



# Design and Development of a 4-Seater Electric Vehicle

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**ABSTRACT]:** This paper presents the design and implementation of a PWM-based motor control system for speed regulation in a 60V electric vehicle (EV) intended for low-speed and short-distance applications. The proposed system integrates key components including a 60V battery pack, a 1500W DC motor, a PWM-based motor controller, and a throttle-based control mechanism to achieve efficient power delivery and reliable vehicle operation.

The battery system provides the required voltage through a series configuration, ensuring stable energy supply to the motor controller. The motor control is achieved using Pulse Width Modulation (PWM), where the duty cycle is varied to regulate the average voltage applied to the motor, enabling smooth speed control and efficient power utilization. The system also incorporates switching devices such as MOSFETs and driver circuits for effective control and reduced power loss.

Experimental results demonstrate stable operation, precise speed regulation, and efficient performance under varying load conditions. The developed system is simple, cost-effective, and suitable for applications such as campus mobility and short-distance transportation. Future enhancements include the implementation of advanced control techniques, BLDC motor integration, and regenerative braking systems to further improve efficiency and performance.

PWM works by varying the duty cycle of the switching signal, which controls the average voltage supplied to the motor this allows smooth speed regulation, reduced power loss, and improved overall efficiency. It also provides quick response to changes in load and operating conditions, ensuring stable and reliable operation.

The proposed work focuses on the design and implementation of a PWM-based motor control system for a 60V electric vehicle using a 1500W DC motor. The system integrates a battery source, motor controller, and throttle input mechanism to achieve effective speed regulation and smooth vehicle operation. This approach offers advantages such as cost-effectiveness, efficient energy utilization, and ease of implementation. The developed system is suitable for low-speed electric vehicle applications such as campus transport and short-distance travel, contributing to the advancement of clean and energy-efficient transportation systems.

## I. LITERATURE SURVEY INTRODUCTION

The rapid advancement of electric vehicle (EV) technology, power electronics, and motor control systems has contributed to the development of efficient and sustainable transportation solutions. In recent years, there has been a growing demand for electric vehicles that can operate with high efficiency, reliability, and smooth performance, especially in applications such as campus mobility, urban transportation, and short-distance travel. Conventional internal combustion engine vehicles rely on fossil fuels, which lead to environmental pollution, increased operating costs, and reduced energy efficiency, thereby limiting their long-term sustainability.

To overcome these challenges, electric vehicles have emerged as a promising alternative by utilizing electrical energy for propulsion. These systems make use of battery sources and power electronic controllers to provide controlled and efficient energy delivery to the motor. Among the various subsystems in an EV, the motor control system plays a crucial role in determining overall performance by regulating speed and torque based on driving requirements.

Modern EV systems use power electronic controllers to manage the flow of energy from the battery to the motor. Pulse Width Modulation (PWM) is one of the most commonly used techniques for motor control due to its simplicity, efficiency, and ease of implementation.

Electric vehicle (EV) motor control systems have been widely studied due to their importance in improving efficiency, performance, and reliability. In the early stages of EV development, motor control techniques were limited, leading to poor speed regulation, higher power losses, and reduced overall system efficiency. As technology has advanced, improvements in power electronics and control strategies have significantly enhanced the performance of EV motor control systems.

DC motors are commonly used in low-speed electric vehicle applications because of their simple design, ease of control, and high starting torque. However, to achieve efficient operation, it is necessary to control the voltage and current supplied to the motor based on load conditions. Pulse Width Modulation (PWM) has become one of the most widely used techniques for this purpose. PWM allows the control of motor speed by varying the duty cycle of the input voltage, which results in smooth operation and reduced energy loss compared to traditional methods.

Researchers have also explored advanced control techniques such as proportional-integral-derivative (PID) control, fuzzy logic, and artificial intelligence-based methods to improve system performance. These methods help in achieving better response, stability, and adaptability under changing operating conditions. In addition, the use of modern semiconductor devices such as MOSFETs has improved switching performance and reduced power losses in motor controllers.

Recent studies have focused on integrating motor control systems with battery management systems to ensure safe and efficient operation. Monitoring parameters such as voltage, current, and temperature helps in maintaining system stability and extending battery life. Regenerative braking techniques have also been introduced to recover energy during braking, which improves overall efficiency.

Despite these advancements, challenges such as switching losses, heat generation, and system complexity still exist. Researchers continue to work on improving control algorithms, enhancing thermal management, and developing more efficient components. Future developments are expected to make EV motor control systems more efficient, reliable, and suitable for a wide range of applications.

