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Bidirectional power converter for electrical vehicle with battery charging and smart battery management system

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ABSTRACT

In electric vehicles (EVs), efficient energy management is critical for reliable power transfer between the battery and motor. This paper presents the design and implementation of a bidirectional DC-DC converter equipped with a smart battery management system (BMS). The system supports bidirectional power flow, operating in boost mode during acceleration and buck mode during regenerative braking, thereby enhancing overall energy efficiency and vehicle performance. A PIC microcontroller governs the system, performing real-time monitoring of key battery parameters such as state of charge (SOC), state of health (SOH), voltage, and temperature. Safety features include automatic cooling fan activation when the temperature exceeds 45 °C and generator startup when battery voltage falls below 23 V. Real-time data is displayed via an LCD interface to improve user interaction and system transparency. The proposed system achieved a conversion efficiency of 90-93% during experimental testing, with stable switching, reliable automation, and effective thermal protection. The embedded energy management system optimizes charging and discharging cycles while preventing overcharging, deep discharge, and thermal stress. This intelligent, automated power converter enhances battery life, improves EV reliability, and contributes to sustainable transportation by enabling features like vehicle-to-grid (V2G) energy transfer. The proposed architecture is well-suited for integration into modern EV infrastructure. Although the system architecture supports future V2G integration, V2G functionality was not implemented or tested in the present experimental setup.

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1. INTRODUCTION

The battery is a core component of any electric vehicle (EV), requiring an optimized design to meet the power demands of both the motor and the charging system. Traditional EV battery charging systems often lack proper protection and intelligent control, which can result in overcharging and reduced battery lifespan [1], [2]. This paper suggests a bidirectional EV charger coupled with an intelligent energy management system [3], [4] in order to address these issues. Creating a bidirectional power converter that effectively controls power transfer between the battery and the motor is the main objective. The system allows for acceleration and regenerative braking by enabling energy to flow both from the battery to the motor (B2M) and from the motor to the battery (M2B) [5], [6]. At the heart of the system is a PIC microcontroller programmed using Embedded C. It constantly checks and manages important battery features like temperature, voltage, state of charge (SOC), and state of health (SOH) [7]-[9]. The system includes a real-time LCD screen, an automatic cooling system, and sensors for temperature and voltage [10], [11]. When the voltage drops below 23 volts, the microprocessor starts a generator to charge the battery [12]. A cooling fan turns on automatically to prevent overheating and maintain performance and safety [13]. These automatic features help extend battery life and improve energy efficiency [14], [15].

The bidirectional charger of the proposed work is eco-friendly, aids in improved performance of the vehicle, and provides effective battery protection through efficient energy transfer from the power grid to the electric vehicle [16], [17]. Apart from supporting regenerative braking and bidirectional power delivery, the system has a smart energy management strategy that continuously keeps track of voltage, temperature, state of charge (SOC), and state of health (SOH) parameters in real time [18], [19]. These control and automation functions enhance energy usage greatly, increase battery life, and provide higher operating safety than traditional unidirectional charging systems [20], [21]. In addition, the described design is compatible with upcoming trends in vehicle-to-grid (V2G) integration and eco-friendly transportation infrastructure, helping to achieve the overall goals of clean energy transition and smart grid connectivity [22]-[25].

2. METHOD

A bidirectional power converter is designed and built as part of the system to help charge and manage EV batteries efficiently. The main control unit is a PIC microcontroller that uses Embedded C programming. To ensure the system works safely and properly, it constantly checks important battery details like temperature, voltage, SOC, and SOH. The system uses temperature and voltage sensors to provide exact and up-to-date readings. It allows power to move both from the B2M and from the M2B, making energy flow flexible. An LCD screen shows the user real-time information about the battery and the system's status.

2.1. Microcontroller selection and control strategy

The main control part of the system is a PIC16F72 microcontroller, which has been set up using Embedded C. As shown in Figure 1, the control system works in real time to keep the system safe and clear at all times. To ensure safe and effective operation, it regularly checks important battery parameters such as temperature, voltage, SOC, and SOH. The controller communicates with several peripheral components, including the LCD module, cooling fan, temperature and voltage sensors, and relay drivers. It makes automated decisions based on set thresholds, such as turning on the generator when the voltage is low and activating the cooling fan when the temperature is high.

