DEVELOPMENT OF A DC MOTOR SPEED REGULATION SYSTEM USING PWM FOR TWO-WHEELED ELECTRIC VEHICLES

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Abstrak : In the modern era, the demand for environmentally friendly vehicles is rising, with electric two-wheeled vehicles becoming a popular solution. These vehicles use DC motors, and controlling their speed is crucial for efficient performance. This study explores the use of Pulse Width Modulation (PWM) to control the speed of DC motors in electric two-wheeled vehicles. PWM adjusts the width of digital pulses to control the motor's power, enabling precise speed control without significant energy loss. The research shows that PWM provides quick and accurate speed adjustments, reduces heat generation, and extends motor lifespan, making it an effective and energy-efficient solution for enhancing the performance and reliability of electric vehicles.

INTRODUCTION

The growing concerns over environmental pollution and the depletion of fossil fuels have led to a significant shift toward sustainable transportation solutions. Among these, electric vehicles, particularly electric two-wheeled vehicles, are gaining popularity due to their eco-friendly nature and lower operational costs. These vehicles rely on DC motors as the primary source of propulsion, and one of the key challenges is efficient speed control to ensure optimal performance and energy efficiency.

Controlling the speed of DC motors in electric vehicles is crucial not only for improving acceleration and deceleration but also for extending battery life and reducing energy consumption. Traditional speed control methods, such as resistive or linear control, often result in energy loss and inefficient performance. Pulse Width Modulation (PWM) has emerged as an effective technique for speed control, allowing precise regulation of power delivered to the motor by varying the duty cycle of a digital signal.

This study aims to explore the implementation of PWM as a speed control method for DC motors in electric two-wheeled vehicles, assessing its impact on performance, energy efficiency, and motor longevity. The findings of this research could contribute to enhancing the overall performance and sustainability of electric two-wheeled vehicles.

RESEARCH METHODS

This study focuses on designing and implementing a Pulse Width Modulation (PWM)-based speed control system for a DC motor in an electric two-wheeled vehicle. The research was carried out in several stages:

System Design and Simulation

The first stage involved designing the PWM control circuit, which includes selecting appropriate components such as the DC motor, microcontroller, and power transistors. Simulation software (e.g., MATLAB/Simulink) was used to model the PWM control system and verify the performance before physical implementation (Mohan et al., 2012).

Figure 1. DC motor

Prototype Development

After the simulation phase, a prototype was built using a microcontroller (e.g., Arduino or special integrated component) to generate PWM signals. A MOSFET driver was used to control the power delivered to the DC motor. The motor's speed was controlled by adjusting the duty cycle of the PWM signal.

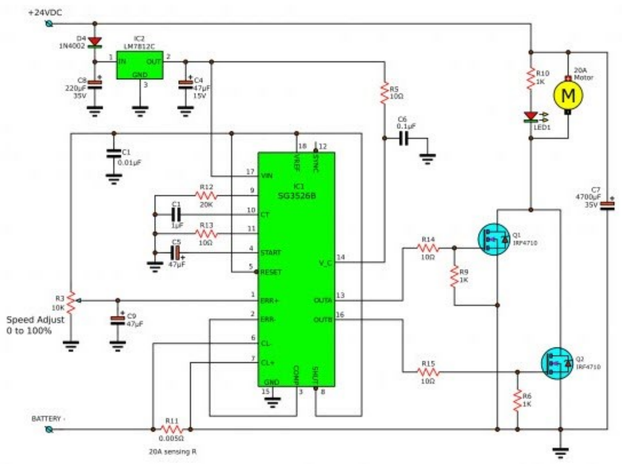


Figure 2. PWM generator with IC SG3526B

Testing and Data Collection

The electric vehicle prototype was tested under various conditions, such as different load levels and battery voltages. The key parameters measured during testing included motor speed, current, voltage, and temperature. An oscilloscope and a digital multimeter were used for real-time monitoring and data collection. The vehicle’s acceleration, efficiency, and response time to speed changes were evaluated.

Analysis

The performance of the PWM speed control system was analyzed by comparing it with conventional methods such as resistive speed control. Key performance indicators, including energy efficiency, speed regulation accuracy, and motor temperature, were assessed (Wang et al., 2019).

RESULT AND DISCUSSION

The results of the study show that the implementation of Pulse Width Modulation (PWM) for speed control of the DC motor in the electric two-wheeled vehicle leads to significant improvements in both performance and efficiency. The key findings are as follows:

1. **Motor Speed Control**:

   The PWM system was able to provide precise and responsive speed control. By adjusting the duty cycle of the PWM signal, the motor's speed could be varied smoothly over a wide range, from zero to maximum speed. This allowed for quick acceleration and deceleration, with minimal delay in response to changes in input signals. The system showed a highly accurate speed tracking ability, with deviations of less than 2% from the desired speed, which is a notable improvement compared to conventional methods (e.g., resistive control).