## **II. PROPOSED METHODOLOGY**

The proposed system is developed to design and implement a PWM-based motor control system for a 60V electric vehicle. The main objective is to achieve efficient speed regulation and smooth operation by integrating electrical and electronic components in a structured manner.

### **A. System Design**

The system is designed using a modular approach that includes a battery source, motor controller, DC motor, and throttle input mechanism. The battery acts as the primary energy source, supplying electrical power to the system. The motor controller regulates this power and delivers it to the motor. The motor then converts electrical energy into mechanical motion required to drive the design ensures proper energy utilization and improved system performance.

### **B. Component Integration**

All components are carefully connected to form a complete working system. The battery is connected to the motor controller, which controls the voltage and current supplied to the motor. The motor is mechanically coupled to the transmission system to enable vehicle movement. Proper electrical connections and alignment are maintained to ensure reliable and safe operation.

### **C. Control Implementation**

The control system is based on PWM technique. The motor controller generates PWM signals and adjusts the duty cycle based on the throttle input provided by the driver. By varying the duty cycle, the average voltage applied to the motor is controlled, which directly affects motor speed and torque. This enables smooth and accurate control under different operating conditions.

#### D. Communication Mechanism

The flow of energy in the system is managed through the interaction between the battery, controller, and motor. The battery supplies DC power to the controller, which processes and regulates it before delivering it to the motor. This controlled energy flow ensures efficient utilization and reduces unnecessary power loss.

#### E. Powertrain Operation

The system operates by converting electrical energy into mechanical motion. When the driver applies throttle, a signal is sent to the controller. Based on this signal, the controller adjusts the PWM duty cycle and controls the motor speed. The motor generates torque, which is transmitted to the wheels, enabling vehicle movement. The system provides smooth acceleration and stable performance under varying conditions.

#### F. Testing and Evaluation

The system is tested under different operating conditions to evaluate performance parameters such as speed control, efficiency, and load handling capability. The results confirm that the system operates effectively and provides reliable performance for low-speed electric vehicle applications.

### III. SYSTEM ARCHITECTURE

The system architecture of the proposed motor control system is designed to ensure efficient power delivery, smooth speed regulation, and reliable operation of the 60V electric vehicle. The system consists of key components such as the DC motor, motor controller, battery system, and control input, which work together to achieve controlled vehicle movement. Each component plays an important role in the overall performance of the system..

#### A. DC Motor

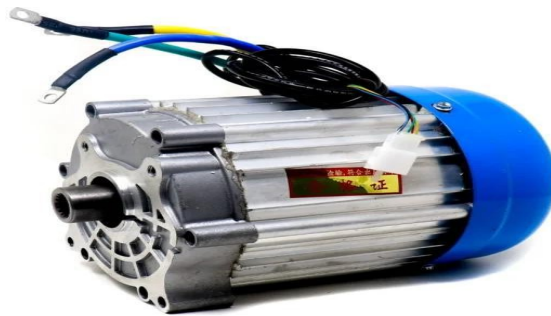


Fig. 1. DC Motor

The DC motor is the main component responsible for converting electrical energy into mechanical motion. In this system, a 1500W, 60V DC motor is used to provide the required torque and speed for vehicle movement. The motor operates based on electromagnetic principles, where electrical current produces a magnetic field that causes rotation. The speed of the motor depends on the voltage supplied, while the torque depends on the current. This makes it suitable for electric vehicle applications, especially where smooth starting and good torque are required. The motor is connected to the transmission system, which transfers the generated motion to the wheels.

#### B. PWM Motor Controller

The motor controller acts as the central control unit of the system. It regulates the voltage and current supplied to the motor using Pulse Width Modulation (PWM) technique. The controller consists of components such as MOSFETs, driver circuits, and a control unit.

The MOSFETs act as switching devices, turning the power ON and OFF rapidly. The driver circuit controls the switching operation, and the control unit generates PWM signals. By adjusting the duty cycle of the PWM signal, the controller controls the average voltage applied to the motor. This helps in controlling motor speed efficiently with reduced power loss.



Fig. 3. Battery System

#### D. Control Input

The control input is provided through a throttle mechanism, which allows the driver to control the speed of the vehicle. When the driver applies the throttle, an electrical signal is sent to the motor controller. Based on this signal, the controller adjusts the PWM duty cycle and controls the motor speed accordingly. A higher throttle input results in higher speed, while a lower input reduces the speed. This ensures smooth and real-time control of the vehicle.