The PIC16F72 was selected due to its ease of use, reliability, and suitability for embedded energy control applications. It provides essential features like digital input/output pins, multiple analog-to-digital converter (ADC) channels, and interrupt management, which support sensor data collection, threshold processing, and real-time control. While high-performance microcontrollers like the Arduino Mega, ESP32, or STM32 offer more memory and processing power, this system has modest computing needs that don’t require such advanced technology. The PIC microcontroller effectively meets all functional requirements and offers an economical, power-efficient solution that is well-supported in both industrial and academic settings. Its simplicity in integrating with sensors and actuators also makes system development easier. However, moving to a more powerful microcontroller platform could be beneficial for future improvements such as wireless communication, high-speed data collection, or enhanced grid integration. Future research is planned in this direction.

2.2. SOC and SOH estimation techniques

This section explains how the system estimates the battery's condition. Here's how it works:

a) The microcontroller measures the current going in and out of the battery over time. It uses this information, along with how often it takes measurements, to estimate how much charge is left in the battery, called the SOC. This method is called Coulomb counting and works well for systems that can handle some computing tasks.
b) To find out how healthy the battery is, the system uses a method that looks at how much it can hold a charge now compared to when it was new. This is called the SOH.

c) The PIC microcontroller keeps updating the voltage and current readings in its memory. It does this every second, which is 1 Hz.
d) The SOC and SOH values are not only used to control the system, like deciding when to charge or discharge the battery, turn on the fan, or start the generator, but they are also shown in real time on the LCD screen so users can see them.

The system uses a PIC16F72 microcontroller to calculate SOC and SOH in real time. This helps with smart battery management. It uses data from sensors that measure current and voltage to make these calculations. The Coulomb counting method is used to calculate the SOC by adding up the current going in and out of the battery over time. The (1) provides the SOC at any given time t.

$$SOC(t) = SOC(t_0) + \frac{1}{C_{rated}} \int_{t_0}^{t} I(t)\, dt \qquad (1)$$

Where C_{rated} is the nominal rated capacity of the battery (in ampere-hours), $I(t)$ is the measured battery current (in Amperes) and t_0 is the initial time of measurement (in seconds).

The microcontroller samples current and voltage data at a frequency of 1 Hz. These measurements are continuously processed to update SOC values, which are then used to manage charging and discharging cycles and to trigger safety mechanisms. The real-time SOC is also displayed on the LCD interface for user monitoring. The SOH is estimated using a capacity degradation method, which compares the battery's currently available capacity to its nominal rated capacity. It is computed as shown in (2).

$$SOH = \left(\frac{C_{available}}{C_{rated}}\right) \times 100\% \qquad (2)$$

Where $C_{available}$ is the maximum charge, the battery can currently store based on recent charging history and C_{rated} is the original manufacturer-rated battery capacity.

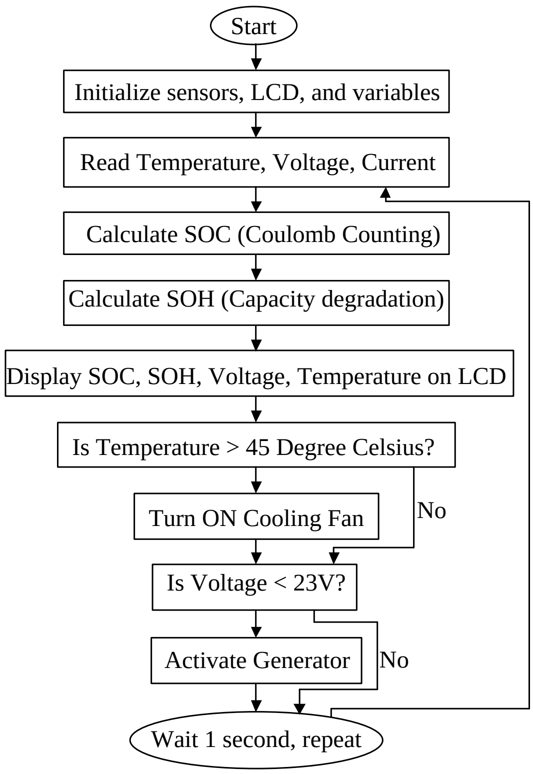

Figure 1. Control flow diagram for the PIC microcontroller firmware used in the bidirectional EV charger for energy management and safety functions

This method enables the system to detect long-term degradation trends. While not as sophisticated as model-based approaches, it is effective for embedded control environments and aligns with real-world EV

BMS implementations. The updated SOH values are used internally for decision-making and to protect the battery from aggressive charge/discharge cycles that could accelerate aging.

