

Sustainable Electric Mobility: Dual-Battery and Solar Assisted Energy Management System for EVs

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Abstract: This paper illustrates a dual battery electric vehicle (EV) development with integrated solar charging designed to increase the stability, range, and overall performance of the vehicle. The system is equipped with two large-capacity lithium-ion batteries; one serves as the power source, and the other powers the electronic device. Both are controlled by the battery management system (BMS), power distribution unit (PDU), and vehicle Control Unit (VCU). These components work together to provide efficient power distribution, seamless battery transfer, and optimum performance under various driving conditions. The integration of solar panels and smart devices reduces dependency on external energy sources by using renewable energy. This innovation helps increase the number of vehicles, reduce operating costs, and lower carbon emissions. The system also features advanced thermal management and instant fault detection to ensure vehicle reliability, safety, and longevity. To further enhance usability, the system features a user-friendly interface that enables monitoring of battery life, solar energy collection, and overall system health. The system is designed with scalability in mind to accommodate vehicles of different types and sizes, making it a versatile solution for a variety of applications. Through extensive and practical testing, the paper aims to create a future-proof, efficient, and effective solution to electric vehicle challenges that will set new standards in electricity usage.

Keywords: Solar Charger; Vehicle Control; Power Distribution; Bi-Directional Charging; Battery Management; Electric Vehicles; Renewable Energy; Thermal Management; Carbon Emission.

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1. Introduction

The transportation industry is transitioning towards becoming a sustainable sector, driven by a growing demand for clean options and increased energy efficiency. Electric vehicles (EVs) have also emerged as a viable alternative to internal combustion engine (ICE) vehicles, offering cleaner and more adaptable options that minimize greenhouse gas emissions and reduce reliance on non-renewable energy sources. However, while EV technology has the potential to transform mobility, it is currently being hindered by several issues, including limited driving range, prolonged charging times, and excessive reliance

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on the power grid, which is primarily based on fossil fuels. Those constraints stand as the overwhelming imperative for fresh innovations to challenge the problems limiting mass adoption of electric vehicles. Fortunately, the potential paper aims to develop a solar-powered, dual-battery integrated electric vehicle that addresses such issues and raises the bar in transportation. This method combines the best power management, new battery technology, and harnessing renewable energy to address the shortcomings of traditional electricity. It utilises a dual battery architecture comprising two lithium-ion batteries: a primary battery used in normal vehicle operation, and a redundant battery structure used to provide coverage and enhance reliability. The configuration addresses one of the largest problems for electric vehicle owners by maintaining an uninterrupted economy while enhancing operating flexibility.

The system incorporates the latest power distribution unit (PDU), vehicle control unit (VCU), and battery management (BMS) to achieve energy efficiency and seamless operation. The components are integrated in such a way as to provide power distribution, balance battery cycling, and allow automatic transfer of main and auxiliary batteries as needed. The system delivers improved performance under varying operating conditions, enhancing confidence in the application of this technology. One of the project's most significant achievements is the utilisation of solar panels as an alternative power source. The integration of solar power into a vehicle's design can address the issue of relying on the grid for energy when the car is in motion, thereby utilising renewable energy. A solar panel is installed inside the energy storage system of the car, which an intelligent solar controller powers to preserve energy and optimise charging. This capability not only enhances motor vehicle performance but also lowers operating costs, thereby improving safety and environmental stewardship. The envisioned process encompasses product design, as well as considerations for reliability and safety. Thermal management technology and real-time monitoring ensure the integrity of the battery and its associated components, thereby reducing the risks of overcharging and overheating. They extend the lifespan of the car's power supply, reduce maintenance costs, and promote user confidence. The styling boasts an inviting interface that delivers real-time feedback on key parameters, such as battery health, solar energy harvesting, and exercise, to maximise user experience [1]. It offers users actionable data to make informed decisions about the vehicle's energy management. The interface is transparent and intuitive, designed to make users feel at ease and experts in the new technology. The explicit motivation of the project is to address current EV usage constraints and contribute to the global response to climate change [13].

The idea proposes to redefine the limits of EV efficiency and sustainability by integrating dual batteries and solar charging. The system is utilised in numerous applications, ranging from individual vehicles to public and commercial transportation [14]. The importance of the paper lies in its potential to revolutionise the EV sector by addressing major issues such as excessive stress, high energy costs, and grid dependency. Solar dual cell integration provides a cost-effective and durable solution compared to existing designs, facilitating a transition towards cleaner and greener mobile products that comply with international sustainability standards. In addition, the system's scalability enables it to be designed to meet any level of transportation demand, making it a flexible and future-oriented solution for current and future needs. Reliability and user safety are also taken into consideration in the design. The hardware monitors high pressure, as well as sophisticated power and heat management, to maintain stable operations in any environment. A simple-to-operate interface and real-time monitoring ensure a less stressful driving experience, allowing users to easily switch and transition to an electric vehicle. Overall, the solar-powered dual-battery EV system is a new solution for the shortcomings of existing EV technology. The paper seeks to establish new standards for electric vehicles by providing power connectivity with convenience, sophisticated power management, and real-time monitoring functions. In addition to extending range, reliability, and security, it contributes to global efforts in decreasing reliance on fossil fuels and enhancing the use of renewable resources. The program is focused on accelerating the evolution of next-generation electric vehicles by offering flexible, clean, and efficient solutions for today's transportation needs [2].

