Control System for BLDC (Brushless Direct Current) Motor in Electric Vehicles

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Abstract. Electric vehicles represent an effective alternative to reduce environmental pollution caused by emissions from fossil fuel-powered vehicles. This study utilizes a 1500-watt Brushless Direct Current (BLDC) motor as the drive motor. Unlike conventional DC motors, BLDC motors operate with three phases, requiring an automation system to ensure optimal distribution of current and voltage across each phase. For motor control, a Convenient Speed Control system with a maximum power of 3000 watts is implemented. This system allows the vehicle to move forward and backward, as well as enabling manual throttle operation. During the experiment, the fully charged battery displayed an initial voltage of 53.2 volts for the forward mode and 52.8 volts for the reverse mode. The current required for forward movement was measured at 18 A, while for reverse it was 12.9 A. The minimum speed achieved by the electric vehicle was 88.8 RPM, whereas the maximum recorded speed was 316.9 RPM. Thus, this control system is not only efficient in regulating speed but also provides flexibility in operating the electric vehicle, supporting efforts toward more environmentally friendly transportation solutions.

Keywords: BLDC, vehicle, RPM

INTRODUCTION

Unlike conventional induction motors, Brushless DC (BLDC) motors do not experience slip, as the magnetic fields of the stator and rotor rotate at the same frequency and speed. A BLDC motor is an electromagnetic device that converts electrical energy into mechanical energy, and it is one of the most commonly used types of motors in electric vehicles. One of the main advantages of BLDC motors is their electronic commutation, which eliminates the need for brushes to switch the magnetic field, a requirement in traditional DC motors[1].

This electronic control enhances efficiency, reduces maintenance, and prolongs the lifespan of the motor. BLDC motors also offer higher torque-to-weight ratios and greater operational efficiency, making them suitable for a variety of applications beyond electric vehicles, such as in industrial equipment, robotics, and consumer electronics. Additionally, the absence of brushes reduces electrical noise and improves reliability, contributing to the overall performance of the motor. With advancements in technology, BLDC motors continue to evolve, driving innovation in electric mobility and automation. Their ability to deliver precise control and high efficiency makes them a preferred choice for modern applications, paving the way for more sustainable energy solutions.

BLDC motors offer several advantages over induction and conventional DC motors, such as higher efficiency, longer lifespan, and minimal maintenance requirements. In applications that demand high reliability and efficiency, BLDC motors are the ideal choice. Known for their high performance, these motors can deliver substantial power with rapid response and precise control. Due to their ability to provide optimal performance, BLDC motors are becoming increasingly popular in various applications, particularly in the automotive sector, such as in electric vehicles that require maximum performance and good energy efficiency. Their advanced capabilities make them well-suited for modern demands, ensuring they play a crucial role in the evolution of electric mobility and other high-performance technologies.

Electric vehicles (EVs) are powered by Brushless DC (BLDC) motors and utilize energy stored in batteries. The use of electric vehicles is considered highly effective because they produce no air pollution and have simpler engine construction. With more efficient designs, EVs offer excellent performance and lower operating costs compared to fossil fuel-powered vehicles. Additionally, these vehicles support efforts to reduce carbon emissions and protect the environment. The development of charging infrastructure is also on the rise, making it easier for users to recharge their batteries. As technology advances, electric vehicles are becoming an increasingly popular choice for individuals concerned about sustainability and environmental health [2].

The use of power electronic components is prevalent in everyday life, both in industry and at home. One common application is the speed control of two Brushless DC (BLDC) motors, frequently found in electric vehicles, trains, electric railways, drones, and more. To control two three-phase BLDC motors simultaneously, two three-phase inverters are typically used. This concept is outlined by Tsutomo Kominami and Yasutaka Fujimoto in their paper titled A Novel Nine Switch Inverter For Independent Operation Of Two Three-Phase Loads [3].

The main component used by electric vehicles to enable movement is the electric motor. The selection of the electric motor is based on the specific needs of the vehicle. Direct current (DC) motors are commonly used because they can easily rotate in either direction by simply reversing the polarity. Additionally, DC motors have high rotational speeds (RPM) and straightforward speed control. One type of DC motor that is becoming increasingly popular is the Brushless Direct Current (BLDC) motor.