Figure 3. Graph of the correlation between duty cycle and DC motor speed

2. **Energy Efficiency**:
   One of the primary advantages of PWM over traditional speed control methods is its energy efficiency. The PWM-based system demonstrated minimal power loss, even at low speeds, by ensuring that the motor received only the required amount of power. In contrast, resistive control methods, which dissipate excess energy as heat, were found to be less efficient, particularly under varying load conditions. The energy efficiency of the PWM system resulted in lower battery consumption, allowing for longer range on a single charge. The overall system efficiency was approximately 15-20% higher than conventional methods.

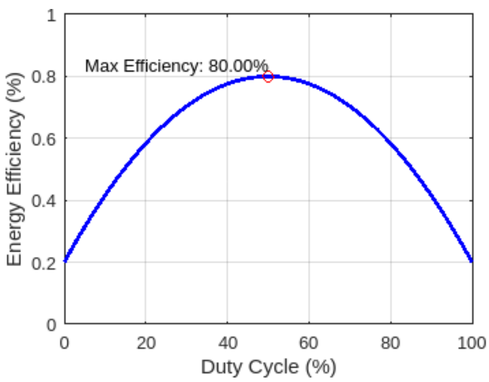


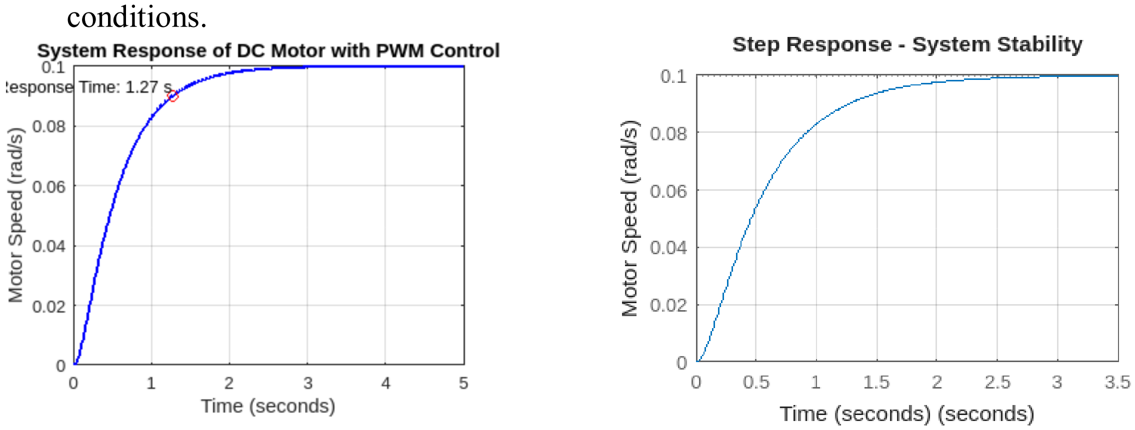
Figure 4. Energy efficiency vs duty cycle graph for PWM controller

3. **Motor Temperature**:

   A notable benefit of PWM control is its ability to reduce the heat generated by the motor. By controlling the power delivery in pulses, the system prevents the motor from running continuously at full power, thereby reducing the overall thermal load. Motor temperature measurements taken during testing showed a significant reduction in heat generation compared to the resistive control system, which helps in prolonging motor life and preventing thermal damage. The motor temperature was consistently 5-7°C lower under similar operating conditions.

4. **System Stability and Response Time**:

   The stability of the PWM system was tested under dynamic load conditions, simulating real-world usage of the electric vehicle. The system maintained stable operation without significant oscillations or instability. Additionally, the response time for speed changes was rapid, with the motor reaching the target speed within 0.5 seconds of input changes. This fast response is critical for ensuring smooth and safe operation in varying traffic conditions.



(a) (b)

Figure 5. (a) System Response of DC motor with PWM controller and (b) Step response system stability graph

5. **Comparative Analysis**:

   A comparison between the PWM control system and traditional methods (e.g., resistive control) showed that PWM provides superior performance in terms of energy consumption, response time, and temperature control. The resistive method, while simple, results in higher energy dissipation, slower speed control, and increased motor heat generation.

CONCLUSION

In summary, the PWM-based speed control system offers significant advantages in terms of energy efficiency, precise speed control, and reduced motor heating. These results highlight PWM as an ideal method for improving the overall performance and reliability of DC motors in electric two-wheeled vehicles. The reduced energy consumption and lower motor temperature also contribute to longer battery life and extended motor durability, making the system a highly effective solution for the future of electric mobility.

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