2. Review of Literature

Smith and Johnson [3] proposed an adaptive management strategy for single-phase grids with photovoltaic inverters. Their method dynamically adjusts control parameters based on grid voltage and frequency measurements to improve system stability and reliability. Simulation results demonstrate the effectiveness of this strategy in managing grid performance in response to system changes. Effect of alternating current and frequency on inverter performance. The system using the best feedback device has higher fault tolerance and ensures the stability of the inverter even when the power supply is unstable. Mishra et al. [4] developed a time learning system for single-phase inverters in AC microgrids. The system uses neural networks that learn from previous network data to predict network inconsistencies and ensure accurate and stable synchronisation. Similarly, Ali et al. [5] proposed a virtual oscillator control (VOC) method that eliminates the need for phase-locked loops (PLLs) and improves synchronisation simplicity and efficiency. Taylor and Rodriguez [6] studied the model predictive control (MPC) strategy for single-phase inverters to improve power quality. Their approach reduces the differences between distribution lines and improves power management. Additionally, Vijayaprakash et al. [7] proposed a method to control components to eliminate voltage inequality and increase the overall power of the grid. Tan [8] studied the integration of single-phase inverters with energy storage (ESS).

Their work demonstrates the potential of connecting ESS inverter systems to grid support, including peak control, frequency control, and voltage measurement. Simulation results show increased grid security and efficient use of storage resources. Their findings underscore the importance of inverters in maintaining grid stability, particularly in contemporary projects that utilise renewable energy sources. Rodriguez and Garcia [9] proposed a fault management policy to ensure plan compatibility for single-phase grid-tied inverters. Its controls enable the inverter to operate during grid disturbances, thereby making the grid more robust and reliable. Rahman et al. [10] studied control strategies for multiple inverters in grid support. This approach allows inverters to communicate and coordinate functions such as power management and coordination. Also, Sharma et al. [11] compared traditional control methods, such as PI control and fuzzy logic, with advanced control methods to determine the most suitable strategies for microgrid applications. Akpolat et al. [12] analyse the energy efficiency of single-phase inverters in various applications. Their study identifies strategies to reduce conflicts and optimise energy use to facilitate the integration of strategic plans. Smith and Johnson [3] proposed an adaptive control strategy for network connections. This method enhances the inverter's efficiency in the switching grid, ensuring stable and reliable operation.

3. Methodology

The twin battery EV system design offers an upgrade to traditional EV models, enhancing range, reliability, and overall performance. The system comprises two lithium-ion high-capacity batteries, with one serving as the backup power source and the other as the primary power source. Not only can the double battery unit be charged, but it also maximises the range and achieves improved power stability. The vehicle is equipped with an advanced battery management system (BMS) that controls the charging and discharging of the batteries. BMS provides power balance, battery state, and automatic failover between primary and secondary batteries on demand. The car is more efficient for different driving conditions and extends battery life. Solar panels integrated minimise the use of external sources by tapping into power from the sun. The solar panel, in conjunction with intelligent charging control, harnesses solar power and converts it into usable energy for the battery, supplementing the charging process on the road. This combination not only increases the car's range but also lowers running costs and the carbon footprint of electric vehicle operation. The system also includes a Power Distribution Unit (PDU) and a Vehicle Control Unit (VCU) that interact to control the flow of energy in the car. While the PDU can distribute power effectively to all the car's components, the VCU controls and checks the vehicle's behaviour to ensure suitability and functionality. The system is shown in Figure 1, which employs:

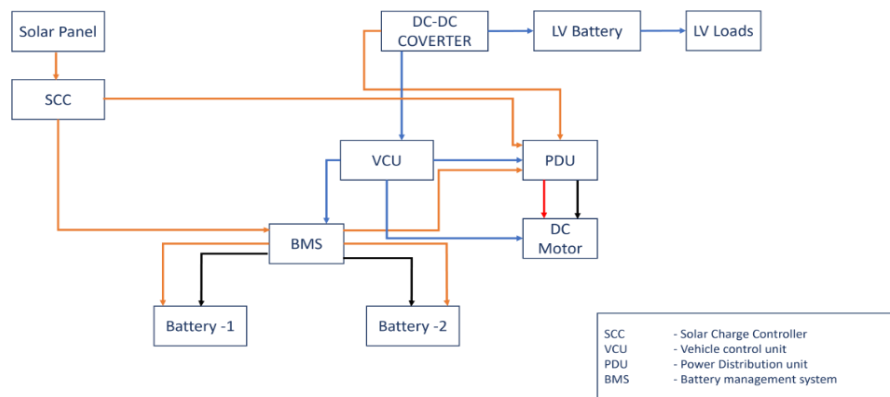


Figure 1: Proposed system block diagram

3.1. Maximum Power Point Tracking for Solar Panel

Maximum Power Point Tracking (MPPT) is a key technology used in solar power systems to maximise the energy harvested from photovoltaic (PV) panels under varying environmental conditions. The power developed by the PV panel depends on sunlight intensity and temperature, among other factors, and the MPPT algorithm dynamically adjusts the PV panel's operation point so that it always operates at its peak power point. MPPT has been utilised in the current paper in a dual-battery electric vehicle system to maximise the utilisation of solar power for charging the batteries, thereby enhancing efficiency and reducing reliance on external power. The maximum power point (MPP) of a PV panel is the point at which the voltage and current product ($P = V \times I$) will be maximum. But MPP is not constant and changes with Irradiance. The maximum power point is increased by higher irradiance. Higher temperatures reduce the maximum power output of the panel. The MPPT controller measures the output voltage and current of the solar panel. The controller applies the Perturb and Observe (P&O) algorithm to calculate the optimal operating point. Figure 2 illustrates the MPPT connected to a solar PV system. The DC-DC converter to MPPT regulates the panel operating voltage to match the MPP. A DC-DC converter within the MPPT adjusts the panel's

operating voltage to align with the MPP. Battery Charging: The controlled charging circuit supplies optimised power to the battery, enabling efficient energy storage.