Therefore, this research aims to develop a 3000-watt controller for BLDC motors that will serve as the drive for electric vehicles. By utilizing a BLDC motor, it is expected that this electric vehicle will deliver optimal performance and high energy efficiency, aligning with the goals of developing environmentally friendly vehicle technology. This advancement will contribute to sustainable transportation solutions and enhance the overall effectiveness of electric mobility.

Yakob Liklikwatil and Asep Diman, in their research, discuss the analysis of PID control regulation for the speed of Brushless Direct Current (BLDC) motors in electric vehicles. This study focuses on controlling the speed of BLDC motors as the primary drive for electric vehicles. BLDC motors offer several advantages that make them a suitable choice for electric vehicle applications, including high efficiency, longer operational life, and low maintenance. The main objective of this research is to control the speed of the BLDC motor to achieve stable responses. By implementing PID control, it is expected that motor control can be performed with precision, providing optimal performance and enhancing the comfort of operating electric vehicles. This research aims to contribute to the development of more efficient, environmentally friendly vehicle technology, supporting the shift toward sustainable transportation solutions.

METHODS

In the implementation and analysis of a convenient 3000-watt speed control system for Brushless Direct Current (BLDC) motors in electric vehicles, several components play crucial roles in the overall operation of the BLDC motor control system. One of the key components is the BLDC motor itself, which serves as the primary drive for the electric vehicle. Additionally, the 3000-watt speed control system acts as the brain of the BLDC motor control, managing not only the motor's speed but also ensuring efficient and responsive performance during operation.

With the combination of the BLDC motor and the appropriate speed control system, electric vehicles can operate optimally, delivering the necessary power and efficiency to support vehicle performance. This implementation and analysis aim to enhance the understanding and performance of the BLDC motor control system, enabling electric vehicles to meet the demands of modern, environmentally friendly transportation. By improving these systems, the research contributes to the development of sustainable mobility solutions that align with current environmental goals

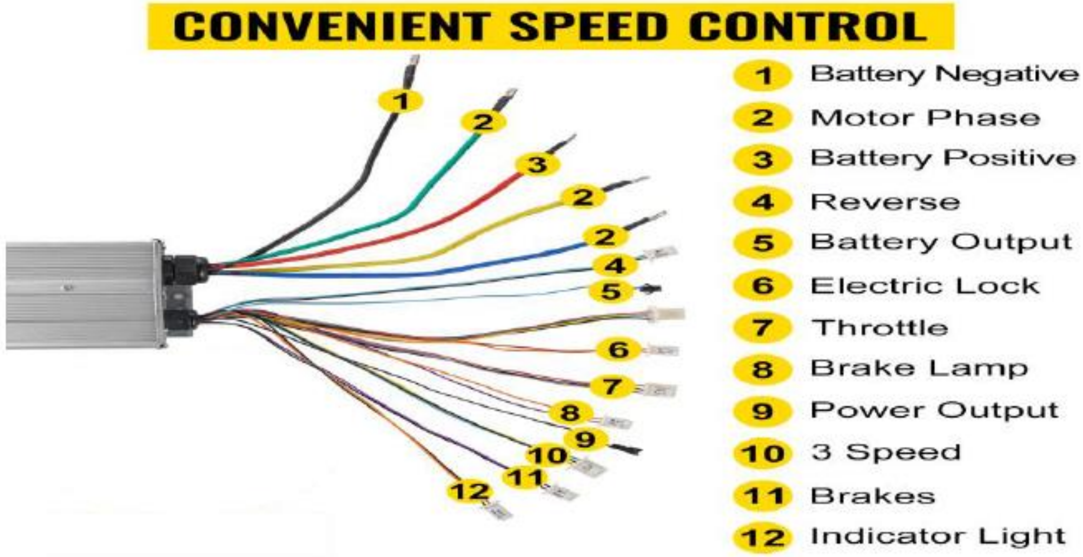

FIGURE 1. Convenient Speed Control 3000 Watt

The operational system in the implementation and analysis of a convenient 3000-watt speed control system for Brushless Direct Current (BLDC) motors in electric vehicles involves several operational processes, as illustrated in Figure 2. This figure shows the placement and numbering of functions within the control system. These processes include the input signals that dictate motor speed, the control algorithms that process these signals, and the output commands that drive the BLDC motor accordingly. Each component plays a vital role in ensuring the system operates efficiently, providing precise control and responsiveness to changing conditions. By examining the arrangement of these functions, the analysis aims to optimize the performance and reliability of the BLDC motor control system in electric vehicles.