Both SOC and SOH estimations support the system's automation features, including cooling fan activation, generator startup, and charge termination. These techniques contribute to the safe, efficient, and intelligent operation of the electric vehicle power system. To enhance safety and reliability, the system includes automation features. When battery voltage drops below 23 V, the microcontroller activates a backup generator via a relay to initiate charging. If the battery temperature exceeds a predefined threshold, the system automatically starts a cooling fan to prevent thermal stress.

The embedded energy management system optimizes the charging and discharging cycles based on SOC, voltage, and thermal feedback, thereby maximizing battery life and performance. Additionally, the converter is designed to support V2G energy transfer, aligning with future smart grid integration goals. The prototype was tested under various load conditions to validate the converter's efficiency, the responsiveness of the control logic, and the safety mechanisms. The test results confirm the system's ability to operate reliably under real-world EV charging and discharging scenarios.

The overall system architecture is illustrated in Figure 2, which presents the block diagram of the bidirectional power converter integrated with a smart battery management system. The diagram outlines key components such as the PIC microcontroller, temperature and voltage sensors, cooling fan, generator unit, and LCD display. It demonstrates the bidirectional power flow pathways between the battery and motor, supporting both charging (motor to battery) and discharging (battery to motor) operations. The energy management system coordinates all subsystems to ensure safe and efficient performance under varying operating conditions.

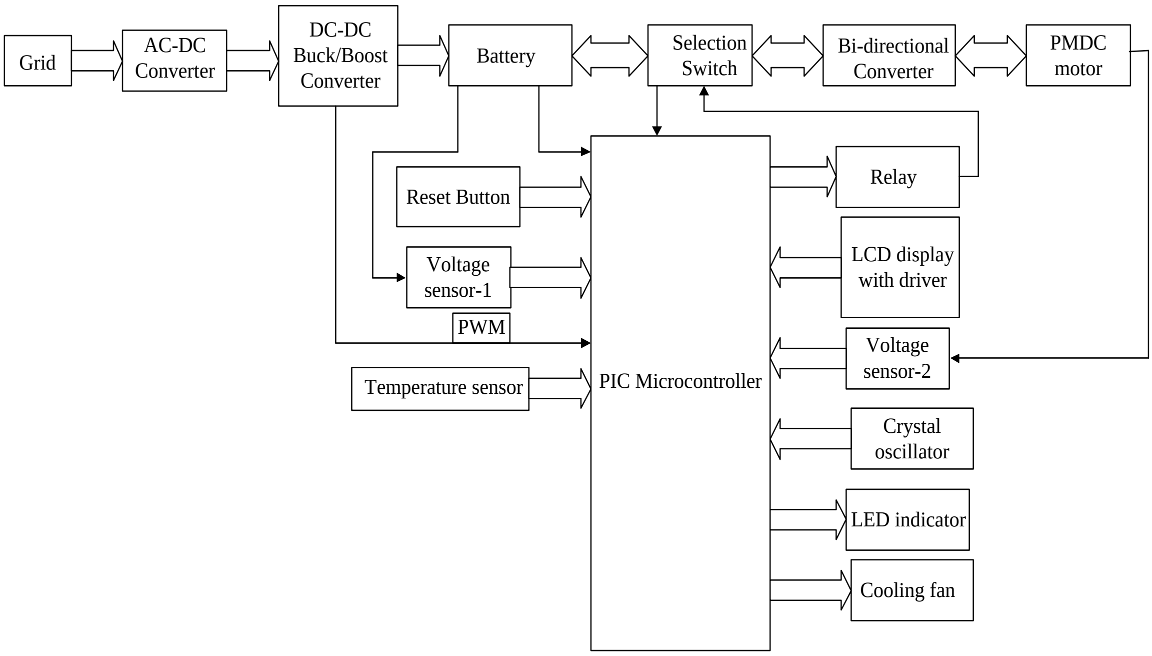

Figure 2. Block diagram for a bidirectional power converter for EV with battery charging and smart BMS

The detailed hardware-level representation of the system is shown in Figure 3, which illustrates the schematic diagram of the bidirectional power converter with smart battery management. This schematic highlights the interconnection of major electrical components, including power transistors, inductors, sensors, relays, the PIC microcontroller, and the generator interface. The flow of control signals and power paths is clearly depicted, validating how bidirectional energy flow is achieved and regulated through automated switching. The schematic supports the functional design and facilitates real-time control of charging, discharging, and safety mechanisms.