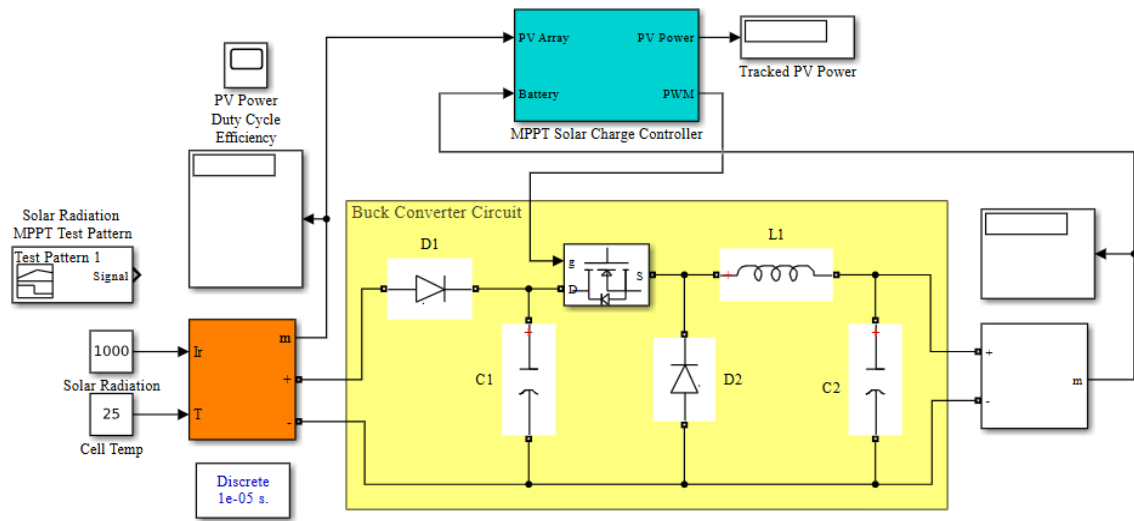


Figure 2: MPPT of solar panel output

3.2. Bidirectional Converter

Bidirectional converters are important power electronics devices that allow power to flow in both directions between two systems. In an electric vehicle (EV), they allow efficient energy transfer between the battery system and other components, such as the motor, during operation or regenerative braking. This dual-mode capability is important for optimising energy usage and increasing system efficiency. In this paper, a bidirectional converter is used to control the energy flow between the dual battery system and the motor, and to provide regenerative braking that captures kinetic energy and converts it back into electrical energy to charge the batteries. The Charging Mode is called Buck Mode. During regenerative braking, the kinetic energy of the wheels is converted into electrical energy by the engine acting as a generator. The high voltage generated is stepped down by the converter and stored in the battery. The control system adjusts the PWM duty cycle to regulate the charging current. The Discharging Mode is called boost Mode. The converter increases the battery's voltage to supply power to the engine during acceleration or when power demand is high. The control system adjusts the gain to ensure a stable power supply. Figure 3 displays the bidirectional converter used in the proposed model.

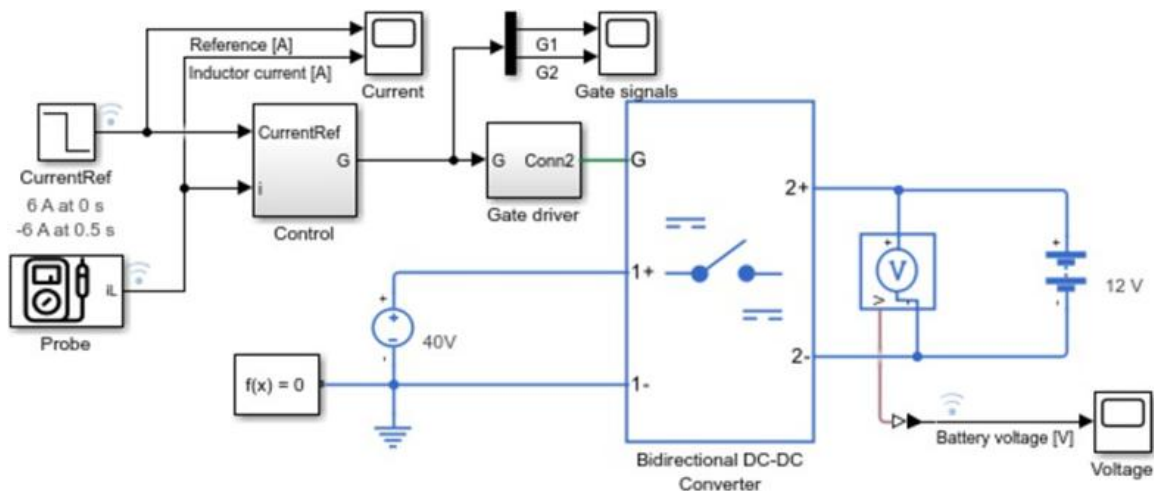


Figure 3: Bidirectional converter

3.3. Boost Converter

A boost converter, also known as a step-up converter, is a type of DC-DC converter that boosts the input voltage to a higher output voltage while maintaining efficient power transfer. It is widely used in renewable energy systems, electric vehicles

(EVs), and battery management systems to regulate and optimise the power supply. In this paper, a boost converter is integrated into the EV system to increase the battery voltage, enabling the engine to operate under high-demand conditions and increasing the utilisation of energy from renewable sources, such as solar panels. A boost converter works on the principle of storing energy in an inductor and releasing it to the output at a higher voltage. It involves two main steps. At step 1 (Energy Storage Phase), when the switch (usually a MOSFET) is turned on, current flows through the inductor, storing energy in the magnetic field. During this phase, the output capacitor supplies energy to the load. At step 2 (Energy Transfer Phase), when the switch is turned off, the magnetic field of the inductor is disrupted, resulting in an additional voltage being added to the input voltage. This combined voltage charges the output capacitor and supplies power to the load.