These components work together to ensure the efficient and safe operation of the BLDC motor in the electric vehicle. Here are some components and their functions in the convenient 3000-watt speed control system for Brushless Direct Current (BLDC) motors in electric vehicles:

1. **Negative Battery Terminal**: The output cable from this control connects to the negative side of the battery, serving as the energy source.
2. **Motor Phases**: Three terminals indicate the three phases of control, connected to the BLDC motor. The output cables connect to the phases, neutral, and grounding of the BLDC motor.
3. **Positive Battery Terminal**: The output cable from this control connects to the positive side of the battery, providing the necessary electrical flow for motor operation.
4. **Reverse Motor Direction**: This function allows the control system to reverse the rotation direction of the motor as needed.
5. **Battery Output**: Supplies electrical flow to other components within the system.
6. **Electric Key**: Connected to the ON/OFF switch of the electric vehicle, this component is responsible for turning the system on or off.
7. **Throttle**: Controls the motor speed based on input from the driver.
8. **Brake Lights**: This system is integrated with the brake lights to signal other road users.

With proper configuration, the convenient 3000-watt speed control ensures effective and responsive control of the BLDC motor, enhancing both safety and performance in electric vehicles. A block diagram provides an overall visual representation of the sequence of operations within a system. Its purpose is to facilitate the understanding of the processes occurring within the created system.

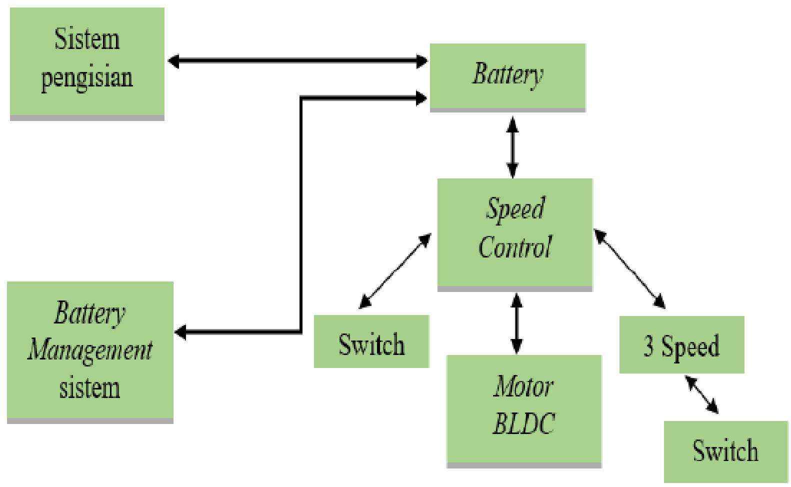

FIGURE 2. General Working System Block Diagram

Hardware and control system devices are essential for facilitating the research on the implementation and analysis of the Convenient 3000-Watt Speed Control for Brushless Direct Current (BLDC) Motor in Electric Vehicles. These components play a crucial role in ensuring effective operation and precise control of the motor. The design layout can be seen in Figure 3. This hardware setup not only supports the technical requirements of the study but also enhances the overall performance and efficiency of the electric vehicle system. Proper integration of these elements is vital for achieving the research objectives successfully.