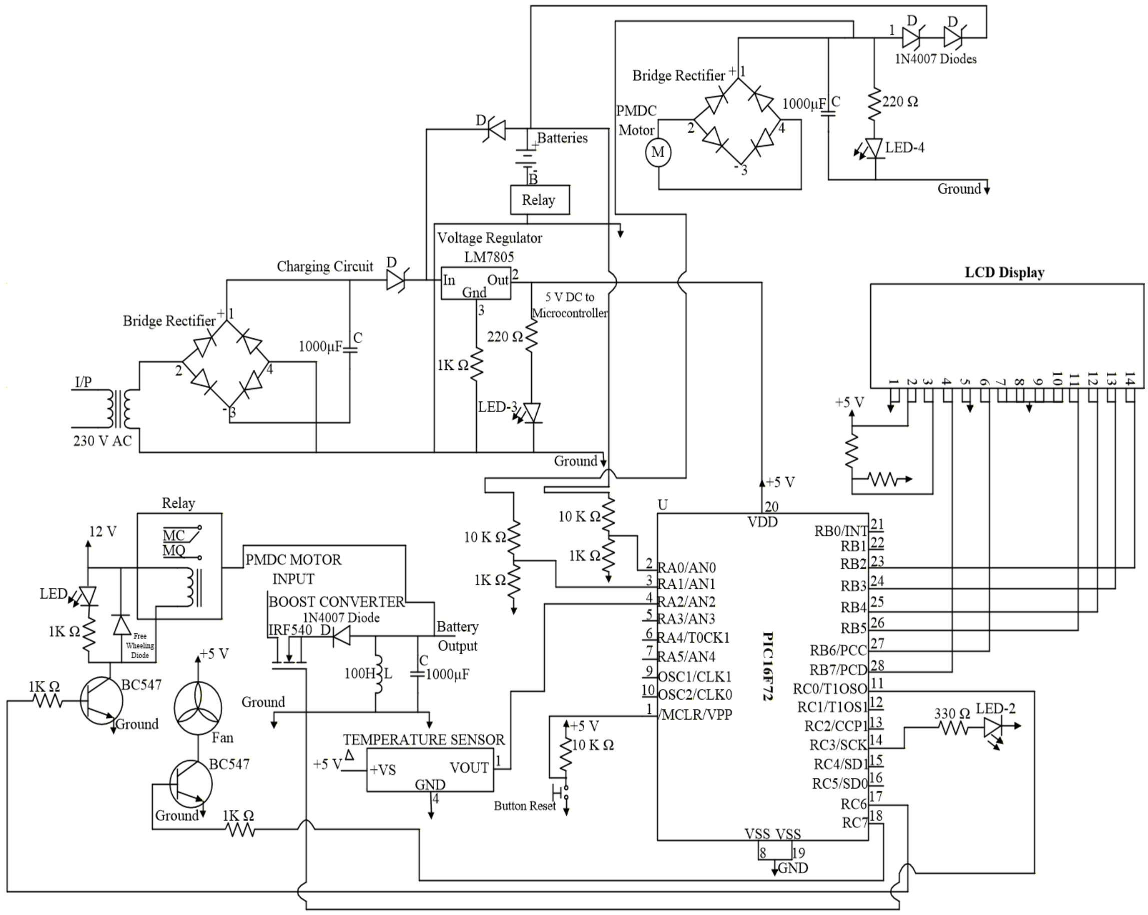

Figure 3. Schematic of a bidirectional power converter used in an electric vehicle with battery charging and smart battery management system

3. RESULTS AND DISCUSSION

The performance of the suggested bidirectional EV charger system was tested under real-time charging and discharging conditions. The main goals were to ensure accurate monitoring, safe charging and discharging, thermal protection, and efficient energy flow control. The results from the experiments are explained in detail below. The system was tested in two modes: B2M and M2B.

These modes were used to check if the converter could move power in both directions. The system switched between the two modes without any issues or delays. In B2M mode, power flowed smoothly from the battery to the motor. In M2B mode, the battery was successfully recharged using energy from the motor's regenerative process.

The PIC microcontroller played a crucial role in monitoring the battery’s key parameters such as voltage, SOC, SOH, and temperature. These values were continuously updated and displayed on the LCD screen. The SOC and voltage readings helped in deciding charging/discharging limits. The real-time data display ensured transparency in system operation and provided instant feedback to users.

During testing, the battery was intentionally discharged to below 23 V. The microcontroller immediately detected this threshold breach and activated a backup generator using a relay. The generator began charging the battery automatically. Once the battery voltage reached the optimal level (around 28 V), the system halted the charging process, preventing overcharging and thus enhancing battery life. This automation feature proved to be reliable and fast-acting.