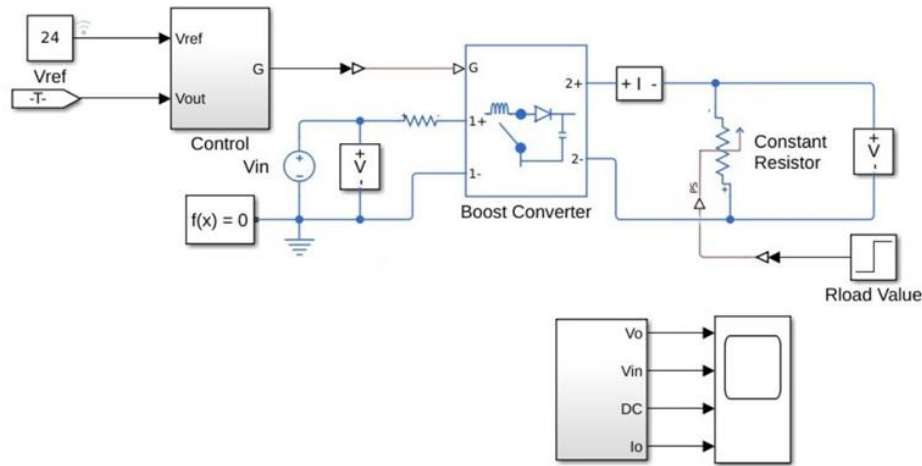


Figure 4: Boost converter

Figure 4 shows the boost converter used in the proposed model. The solar panels generate electricity, which the solar charge controller and the DC-DC converter regulate. Battery 1 is currently in the discharge and management (BMS) controlled by the vehicle control unit (VCU). When battery 2 starts charging, it is controlled by the BMS and monitored by the VCU. The VCU controls the entire system, including the charging and discharging process, and communicates with the BMS. The VCU also controls the traction motor, MCU, and PDU to control power distribution and vehicle propulsion. Electrical loads are supplied from the system based on the requirements and control decisions of the VCU. The Power Distribution Unit (PDU) and Vehicle Control Unit (VCU) facilitate seamless switching between batteries, ensuring efficient power distribution and management. These components work together to ensure efficient power distribution, smooth battery switching, and optimal performance under various driving conditions.

3.4. Flow of Charging Battery

The solar panel generates DC electricity from sunlight. The solar charge controller regulates this power to ensure safe and efficient battery charging. The DC-DC converter regulates the voltage according to the battery requirements. Battery 1 (and additional batteries) stores the energy from the solar panels.

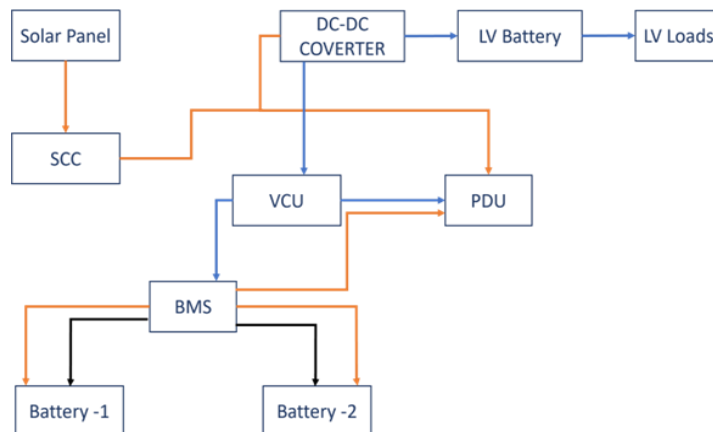


Figure 5: Flow of charging

The battery management system (BMS) monitors and manages the battery charging process. The charge and discharge controller (BMS) controls the entire charging process to ensure safety and efficiency. The vehicle control unit (VCU) integrates the charging system with other vehicle systems and controls all operations. The electric load is powered by the battery as needed. Figure 5 exemplifies a battery charging model.

3.5. Flow of Discharging Battery

Battery 1 supplies electrical energy during the discharge phase. BMS monitors the battery status and ensures safe discharge. Sends data to VCU. VCU acts as the primary controller, directing the flow of power. Controls the discharge process using information from BMS. Controls the traction motor through the motor control unit (MCU) to provide propulsion. Controls the power distribution unit (PDU) to supply power to various components. The electrical loads are supplied with power according to the distribution controlled by the VCU. The VCU ensures that all components work together and discharge the batteries safely and efficiently. Figure 6 exemplifies the battery discharging model.

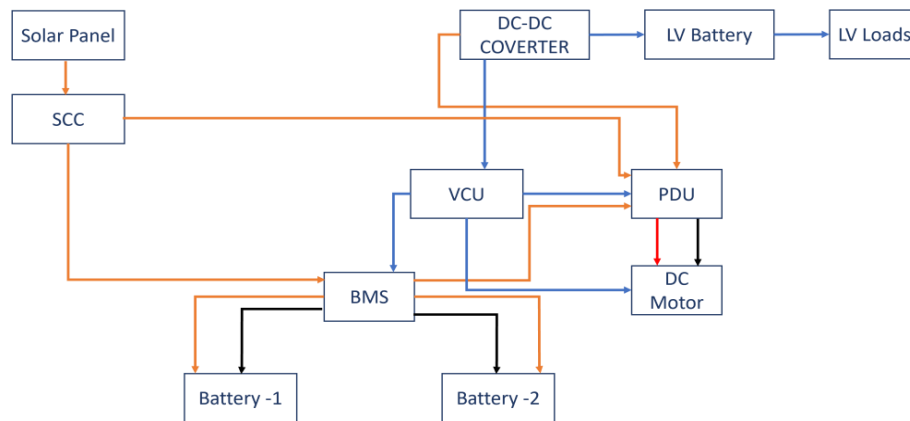


Figure 6: Flow of discharge

4. Simulation Results and Discussion

The proposed dual-battery and solar-assisted energy management system for electric vehicles was modelled and simulated using MATLAB/Simulink to evaluate its operational effectiveness and technical feasibility, as shown in Figure 7.