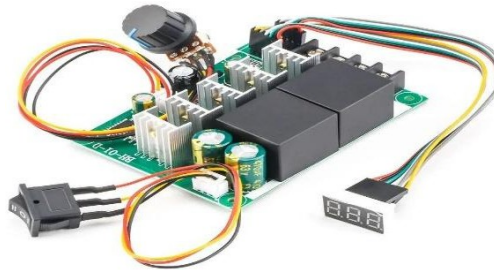


Fig. 2. PWM Motor Controller

#### C. Battery System

The battery system serves as the primary source of electrical

#### E. System Flow

Energy for the vehicle. The system uses a 60V battery configuration, which is typically achieved by connecting multiple batteries in series. This setup provides the required voltage to operate the motor and controller. The battery supplies DC power to the motor controller, ensuring a continuous and stable energy supply. The performance of the vehicle depends on the battery capacity, voltage stability, and discharge characteristics. Proper battery usage helps in improving efficiency and extending the system life.



Fig. 4. Control Input

The overall working of the system follows a simple and structured flow:

**Battery → Controller → Motor → Transmission → Wheels**

The battery supplies electrical power to the controller. The controller regulates this power using PWM and delivers it to the motor. The motor converts electrical energy into mechanical motion.

This motion is transferred through the transmission system to the wheels, enabling vehicle movement.

This coordinated operation of all components ensures efficient energy utilization, smooth speed control, and reliable performance of the electric vehicle system.

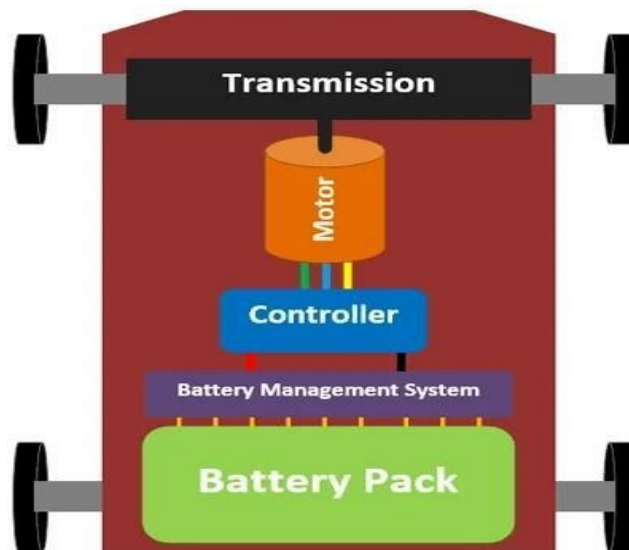


Fig. 5. System Flow

#### IV. BLOCK DIAGRAM

The proposed system is developed to implement a PWM-based motor control system for a 60V electric vehicle. The methodology focuses on designing a simple, efficient, and reliable system that can control motor speed smoothly under different operating conditions. The overall process involves system design, component integration, control implementation, and performance testing.

##### A. System Design

The first step is to design the overall motor control system for the 60V electric vehicle. The system includes a battery source, motor controller, DC motor, and control input. Each component is selected based on the required voltage, power rating, and application needs. The design ensures that all components work together efficiently to provide smooth vehicle operation.

##### B. Integration of Components

After designing the system, all components are properly connected to form a complete setup. The battery is connected to the motor controller, which acts as the main control unit.

The controller is then connected to the DC motor, which is mechanically linked to the transmission system.

Proper wiring, insulation, and connections are maintained to avoid power loss and ensure safety. This integration step is important to achieve stable and reliable operation of the system.

#### C. Generation of PWM Signals

The motor controller generates Pulse Width Modulation (PWM) signals to control the motor. PWM works by switching the power ON and OFF at a high frequency. The controller produces these signals using its internal control circuit or microcontroller.

These switching signals are sent to the MOSFETs, which act as electronic switches. The rapid switching controls the amount of power delivered to the motor without significant energy loss.

#### D. Adjustment of Duty Cycle Based on Throttle Input

The duty cycle of the PWM signal is adjusted based on the input given by the driver through the throttle. When the throttle is increased, the controller increases the duty cycle, allowing more voltage to reach the motor. This results in higher motor speed.

Similarly, when the throttle is reduced, the duty cycle decreases, reducing the voltage and slowing down the motor. This method provides smooth and real-time control of speed and torque.