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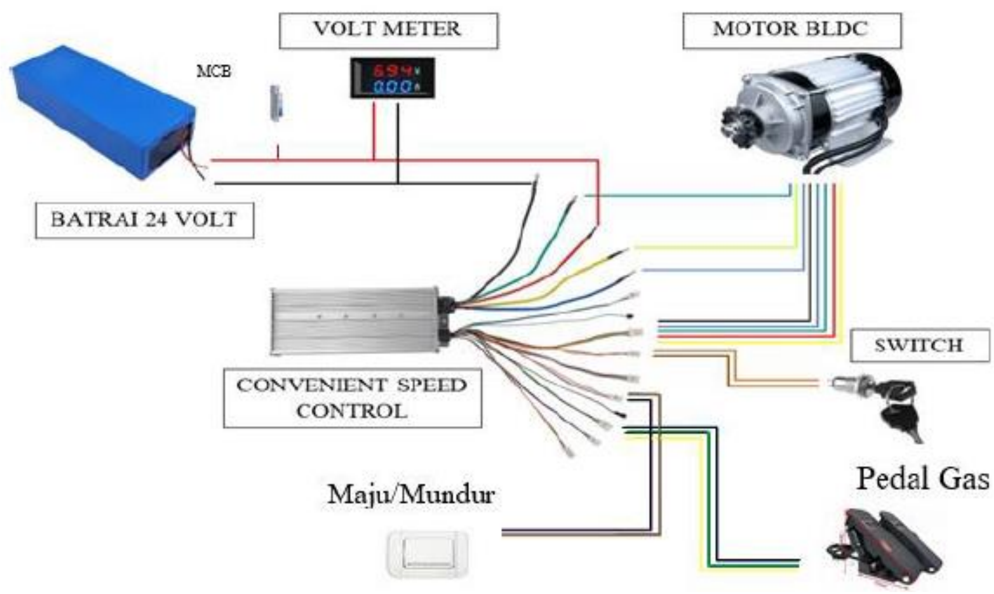

FIGURE 3. Hardware Design

RESULTS AND DISCUSSION

The data obtained from the construction and assembly of the device will be followed by testing and analyzing the data from the completed system. The goal of this research is to determine whether the device operates as intended.

The tests conducted include hardware testing and data analysis. All data is collected by applying a load to the measuring instrument and recording the readings. These tests are conducted over a period of three days, with each trial lasting two to three hours. The testing takes place at the Dedap building of the Computer Engineering department, as a spacious area is required to operate the electric vehicle during this time.

The results of the testing process conducted include:

1. Testing with One Driver: A load of 103 kg.
2. Testing with One Driver and One Passenger: A total load of 168 kg.
3. Testing with One Driver and Two Passengers: A total load of 238 kg.
4. Testing with One Driver and Three Passengers: A total load of 308 kg.

These tests help evaluate the performance of the system under varying loads, ensuring that it meets the operational requirements for different scenarios. The results of the design can be seen in Figure 4.

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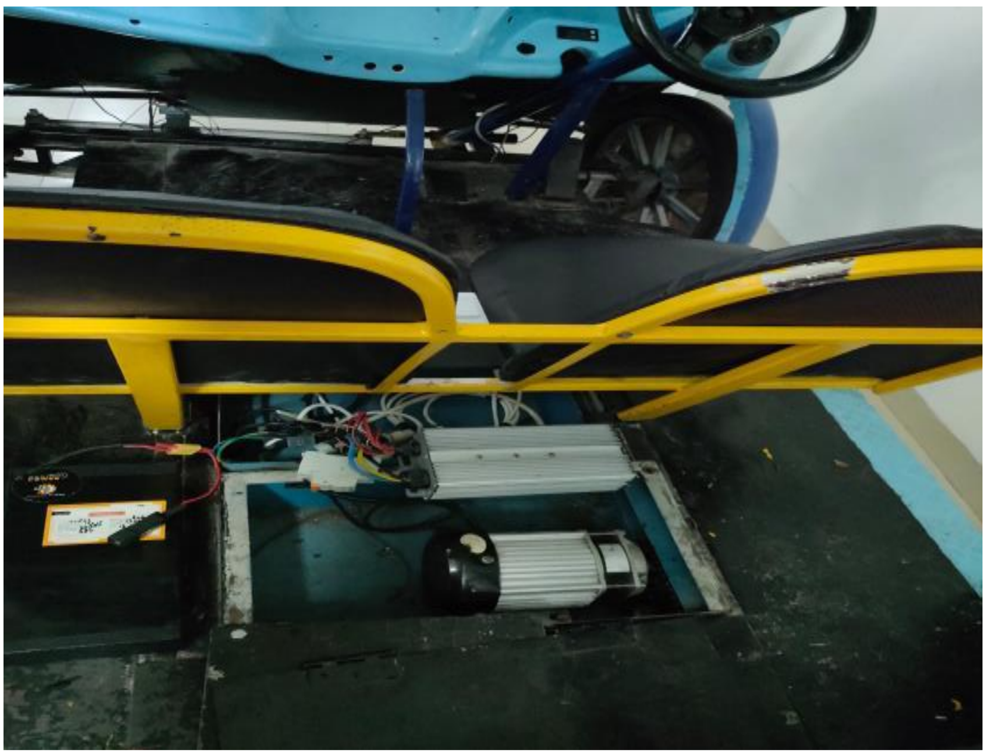