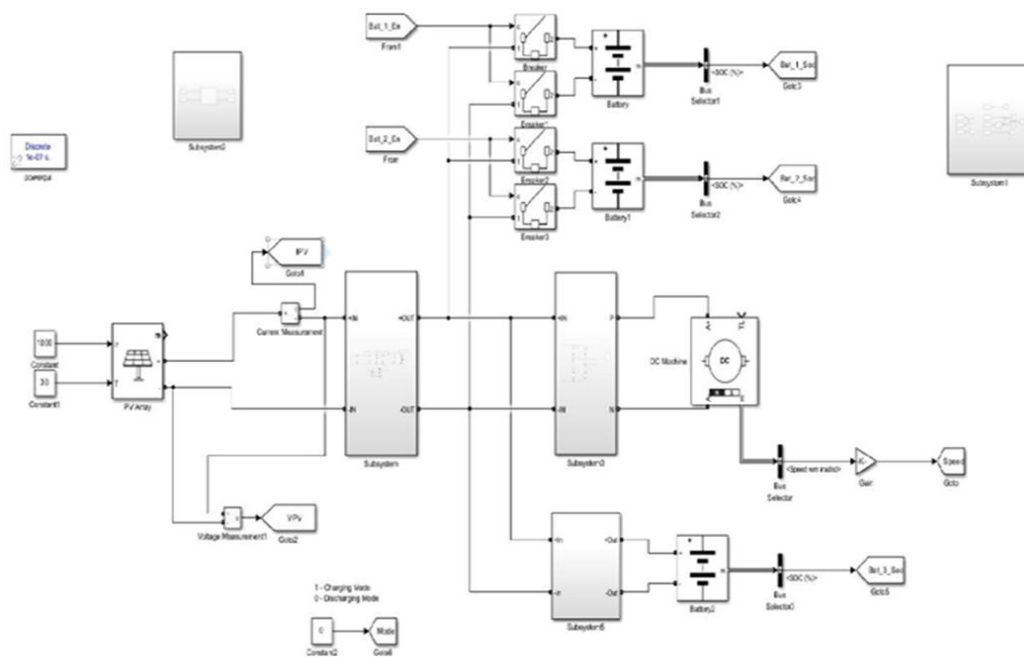


Figure 7: Proposed system Simulink model

The simulations were conducted under varying operating conditions, with particular attention to parameters such as system output voltage, battery state of charge (SOC), photovoltaic (PV) array voltage and current, and motor performance. The results collectively demonstrate that the coordinated operation of dual batteries, PV input, and motor load enhances efficiency, reliability, and sustainability in electric vehicle applications. One of the most important observations was the behaviour of the output voltage. The simulation revealed that the solar PV array produced an average of 325 V DC under an irradiance level of 500 lumens and an ambient temperature of 25 °C, as illustrated in Figure 8. The voltage of the DC bus was maintained very stable at this level, even when load demand and operating modes varied. This stability is a significant improvement over single-battery systems, which are typically plagued by significant voltage fluctuations due to the use of a single storage unit and the limited number of control techniques employed.

Voltage stability is crucial in electric vehicles because abrupt changes can directly affect acceleration, torque supply, and safety. Within the system, the battery management subsystem ensured seamless switching between charging and discharging operations, preventing interruptions in the DC supply. The dual-battery configuration provided additional redundancy, allowing one battery to compensate seamlessly when the other approached a lower SOC. As a result, the system effectively avoided undervoltage and overvoltage conditions, preserving robustness and protecting sensitive electronic components. The stable 325 V DC supply also highlighted the supportive role of the PV array, which minimised fluctuations and relieved stress on the batteries by sharing the energy burden during daytime charging cycles. The photovoltaic subsystem made a significant contribution to the overall system performance. At an irradiance of 500 lumens and a temperature of 25 °C, the PV array produced a DC voltage of 325 V and a current of 120 A, as illustrated in Figure 9.

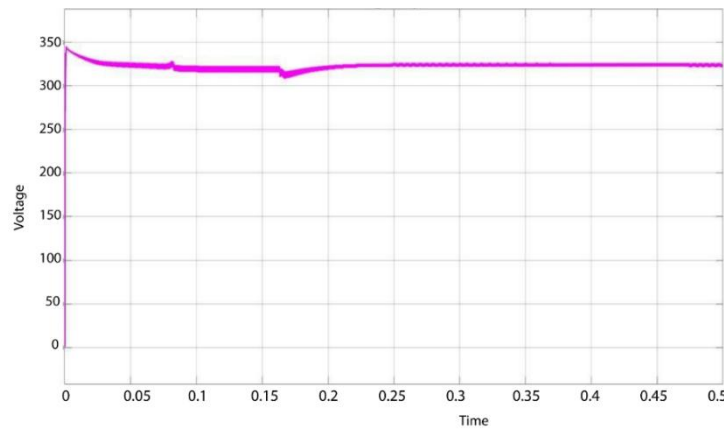


Figure 8: Proposed system PV output voltage

These values indicated that the solar unit could meaningfully supplement the batteries and contribute to the DC bus. The PV voltage remained stable even under moderate irradiance conditions, which ensured reliable renewable input. The current varied with irradiation levels but consistently reflected the system's ability to harvest solar energy effectively. The incorporation of maximum power point tracking ensured that the array operated at its optimum point, thereby maximising the harvested current. While the PV contribution was smaller compared to battery discharge currents during acceleration, its impact on the system was significant. By reducing the net discharge rate of the batteries, the solar subsystem effectively extended driving range and decreased the frequency of external charging. This integration highlighted the critical role of renewable energy in addressing one of the most pressing challenges in electric mobility, namely, limited vehicle range.