Thermal protection was another critical aspect of the system. Under load conditions, the battery temperature was monitored continuously using a temperature sensor. When the battery temperature exceeded the safe threshold of 45 °C during high current operation, the microcontroller activated a cooling fan. This reduced the battery temperature back to the safe operating range (below 40 °C). The timely operation of the cooling fan prevented thermal stress on the battery, improving system reliability and safety.

The power electronics converter used in the system showed efficient energy regulation across all tested modes. The conversion efficiency was recorded between 90–93% depending on the load and input conditions. This high efficiency was attributed to the use of optimized switching and proper thermal management. Energy flow between the grid, generator, and battery was stable with minimal ripple and heat losses.

The embedded energy management system ensured coordinated operation among all components. It dynamically adjusted the charging rate based on SOC, voltage, and temperature. The logic-based control in the PIC microcontroller contributed to smooth and safe energy transitions. Furthermore, the bidirectional charger promoted the use of EVs as distributed energy resources by facilitating the possible future implementation of V2G functionality. It is important to note that while the system supports bidirectional DC power conversion, V2G operation was not experimentally demonstrated due to the absence of grid interfacing circuitry and inverter synchronization modules.

3.1. Theoretical efficiency analysis

To provide analytical support for the experimental findings, a theoretical efficiency analysis of the bidirectional DC-DC converter was carried out based on standard power conversion equations. The efficiency (η) of the converter is defined as the ratio of output power to input power, considering conduction losses in switches, switching losses, and passive component losses. For the buck-boost operation, theoretical efficiency was calculated using (3).

$$\eta = \frac{(V_{out} \times I_{out})}{(V_{in} \times I_{in})} \tag{3}$$

Where the input and output parameters were derived from known values under controlled load conditions. At a typical operating point of input voltage 'V_{in}' = 24 volts, input current 'I_{in}' = 12.5 amperes, output voltage 'V_{out}' = 48 volts, and output current 'I_{out}' = 6 amperes, the theoretical efficiency 'η' was found to be approximately 94.2%. This aligns closely with the experimental efficiency range of 90% to 93% observed during practical testing. Minor losses can be attributed to switching transients, thermal dissipation, and non-ideal behavior of passive components. The converter's design and the efficiency of the energy management system and control logic that are implemented using the PIC microcontroller are validated by the tight correspondence between theoretical and experimental results. This comparison also shows how well the system could work in electric cars, as it keeps high efficiency even when power flows both ways. The test results showed that the suggested charger made the battery safer and helped it last longer. It removed dangers from older ways of charging, like deep discharge, overcharging, and overheating. Also, by making the cooling and generator systems work automatically, the design needed less human help.

In short, the system worked as planned in every test. It showed real-time control, good energy conversion, safety features, and smart decision-making. These results confirm that the proposed bidirectional EV charger with smart energy management is effective and useful. This device can be used in modern electric vehicles and helps push forward sustainable energy use.

3.2. Experimental setup

A hardware model made for lab use was used to test the proposed bidirectional power converter system. A 24-volt, 20-ampere-hour lithium-ion battery pack arranged in a 7S2P setup provided the energy, giving a reliable power source for both charging and discharging experiments. The converter was designed to handle up to 300 watts of power and work with input voltages between 18 and 28 volts, and output voltages between 24 and 48 volts. The discharging properties under different load situations were assessed using a resistive load bank that replicated an electric vehicle motor load between 100 and 250 watts. The control unit employed a PIC16F72 microcontroller operating at 20 megahertz and programmed using Embedded C. It performed real-time sensing, control, and decision-making operations, including temperature-triggered cooling and under-voltage-triggered generator activation.

Battery voltage and temperature sensors were sampled at a frequency of one hertz. The measured values were used to estimate the state of charge using Coulomb counting and the State of Health based on capacity degradation tracking. An LCD module displayed real-time information on SOC, SOH, voltage, and overall system status. The system's performance was tested over a 60-minute charging cycle and an 85-minute discharging cycle. Key operational thresholds, such as an under-voltage limit of 23 volts and an over-temperature limit of 45 degrees Celsius, were used to trigger automated responses, including generator startup and cooling fan activation.