FIGURE 4. The results of the device design

From the data in Table 1, it can be observed that each experiment exhibits significant variations. The results indicate that as the load applied to the vehicle increases, the number of rotations produced decreases. In the initial test, with only one load, the motor's rotations were notably higher compared to tests conducted with heavier loads. Each experiment shows a difference that can be analyzed for further insights. As the load increases, both the distance traveled and the time required to complete the journey decrease. This demonstrates that the load has a considerable impact on the performance of the BLDC motor during operation. Therefore, it is crucial to consider load variations in testing to understand the limitations and capacities of the BLDC motor control system effectively.

TABLE 1. TESTING USING LOADS

No	Day	Duration of Experiments	Number of rotations	Number of people	Number of load
1	Day 1	2 hours and 40 minutes	14,356 Km	1	103 Kg
2	Day 2	2 hours and 20 minutes	13,192 Km	2	168 Kg
3	Day 3	2 hours and 35 minutes	13,192 Km	3	238 Kg
4	Day 4	2 hours and 45 minutes	12,610 Km	4	308 Kg

Based on the experiments conducted, as illustrated in Table 2, data collection was performed through multiple test iterations to achieve results that are both accurate and reliable. The absence of load during the BLDC motor tests in the electric vehicle yielded the following findings: in the first test, the voltage obtained across each phase was measured at 10 volts. Subsequently, in the second test, the measured voltage increased to 20 volts across each phase. In the third test, a further enhancement was observed, with the voltage reaching 38 volts for each phase.

These results indicate that as the number of trials increased, there was a significant rise in the measured voltage. This increase in voltage may serve as an important indicator of the performance characteristics of the BLDC motor utilized, particularly within the context of electric vehicle applications. The data amassed from this series of experiments provides deeper insights into the efficiency and responsiveness of the motor in relation to voltage variations. Such information is invaluable for the design of more optimized electrical power systems in electric vehicles.

TABLE 2. TESTING IN FORWARD MOTION WITHOUT LOAD

No	Voltage phasa RS	Voltage phasa ST	Voltage phasa RT	Explanation
1	10 volt	10 volt	10 volt	Speed 1
2	20 volt	20 volt	20 volt	Speed 2
3	38 volt	38 volt	38 volt	Speed 3

Table 3 presents the voltage data obtained while the electric vehicle was in reverse. This experiment was conducted multiple times with varying speed comparisons to achieve the desired results. The measurements recorded included parameters RS, ST, and RT. Data collection was performed alternately to ensure each variable was accurately measured. By testing different speed variations, it is anticipated that a clearer picture of the motor's performance in reverse conditions will emerge. The data gathered from these tests is crucial for analyzing system response and ensuring that the electric vehicle operates optimally in various situations. Additionally, the results from this experiment can be utilized for further development in the design and operation of electric vehicles, aiming to enhance efficiency and stability when reversing. Through this systematic approach, a deeper understanding of voltage dynamics during electric vehicle operation is expected to be achieved.