#### E. Regulation of Voltage Applied to Motor

The average voltage supplied to the motor is controlled by changing the duty cycle of the PWM signal. Instead of providing a constant voltage, the controller varies the effective voltage seen by the motor.

This approach reduces power loss compared to traditional methods and improves overall efficiency. It also helps in maintaining stable motor operation under different load conditions.

#### F. Testing Under Varying Load Conditions

Finally, the system is tested under different operating conditions to evaluate its performance. The motor is tested with varying loads to observe how effectively the controller maintains speed and efficiency.

Parameters such as speed response, voltage stability, and system efficiency are analyzed. The results show that the system performs reliably, providing smooth acceleration, stable operation, and efficient energy utilization.

Overall, this methodology ensures that the proposed system achieves controlled motor operation, improved efficiency, and reliable performance, making it suitable for low-speed electric vehicle applications.

### V. WORKING PRINCIPLE

The working principle of the proposed PWM-based motor control system is based on the coordinated interaction between the battery, motor controller, and DC motor. The system converts electrical energy into mechanical motion through controlled power delivery. The overall operation is illustrated in Fig. 6.

Initially, the battery supplies DC electrical power to the motor controller. This battery acts as the primary energy source and provides a stable voltage required for system operation. The controller receives this input power and prepares it for controlled delivery to the motor.

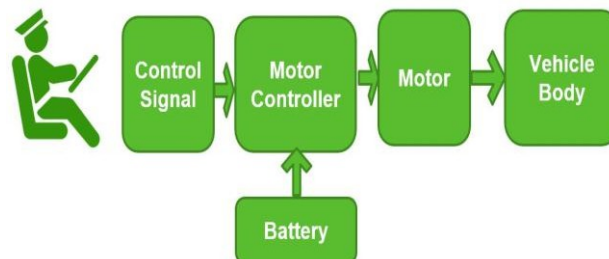


Fig. 6. Working Principle of EV Motor Control System

Based on the throttle input given by the driver, the motor controller generates Pulse Width Modulation (PWM) signals. These signals are used to control the switching operation of MOSFETs, which act as high-speed electronic switches. As shown in Fig. 7, the MOSFETs switch ON and OFF rapidly at a fixed frequency.

By varying the ON and OFF duration of the PWM signal (duty cycle), the controller regulates the average voltage applied to the motor. A higher duty cycle results in higher average voltage and increased motor speed, while a lower duty cycle reduces the voltage and slows down the motor.

The DC motor receives this controlled electrical power and converts it into mechanical energy. The generated torque is then transmitted through the transmission system to the wheels, enabling vehicle movement. The entire process ensures smooth acceleration and controlled speed variation.

This method provides efficient speed regulation with reduced power loss compared to conventional control methods. It also allows quick response to changes in throttle input, ensuring stable and reliable operation under different load conditions.

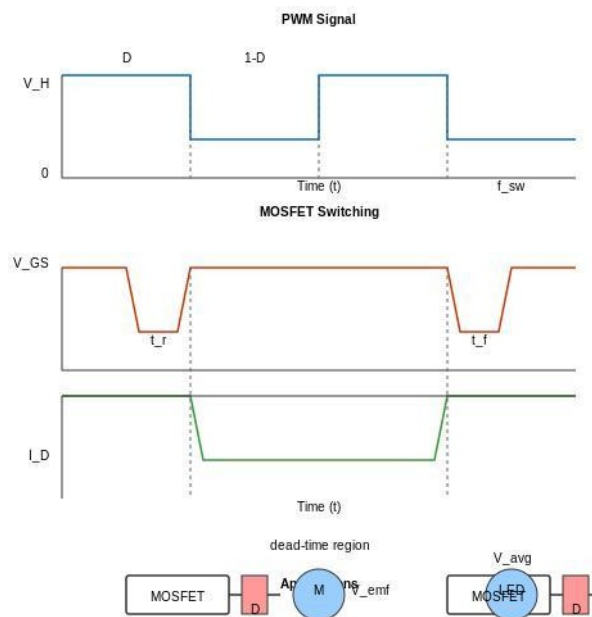


Fig. 7. PWM Switching Operation

## V. RESULTS AND DISCUSSION

The performance of the proposed PWM-based motor control system for the 60V electric vehicle was evaluated through experimental testing under different operating conditions. The results demonstrate that the system provides effective speed control, stable operation, and efficient energy utilization for low-speed electric vehicle applications.