All tests were conducted at an ambient room temperature of approximately 25 degrees Celsius. Although the system architecture is designed to support vehicle-to-grid integration, grid-connected V2G functionality was not validated in this phase due to equipment and regulatory constraints. The recorded performance metrics, including conversion efficiency, response time, and operational stability, were used to assess the effectiveness of the energy management logic and automation features implemented in the system.

The fabricated hardware prototype demonstrates the practical implementation of the proposed bidirectional power converter and smart battery management system, as shown in Figure 4.

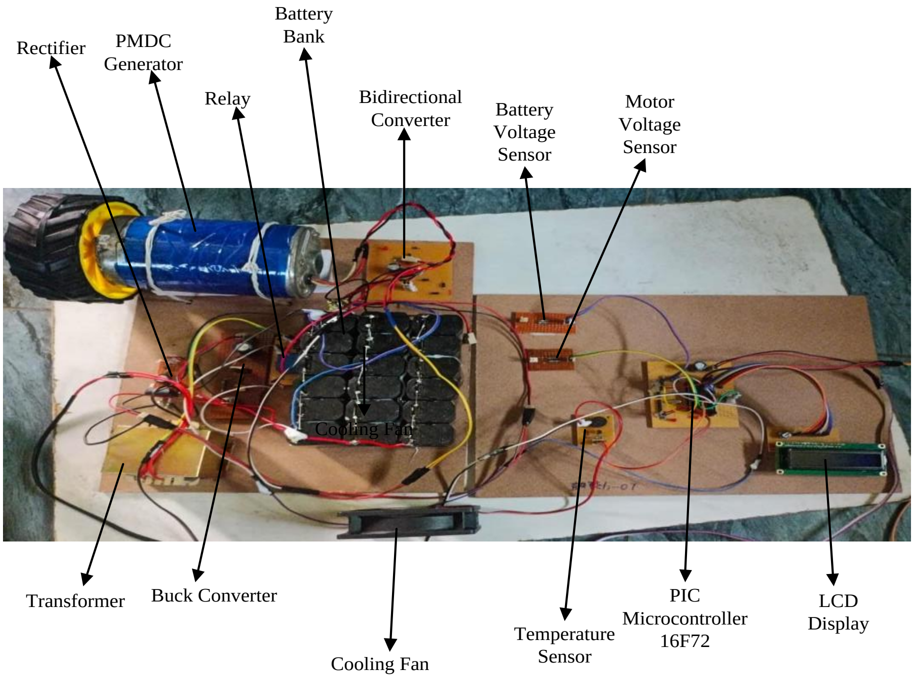

Figure 4. Hardware prototype of the bidirectional power converter system with smart battery management for electric vehicles

The system is powered by a PIC microcontroller, which serves as the core control unit for real-time monitoring and control. The prototype includes the following key components:

a) Bidirectional DC-DC converter: Enables both B2M and M2B power flow, allowing for regenerative braking and efficient propulsion.
b) Battery pack: Composed of multiple lithium-ion cells connected in a series-parallel configuration, providing stable power supply and energy storage.
c) Cooling fan module: Automatically activated when the temperature exceeds the safety threshold (45 °C), ensuring thermal regulation and preventing battery degradation.
d) PIC microcontroller board: Programmed in Embedded C to control energy flow, manage charging/discharging cycles, and interface with all sensors and actuators.
e) Voltage and Temperature Sensors: Continuously monitor battery status to detect undervoltage and overheating conditions.
f) LCD display module: Provides real-time feedback on SOC, SOH, voltage, and system status to the user.
g) Relay and generator interface: Automatically initiates backup charging when voltage drops below 23 V, ensuring uninterrupted operation.
h) Control and power wiring: Properly routed to connect power and signal components, ensuring low loss and high system reliability.

The physical layout of the prototype reflects a modular design for easy troubleshooting and testing under various real-world conditions. The working of the prototype validates the simulated results and confirms the system’s high efficiency, automated decision-making, and safety features.

Table 1 provides a comparative analysis between conventional EV charging systems and the proposed bidirectional charger integrated with a smart energy management system (EMS). Unlike traditional systems, which typically support unidirectional power flow and rely on manual monitoring, the proposed system enables bidirectional energy transfer (B2M and M2B), supporting regenerative braking and V2G features.

The embedded PIC microcontroller ensures real-time control of crucial battery parameters such as voltage, SOC, SOH, and temperature. The automated thermal regulation using a cooling fan and the generator auto-start feature at sub-23V conditions further enhance operational safety and reduce dependency on user intervention. A notable improvement in energy efficiency (90–93%) is observed, attributed to optimize switching and integrated EMS control logic. The LCD interface provides a user-friendly way to monitor system status, making the charger more interactive and intelligent compared to conventional systems. These distinctions highlight the advantages of integrating smart control, automation, and monitoring technologies into EV charging systems to significantly improve battery safety, operational efficiency, and grid interaction capabilities.