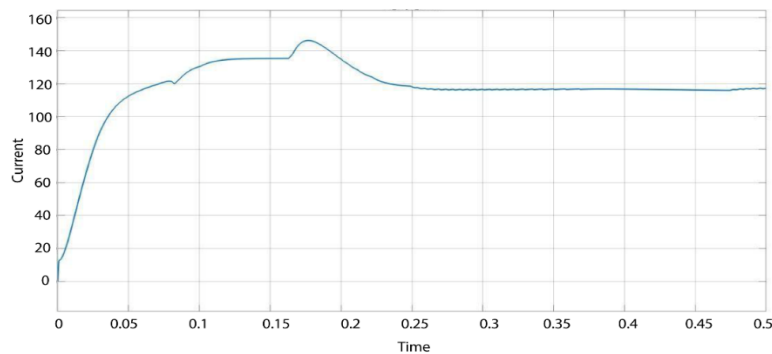


Figure 9: Proposed system PV output current

The SOC profiles of the batteries provided further insight into the advantages of the proposed architecture. During the charging process, the batteries reached 85% SOC, which confirmed efficient energy absorption and utilisation of available power as displayed in Figure 10.

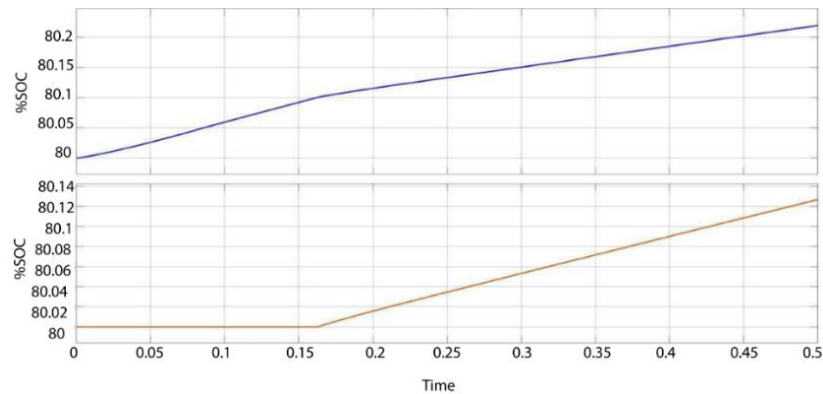


Figure 10: Proposed system battery SOC%

The simulation revealed that the control strategy embedded within the battery management system prioritised the primary battery while maintaining the secondary battery as a balancing and backup unit. This intelligent approach distributes the load evenly and prevents the deep discharge of a single battery, a common issue in traditional systems. The smooth SOC curves observed in the results confirmed that charge and discharge cycles were well-regulated without abrupt changes, thereby ensuring improved battery health and an extended lifecycle. Since the solar power was adequate, both batteries were charged simultaneously, minimising stress on individual cells and maximising long-term reliability. This blissful and seamless functioning was stronger than that of single-battery systems, which experience drastic depletion and sharp SOC variations when operating under high loads. Motor dynamics introduced another imperative aspect of analysis. The motor operated steadily at 1000 rpm, as reflected in the speed curve generated by the simulation. The results confirmed that the power supplied by the coordinated dual-battery and PV system was both stable and sufficient to sustain vehicle propulsion without instability. Even when one battery approached lower SOC levels, the second battery seamlessly compensated, preventing sudden drops in performance. This redundancy ensured that torque delivery remained smooth and uninterrupted, which is vital for both safety and driving comfort. The absence of oscillations in motor speed further validated the effectiveness of the control algorithms managing power distribution. In real driving conditions, this kind of consistent response is essential for maintaining driver confidence and ensuring system reliability.

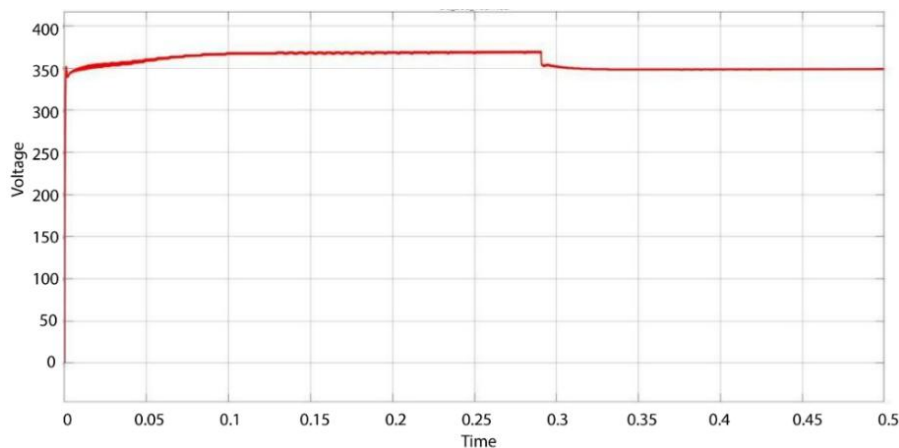


Figure 11: Proposed system DC bus voltage

When compared to conventional single-battery systems, the advantages of the dual-battery solar-assisted design were clear. Single-battery vehicles often face issues such as rapid SOC depletion, unstable voltage under high loads, and limited range. The DC bus voltage of 350V is maintained constant by the boost converter, as indicated in Figure 11. This resulted in smoother SOC evolution, reduced stress on individual cells, and greater overall efficiency. The contribution of the PV subsystem, with its 325 V DC output and 120 A current, directly reduced dependence on battery discharge and external charging. The motor's consistent speed of 1000 rpm without shuddering proved that the design could provide stable car performance even under

changing load conditions. System reliability and redundancy were another equally significant consideration in the results. The vehicle was equipped with a redundant battery and solar system, providing it with redundant power sources that reduced the likelihood of total shutdown in the event of a fault. When the system lost one of its sources, it continued to operate on the remaining units. Integrating real-time SOC monitoring and fault detection into the control infrastructure improved system safety by preventing overcharging, deep discharging, or overheating.