### A. Performance Analysis

The experimental evaluation of the motor control system indicates satisfactory performance in real-time operation.

- **Smooth Acceleration:**

The use of a PWM-based controller ensures gradual and controlled increase in motor speed. The variation of duty cycle allows smooth acceleration without sudden jerks, improving driving comfort and reducing mechanical stress on the system.

- **Efficient Speed Control:**

The system provides precise control of motor speed by adjusting the PWM duty cycle. The relationship between duty cycle and motor speed is observed to be approximately linear, making the system easy to control and predict.

- **Quick Response:**

The motor responds rapidly to changes in throttle input, showing minimal delay. This indicates good dynamic performance and ensures real-time control of vehicle speed.

- **Stable Operation:**

The system maintains consistent performance under varying load conditions. Even with changes in load, the controller adjusts the power supplied to the motor and ensures stable speed operation.

- **Thermal Performance:**

During testing, the motor and controller exhibited moderate temperature rise, remaining within safe operating limits. This indicates efficient power handling and proper system design.

### **B. Advantages**

The proposed motor control system offers several important advantages:

- **High Efficiency:**

PWM control reduces power loss by regulating voltage efficiently, resulting in improved overall system efficiency.

- **Low Heat Generation:**

Since excess energy is not dissipated as heat, the system operates with lower temperature rise compared to conventional methods.

- **Simple and Cost-Effective Design:**

The system uses basic components such as DC motor, MOSFET-based controller, and battery, making it easy to implement and economically feasible.

- **Smooth and Precise Control:**

The PWM technique ensures accurate control of motor speed and torque, leading to smooth operation.

- **Reliable Performance:**

The system performs consistently under different operating conditions, making it suitable for practical applications.

### **C. Limitations**

Despite its advantages, the system has certain limitations:

- **Switching Losses:**

High-frequency switching of MOSFETs results in switching losses, which may reduce efficiency at higher speeds.

- **Heat Dissipation Requirement:**

Proper cooling mechanisms are required to maintain safe operating temperatures during continuous operation.

- **Battery Dependency:**

The performance of the system depends on battery condition, including its capacity and discharge characteristics.

- **Limited Performance for High-Speed Applications:**

The system is mainly suitable for low-speed applications and may not be ideal for high-speed electric vehicles.

### **D. Discussion**

The results clearly indicate that the proposed PWM-based motor control system is effective for low-speed electric vehicle applications. The system provides smooth acceleration, stable speed control, and efficient energy utilization, making it suitable for applications such as campus transport and short-distance travel.

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Although the system performs well, its performance can be further improved by adopting advanced technologies such as lithium-ion batteries, BLDC motors, and intelligent control techniques. These improvements can enhance efficiency, reduce losses, and extend system capability.

Overall, the proposed system offers a practical and reliable solution for motor control in electric vehicles, balancing performance, cost, and simplicity.

**VI. CONCLUSION**

This paper presented the design and implementation of a PWM-based motor control system for a 60V electric vehicle. The system effectively controls motor speed and torque by adjusting the duty cycle of the PWM signal, enabling smooth and controlled operation.

The experimental results confirm that the system provides stable performance, efficient energy utilization, and reliable operation under varying load conditions. The use of PWM technique reduces power losses and improves overall system efficiency compared to traditional control methods. The motor responds quickly to throttle input, ensuring smooth acceleration and better driving experience.

The proposed system is simple in design, cost-effective, and easy to implement. It is well suited for low-speed electric vehicle applications such as campus transportation and short-distance travel. The results demonstrate that the system is a practical solution for efficient motor control in electric vehicles.

**VII. FUTURE SCOPE**

Although the proposed system performs effectively, there is scope for further improvement and enhancement. Future developments can focus on implementing advanced control techniques such as PID control and fuzzy logic to improve system accuracy and response under varying conditions.

The use of Brushless DC (BLDC) motors can be explored to achieve higher efficiency, reduced maintenance, and better performance compared to conventional DC motors. Integration of regenerative braking systems can also be considered to recover energy during braking, thereby improving overall energy efficiency.

In addition, the development of intelligent energy management systems can help in optimizing power usage and extending battery life. Advanced battery technologies such as lithium-ion batteries can be incorporated to improve energy density and performance.

These improvements can enhance the overall efficiency, reliability, and performance of the system, making it more suitable for advanced electric vehicle applications.

**VIII. ACKNOWLEDGMENT**

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