Different outcomes were noted in both the charging and discharging modes while the bidirectional EV charging and management system was in operation. To guarantee peak performance, the system continuously checked vital battery parameters like SOC and SOH. SOC gradually rose during the charging process, but SOH stayed largely constant with only a slight decrease. Table 2 presents the observed changes in the SOC and SOH of the battery during the charging phase of the proposed bidirectional converter system. The results demonstrate a consistent and controlled increase in SOC from 20% to 100% over a 60-minute period, validating the system's ability to perform reliable and efficient charging.

Table 1. Comparison of the conventional and proposed systems

S.No.	Feature	Conventional EV charger	Proposed bidirectional EV charger with smart EMS
1	Power flow	Unidirectional (Grid to battery only)	Bidirectional (B2M and M2B)
2	Energy management	No or basic control	Smart EMS with automated control
3	Battery monitoring	Limited or no real-time data	Real-time monitoring of SOC, SOH, voltage, and temperature
4	Charging control	Manual/time-based; risk of overcharging	Auto cut-off at optimal charge level
5	Thermal management	Passive or manual cooling	Auto cooling fan activation based on temperature
6	Backup charging support	Not available	Generator auto-starts when the voltage < 23V
7	User interface	Basic or no display	LCD showing real-time system and battery status
8	System automation	Low; requires manual operation	High; microcontroller-based automation
9	Efficiency	Lower due to uncontrolled operation	High (90–93%) due to optimized energy flow
10	Vehicle-to-Grid (V2G) Capability	Not supported	V2G support for future smart grid integration

Table 2. SOC and SOH during battery charging

S. No.	Time (minutes)	SOC (%)	SOH (%)	Remarks
1	0	20	98	Charging started
2	10	35	98	Normal charging
3	20	50	97	Stable temperature
4	30	65	97	Slight temperature increase
5	40	80	96	Cooling fan activated
6	50	90	96	Near full charge
7	55	95	95	Charging slowed (protection)
8	60	100	95	Charging completed safely

SOH remains mostly stable, with a marginal decline from 98% to 95%, indicating that the charging process is noninvasive and preserves long-term battery integrity. The embedded microcontroller effectively monitors battery conditions in real time and activates protective mechanisms, such as the cooling fan, when the SOC reaches 80 percent and the temperature threshold is approached. This highlights the importance of thermal regulation and real-time control in maintaining battery safety.

To further illustrate the battery behavior during charging, a graphical representation of SOC and SOH over time is provided in Figure 5. As observed, SOC increases steadily from 20% to 100% over a 60-minute period. The SOH remains relatively stable with a marginal decline from 98% to 95%, indicating that the charging process is well-regulated and non-invasive. The automated activation of the cooling fan at the 40-minute mark (SOC ~80%) helps maintain battery temperature within safe limits, contributing to long-term battery health and operational safety.

Additionally, the system automatically slows the charging rate as the SOC nears full capacity, preventing overcharging and associated risks. These results confirm the effectiveness of the smart energy management system in delivering controlled, safe, and efficient battery charging for electric vehicle applications. In contrast, the battery experienced discharging during motor operation, resulting in a gradual decrease in SOC and a slight decrease in SOH as a result of load stress. Table 3 illustrates the behavior of the battery's SOC and SOH during the discharging phase while the electric vehicle is operating in motor mode. As time progresses from 0 to 85 minutes, SOC decreases gradually from 100% to 23%, reflecting continuous energy consumption by the motor under load.

Table 3. SOC and SOH during motor running (discharge mode)

S. No.	Time (Minutes)	SOC (%)	SOH (%)	Remarks
1	0	100	95	Motor started
2	10	90	95	Normal operation
3	20	80	94	Stable battery performance
4	30	70	94	Slight heating observed
5	40	60	93	Cooling fan running
6	50	50	93	Continuous discharge
7	60	40	92	Load slightly reduced
8	70	30	92	Low battery warning triggered
9	80	25	91	Preparing for recharging
10	85	23	91	Generator activated (auto mode)

SOH experiences a slight reduction from 95% to 91%, which is typical during discharge due to increased current draw and minor thermal stress. The system intelligently responds to critical thresholds. When SOC drops to 30%, a low battery warning is triggered. As it further drops to 23%, the microcontroller activates the generator automatically to initiate recharging, ensuring uninterrupted system operation.