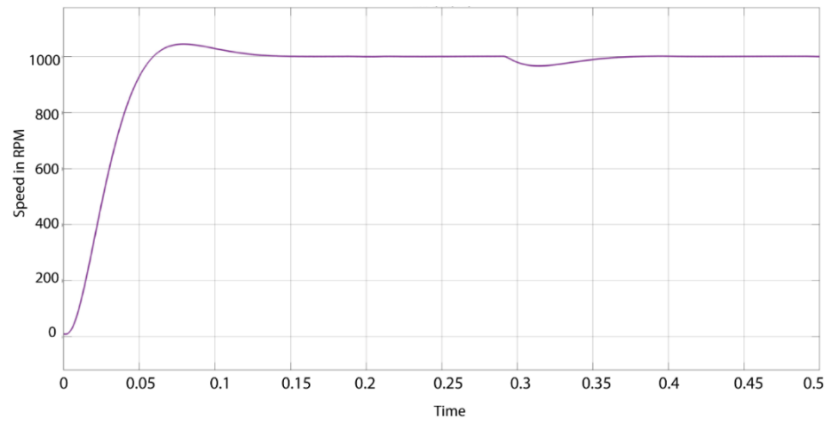


Figure 12: Proposed system Simulink motor speed

All these countermeasures together improved the robustness and reliability of the system compared to conventional methods. In addition to technical performance, the results revealed economic and environmental benefits. Using the sun's energy to charge its batteries, the car reduced its reliance on grid electricity, much of which is still derived from fossil fuels in the majority of the planet. This effort contributed to reducing lifecycle carbon emissions by directly cutting them. Simulation results overall verified the conceptual system design. The results indicated stable voltage output at 325 V DC, successful charging with SOC being 85%, efficient solar contribution of 120 A current under moderate illumination, and steady motor performance at 1000 rpm, as evident from Figure 12. All these parameters ensured that the suggested system adequately addresses critical issues in electric mobility, such as range constraints, voltage instability, and rapid battery degradation. The intelligent control algorithms enabled smooth operation across charging and discharging cycles, while the integration of renewable energy enhanced sustainability. The system's redundancy increased reliability, and its operational cost benefits improved affordability. Collectively, these findings demonstrate that the proposed energy management system not only enhances the technical performance of electric vehicles but also contributes to their economic and environmental sustainability. By combining a dual-battery architecture with solar integration and intelligent energy management, the system lays the foundation for next-generation EV designs that prioritise stability, efficiency, and sustainability.

5. Hardware Implementation

The Hardware of the dual-battery and solar-assisted energy management system for EV is displayed in Figure 13. The components used in hardware include a power source.

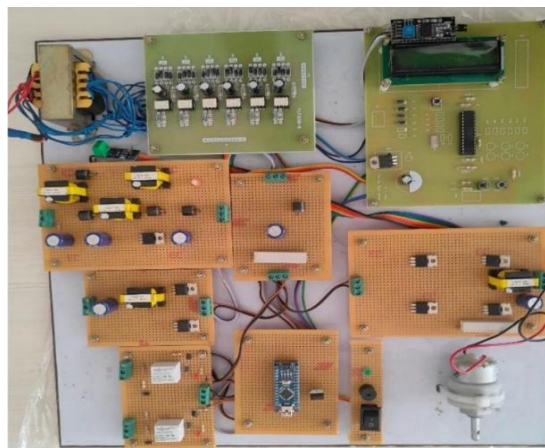


Figure 13: Proposed hardware model

This model contains two high-capacity lithium-ion batteries. The main battery serves as the vehicle's primary power source, while the backup battery provides continued power in the event of a main battery failure.

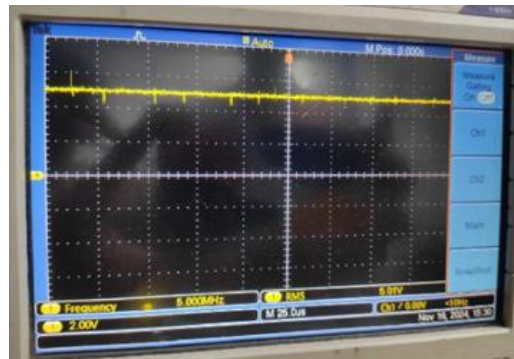


Figure 14: Solar panel output

The battery management system monitors the health, charge, and temperature of both batteries. The BMS manages charging and discharging, balances the batteries, and provides diagnostics to the user interface to ensure proper operation.

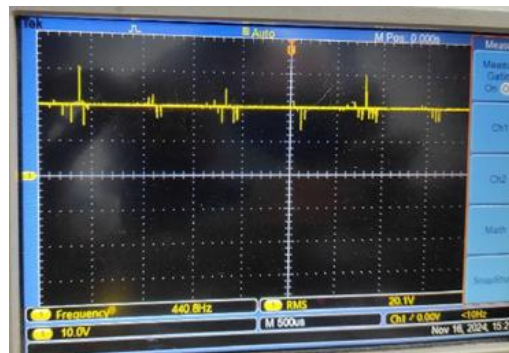


Figure 15: Bidirectional converter

The solar charging system, integrated into the hardware, utilizes solar panels to capture solar energy, which the intelligent charge controller then processes. The controller optimises the conversion of solar energy into electricity and directs the batteries to charge when sufficient sunlight is available. The output of the PV cell is 13.56V, as illustrated in Figure 14. The Power Distribution Unit (PDU) distributes power from the battery to the various components in the vehicle, including the generator, lighting, and other components. This ensures that each component receives the voltage and current it needs to function properly. The Vehicle Control Unit is the master controller that regulates all the vehicle's operations. Interacts with BMS and PDU to regulate operation and regulate power flow based on driving speed. VCU does battery switching, power optimisation, and accurate sensing. Gives real-time feedback about battery status, solar energy harvesting, and system health in a user-friendly dashboard. It gives drivers the choice to monitor their energy usage and make informed decisions about charging and usage.

