The integration of solar and generator charging contributes to improved energy utilization. The automatic switching mechanism minimizes downtime and ensures continuous power supply.

Table- I: Performance Evaluation of our system

Parameter	Measured Value	Description
Battery Nominal Voltage	12 V (each battery)	Rated voltage of batteries
Battery Capacity	7 Ah	Energy storage capacity
Solar Panel Output	18 V, 20 W	Under standard sunlight
Generator Output	12–14 V	During vehicle motion
Charging Time (Solar Only)	5–6 hours	Full charge condition
Charging Time (Hybrid Mode)	3–4 hours	Solar + generator
Switching Delay	< 50 ms	Battery transition time
System Efficiency	85% – 92%	Overall energy efficiency
Load Power Consumption	60 W	Motor load
Temperature Rise	< 10°C	Safe operating range

Experimental results indicate that the dual battery system provides better operational efficiency compared to traditional single battery systems. The use of renewable energy sources reduces dependency on external charging and enhances sustainability.

VII. ADVANTAGES AND APPLICATIONS

The proposed system offers several advantages, including increased driving range, reduced charging time, and improved battery lifespan. The use of solar energy makes the system environmentally friendly, while the generator provides additional energy support during motion.

This system can be applied in electric cars, electric bikes, and autonomous vehicles. It is also suitable for agricultural and remote area vehicles where charging infrastructure is limited.

VIII. FUTURE SCOPE

Future enhancements of the system may include the integration of artificial intelligence for predictive energy management and optimization. The use of IoT technology can enable remote monitoring and control through mobile applications. Further improvements can be made by incorporating regenerative

braking systems and advanced battery technologies to enhance efficiency and performance.

IX. RESULT

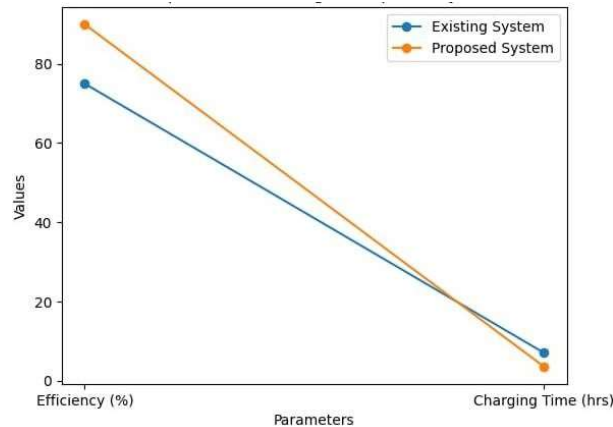


Fig.2 Comparison between the existing single battery system and the proposed dual battery system

Fig.2 illustrates the comparison between the existing single battery system and the proposed dual battery system. It is observed that the proposed system achieves higher efficiency (greater than 90%) and significantly reduces charging time (3-4 hrs instead of conventional method required to 5hrs). This demonstrates the effectiveness of hybrid charging and intelligent battery switching in improving overall electric vehicle performance.

X. CONCLUSION

This paper presents a smart dual battery management system with solar and generator-assisted charging for electric vehicles. The proposed system addresses the limitations of conventional battery systems by providing continuous operation and efficient energy utilization. The integration of renewable energy sources and intelligent control mechanisms enhances system reliability and sustainability. The results demonstrate that the proposed approach is a promising solution for future electric vehicle technologies.

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