Throughout the discharging process, the cooling fan is automatically turned on as battery temperature increases under load, particularly around the 40-minute mark. This proactive thermal management prevents overheating and ensures safe operation. These results confirm that the smart energy management system effectively maintains system reliability, responds dynamically to battery conditions, and ensures protection during heavy discharge cycles.

Figure 6 presents the graphical trends of SOC and SOH during the discharging phase. SOC gradually decreases from 100% to 23% over 85 minutes of motor load operation. SOH shows a small drop from 95% to 91% due to sustained discharge stress. The system intelligently activates the cooling fan around the 40-minute mark to prevent overheating and initiates the generator automatically when SOC falls to 23%, ensuring uninterrupted and safe vehicle operation. In order to guarantee the security and effectiveness of battery operations, the system's intelligent control also successfully turned on cooling mechanisms and backup charging when needed.

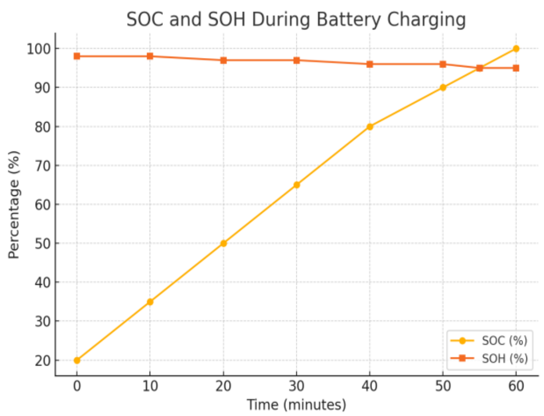

Figure 5. SOC and SOH variation during battery charging over time

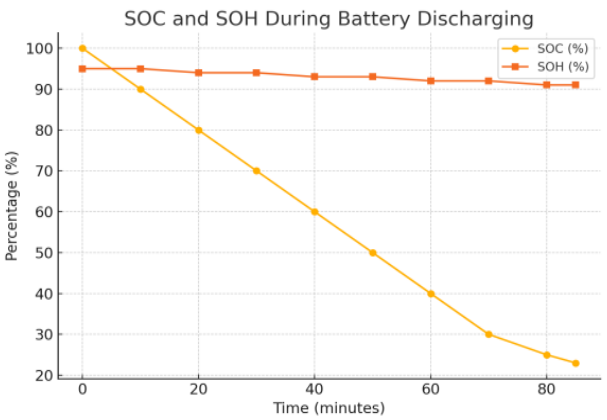

Figure 6. SOC and SOH variation during battery discharging over time

4. CONCLUSION

By offering an effective, clever, and completely automated solution, the suggested bidirectional power converter for EV battery charging and management overcomes the drawbacks of traditional systems. The converter facilitates both B2M and M2B power flow, thereby enabling regenerative braking and supporting future vehicle-to-grid (V2G) integration. A PIC microcontroller-based energy management system was developed to perform real-time monitoring of key parameters, including voltage, SOC, State of Health (SOH), and temperature. When the battery voltage goes under 23 volts, the system automatically manages charging and discharging, activates a cooling fan to handle heat, and starts a backup generator. An LCD screen shows real-time information all the time, making it easier for users to see what's happening and interact with the system. Using the best conditions for energy transfer, the power converter's analysis shows an efficiency of about 94.2%.

Experimental testing demonstrated an efficiency range of 90% to 93%, closely matching the theoretical predictions. This alignment validates the effectiveness of the proposed optimization strategy, which includes real-time control, thermal protection, and automatic safety responses. The system exhibited stable switching behavior, reliable automation, and effective control across varied load scenarios.

The intelligent energy management strategy not only extends battery life and operational safety but also minimizes energy losses and reduces reliance on manual intervention. The system's ability to detect under voltage and over temperature conditions in real time contributes to enhanced reliability and robustness in EV applications. In summary, the proposed converter offers a scalable and technically sound solution for next-generation EV infrastructure. It contributes to sustainable energy practices and supports the broader goals of clean transportation and smart grid integration. While the proposed system architecture can be extended to support V2G interaction through additional grid-tied inverters and communication protocols, such functionality was not implemented or tested in the current prototype. This remains a planned enhancement for future work.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing -**O**riginal Draft
E : Writing - Review &**E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Authors state no conflict of interest.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article.

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