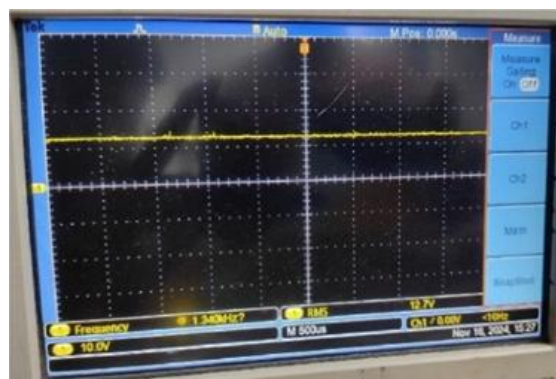


Figure 16: Booster converter

A prototype system and test drive of the dual-battery EV system, powered by solar charging, produced encouraging results, confirming the system's efficiency, effectiveness, and reliability. Through various simulations and experiments, the system demonstrated improved energy management, driving range, and overall performance compared to traditional single-battery systems. The dual-battery layout enabled seamless power transfer from the primary battery to the auxiliary battery, allowing the vehicle to continue running stably even under fluctuating load conditions. Dual converter technology provides an output of 12.5V, as observed in Figure 15. A highly efficient Battery Management System (BMS) ensured healthy battery supervision, optimized charge cycles, and balanced energy allocation, leading to a longer battery lifespan. The integration of solar panels significantly contributed to making the vehicle eco-friendly by providing a source of energy that reduced its dependence on external charging stations. The boost converter provides a constant DC voltage of 12.5V as the DC bus, as indicated in Figure 16. During optimal sunlight conditions, the solar charging mechanism enabled the vehicle to recharge its batteries while in motion or parked, extending the overall driving range by up to 30%.

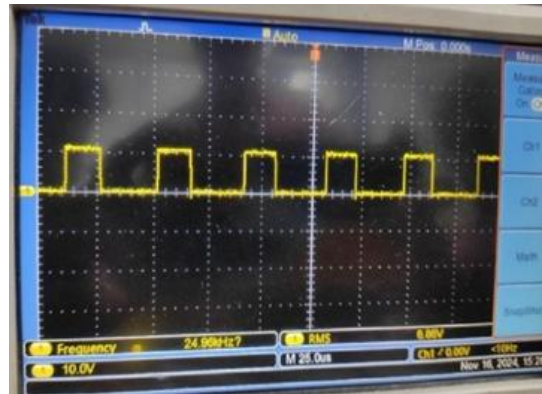


Figure 17: Pulse from driving circuit

The smart charge controller efficiently managed solar energy capture, allowing for optimal use of available sunlight. Testing of the regenerative braking system demonstrated its effectiveness in recovering kinetic energy, with an average of 15% of the energy used during acceleration being recaptured during braking. Overall, the system proved to be user-friendly and reliable, with extensive testing confirming its performance under various driving scenarios. These results highlight the potential of the dual-battery EV system as a sustainable and efficient transportation solution. Future work will focus on further optimising system components, enhancing scalability for different vehicle types, and exploring additional applications in the electric vehicle market. The DSPic30f2010 Central Processing Unit (CPU) seamlessly integrates the best features of a 16-bit microcontroller (MCU) and digital signal processor (DSP). Executing a pulse to drive the boost converter and bidirectional converter used in the systems, as indicated in Figure 17. Table 1 shows the various components used to build the hardware model.

Table 1: Components used to build the hardware model

Component	Features	Task
Power supply Transformer (7-Tapping)	Input 230 V, output 12 V, seven taps output	Controller and driver power supply
Solar panel	Power 8 Watts	Used for discharging and charging by the sunlight
Battery	Input 12V	Input DC source
Rectifier	Input 230V output 12V	Input DC source
Microcontroller board	Dspic30f2010 microcontroller	Program and control signal
Mosfet driver	TLP250	Pulse amplifier and isolator
Mosfet	IRFP840	Pulse amplifier and isolator
Inductor	1mH Inductor, 10 A	Soft switching and
High-frequency Transformer	1:8 Turns ratio	Voltage boosting
Relay	Relay Board 12 V, 5A	Voltage gain improvements
Arduino Nano	Controller in a nano microcontroller	Switching in the battery
Dc motor	12V, PMDC type	Battery voltage reading and feedback relay on off condition
		Battery load condition

6. Conclusion

In this paper, the expansion and execution of a solar dual battery electric vehicle (EV) system represent a significant advancement in sustainable transportation technology. This work successfully demonstrated how integrating a dual-battery setup with solar power can improve vehicle performance, extend the driving range, and reduce reliance on existing charging infrastructure. The combination of high-capacity lithium-ion batteries managed by an advanced battery management system (BMS) ensures efficient energy use and optimal battery health. The inclusion of solar panels enables the vehicle to utilise renewable energy, thereby reducing operating costs and carbon emissions. Additionally, the regenerative braking system enhances the energy recovery rate, thereby further improving the vehicle's overall efficiency. The user-friendly interface offers real-time monitoring and analysis, enabling the driver to actively engage with the system and make informed decisions about energy management. Successful simulations and real-world test results have validated the architecture and functionality of the proposed system, establishing it as a viable solution for a wide range of applications in the electric vehicle market.

6.1. Future Scope

The dual battery-solar electric vehicle system lays the foundation for further innovations in the field of electric mobility. Looking ahead, the dual-battery solar-enhanced EV system lays the groundwork for further innovation in electric mobility. Future studies may involve research on the development of new materials for batteries, improving solar panel efficiency, and scaling up the system to accommodate various car sizes and shapes. Additional studies can also be conducted on the integrated energy management system, building on the observations from this paper, to explore the limits of what can be achieved in green transportation. In general, this paper not only contributes to the knowledge repository in electric car technology but also provides a route to a cleaner future in transportation, aligning with international efforts to mitigate environmental impacts and promote green energy sources.

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