TABLE 3. TESTING IN REVERSE WITHOUT LOAD

No	Voltage phasa RS	Voltage phasa ST	Voltage phasa RT	Explanation
1	5 volt	5,1 volt	5 volt	Speed 1
2	9 volt	9 volt	8,6 volt	Speed 2
3	16 volt	16 volt	16 volt	Speed 3

Table 4 displays the starting current obtained during the BLDC motor tests. This starting current was measured when the motor underwent starting trials, specifically at the moment the accelerator pedal was pressed spontaneously. The data was collected during experiments conducted without any load on the electric vehicle, allowing the wheels to rotate freely. This setup aimed to capture the expected starting current values effectively. The experiment for collecting data on the starting current is detailed in Table 4. The results indicate that the starting current during forward motion is higher than that during reverse motion. This difference arises because, during the reverse starting trials, the motor's rotational speed cannot match the speed achieved when moving forward.

Specifically, the data shows a starting current of 31.6 AC when the motor operates in reverse, while the forward starting current is recorded at 38.8 AC. This results in a difference of 7.2 AC between the starting currents for forward and reverse motions. These findings highlight the impact of motor speed on current consumption and underscore the importance of considering these variations in performance assessments. Understanding the reasons behind the differences in starting current can aid in optimizing motor control strategies and improving overall efficiency in applications such as electric vehicles.

TABLE 4. BLDC MOTOR CURRENT DATA

No	Classification	Current
1	Peak forward	38,8 A
2	Normal forward current	18 A
3	Peak reverse	31,6 A
4	normal reverse current	12,9 A

The battery is equipped with both forward and reverse DC outputs for testing purposes while the vehicle is in operation. The battery is measured using a multimeter to determine its capacity during the data collection phase. This allows for an accurate assessment of the battery's performance in real-world conditions. Table 5 shows the battery output recorded at the start of the experiment, after being fully charged. The measured voltages are 53.2 volts for forward operation and 52.8 volts for reverse operation. These values indicate that the battery is adequately charged and ready for various testing scenarios. The difference in voltage between forward and reverse outputs provides insights into the battery's performance under different operational conditions. This data is essential for evaluating the electric vehicle's capabilities and ensuring it can meet the required power demands during the experiments

TABLE 5. BATTERY VOLTAGE

No	DC Voltage	Explanation
1	53,2 volt	Forward
2	52,8 volt	Reverse

Table 6 presents the measurements of wheel rotation speed using a tachometer during the data collection phase of the experiment. This testing involved several stages to ensure accurate results. Prior to the final data collection, multiple speed tests were conducted to capture a range of variations in performance. The data obtained from these tests provides valuable insights into the wheel speed under different operating conditions, allowing for a comprehensive analysis of the vehicle's performance. By varying the speeds throughout the trials, the study aims to understand how different factors influence wheel rotation, contributing to the optimization of electric vehicle operation.

TABLE 6. SPEED TESTING ON ELECTRIC VEHICLES

No	Speed	Explanation
1	88,8 RPM	Speed 1
2	131,3 RPM	Speed 2
3	316,9 RPM	Speed 3

In this experiment, the RPM results show that testing without a load allows the wheel to rotate faster, as the BLDC motor can operate at its maximum efficiency to provide RPM data for the electric vehicle's speed. Similarly, as the wheel speed increases, the tachometer yields RPM measurements, as illustrated in Table 6. The data from the first table indicates the following: at low speed during the first test, with the throttle pressed gently, the RPM recorded was 88.8. In the second test, the tachometer registered 131.3 RPM, resulting in a difference of 42.5 RPM from the first test. For the third test, the recorded data was 316.9 RPM, which is significantly higher than the results from the first two tests due to variations in data collection methods. The difference obtained in this test was 185.6 RPM, indicating that the third test produced larger results because the testing process was conducted more quickly than in the first and second tests.

CONCLUSIONS

The Convenient Speed Control 3000 Watt device operates as intended, effectively managing the speed of the motor. This system ensures smooth and precise control, enhancing the overall performance of the electric vehicle. With its reliable functionality, it meets the operational requirements and contributes to an efficient driving experience. This system enables the vehicle to operate in both forward and reverse directions, as well as allowing for manual throttle control. During testing, the fully charged battery showed an initial voltage of 53.2 volts in forward mode and 52.8 volts in reverse mode. The current drawn for forward movement was recorded at 18 A, while reverse movement required 12.9 A. The electric vehicle achieved a minimum speed of 88.8 RPM and a maximum speed of 316.9 RPM.

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