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Analysis of the Impact of Controller Variation and Battery Efficiency on the Performance of Light Electric Vehicles

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Abstract: *Electric vehicles (EVs) have emerged as a sustainable transportation alternative to reduce fossil fuel dependence. However, EV performance is strongly influenced by battery efficiency and control system configuration, particularly controller selection. This study analyzes how controller variation and battery efficiency affect the performance of the Viar EV1 1000W electric motor. An experimental approach compared Bosch and QS Motor controllers on a 1000W BLDC motor. Torque, power, speed, voltage, and battery efficiency were systematically measured using a dynamometer and digital multimeter. Testing was conducted to ensure data accuracy across various load conditions. Results demonstrate that the QS Motor controller significantly outperforms Bosch across all parameters, delivering higher torque, power, speed, voltage stability, and battery efficiency. The study concludes that QS Motor controller implementation enhances performance and efficiency in light EVs such as the Viar EV1 1000W. This research contributes practical insights for the automotive industry on selecting optimal controllers to improve energy efficiency and system reliability in electric vehicles.*

Keywords: *Electric Vehicle Optimization, Controller Variations in EVs, Battery Efficiency and Degradation, Lightweight Electric Vehicles.*

Introduction

Transportation that relies on fossil fuels has long been a major contributor to greenhouse gas (GHG) emissions, which substantially affect global climate change (Ghosh, 2020). As an alternative, electric vehicles (EVs) are emerging as a sustainable transportation technology to reduce dependence on fossil fuels and reduce carbon emissions (Dik et al., 2022). Electric cars not only provide high powertrain efficiency but also produce zero exhaust emissions, making them a promising alternative for future mobility (Ravi & Aziz, 2022). However, the environmental benefits of electric vehicles are highly dependent on the energy source used for charging. If power plants are still dependent on fossil fuels, their potential emission reductions will be limited (Kene et al., 2021).

The transition to electric vehicle (EV) technology is driven by the world's growing awareness of energy efficiency and the urgent need for eco-friendly mobility solutions (Popescu, 2022). The rapid growth of the EV market, evidenced by the 160% increase in EV sales in 2021, indicates the expansion of adoption in developed countries (Weiss et al., 2015). However, the complete transition to an electric vehicle-based transportation ecosystem still faces various technical challenges. One of the main components that determines the performance of an electric vehicle (EV) is its electric drive system, which includes an electric motor, control system, and battery as the main energy source(Olabi et al., 2022). Energy efficiency and optimization of electric motor performance are key challenges in increasing electric vehicle mileage, which is one of the key factors in the overall sustainability of electric vehicles(Algorithm, 2023).

In addition, the performance of electric vehicles is substantially influenced by the efficiency of the battery and the configuration of the control system applied (Barman & Azzopardi, 2021). Factors such as controller configuration, power distribution, and energy management strategy play a significant role in determining energy consumption, system reliability, and overall vehicle efficiency(Pierri et al., 2021). Unfortunately, variations in the controller configuration can result in suboptimal electric motor response, increase energy consumption, and decrease the overall reliability of the system (Wang et al., 2022). Furthermore, although electric vehicle (EV) technology has made significant advancements, issues such as limited driving range, slow charging speeds, and premature battery degradation remain major obstacles to EV market penetration(Roy et al., 2022).

Previous research has investigated various dimensions of electric vehicle technology, including battery optimization (Kim et al., 2020), Drive System Design (Tarafdar-Hagh et al., 2023), and energy management strategy (Weiss et al., 2020). However, research that simultaneously links controller variation and battery efficiency in the context of light electric vehicle performance is still limited (Wei et al., 2020). This mismatch creates an opportunity for further research in understanding the relationship between control unit variation (UCU), battery efficiency, and electric motor performance in light electric vehicles.

To address these gaps, this study proposes three main solutions. First, this study will analyze the direct relationship between UCU variation and battery efficiency in light electric vehicles, such as the Viar EV1 1000W, to identify the ideal configuration that improves the performance of the electric motor and reduces energy consumption(Piao et al., 2021). Second, this research will integrate energy and thermal management systems practically to improve power efficiency and maintain battery operation stability (Montaleza et al., 2024). Third, this study will analyze user behavior, including charging patterns and driving habits, to more accurately predict battery degradation and provide practical recommendations to extend battery life (Fioriti et al., 2023).

Thus, this research has three main objectives. First, this study investigated the relationship between UCU variation and battery efficiency in EVs. Second, this study tries to optimize the energy and thermal management system for EVs to be more efficient. Third, predict battery damage using user behavior to improve battery reliability and life. This research is expected to provide new information on the development of electric vehicle technology that is more efficient, reliable, and sustainable.

Methodology

This study uses an experimental method used to test and compare the performance of electric motors with Bosch and QS Motor controls. The main parameters measured include torque, power, speed, voltage, battery energy consumption efficiency, and the time it takes to spin an electric motor. The experimental design ensures that the results of the research are trustworthy. The entire Viar EV1 1000W Brushless DC (BLDC) electric motor used in light electric vehicles is included in the study subjects. To conduct a thorough evaluation, two test samples were purposively selected based on the characteristics of the controller variation used. They are electric motors controlled by Bosch controllers and electric motors controlled by QS controllers. The research procedure was carried out through a series of controlled experimental tests. The steps taken are as follows:

Sample Preparation: Ensure that the Viar EV1 1000W electric motor is in standard condition and ready for testing. The Bosch Controller and the QS Motor Controller are installed alternately according to the test scenario.

Test Execution: Conduct a test with each controller under the same operating conditions. During the testing process, parameters such as torque, power, speed, and voltage are measured directly. The energy consumption efficiency of the battery is also recorded based on the output current and voltage, as well as the time required to spin the electric motor with each controller configuration is recorded.

Data Processing: The data obtained is analyzed quantitatively to compare the performance of the electric motor with the two types of controllers. The evaluation is focused on power efficiency and energy consumption to identify the most optimal controller configuration.

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Primary data is data collected directly from experiments. This primary data includes the performance parameters of the electric motor such as torque, power, speed, voltage, battery energy consumption efficiency, and the playback time of the electric motor.

During the experiment, each test result is recorded systematically. To ensure a valid and accountable analysis, the measurement of each parameter is carried out with great accuracy. To ensure that research findings can reflect real-world circumstances, data collection is done in a structured and direct manner.

Result and Discussion

The torque test results show that the QS Motor Controller provides a significant improvement compared to Bosch at various motor revolutions. At 300 rpm, the QS Motor produces 10.7 Nm of torque, while Bosch only reaches 10.0 Nm. In addition, at higher revs of 450 rpm, QS Motor still shows superior performance with 6.52 Nm of torque, while Bosch is only able to produce 3.26 Nm. Overall, QS Motor increases torque by up to 40% compared to Bosch. Figure 1 shows that QS Motor has a better ability to generate torque under various operating conditions. A complete comparison between the torque produced by Bosch and QS Motor can be seen in Table 1.

Table 1. Comparison of Torque, power, speed, and Voltage of BLDC 1000 Watt electric motorcycle with bosh type controller and Qs Motor

	Torque		Power		Speed		Voltage	
RPM	Bosh	Qs Motor	Bosh	Qs Motor	Bosh	Qs Motor	Bosh	Qs Motor
200	9,67	8,68	2,90	2,53	28	26	71,4	71,7
250	10,5	10,2	3,87	3,65	34	35	79,9	71,0
300	10,0	10,7	4,33	4,35	38	41	69,9	70,8
350	8,8	96,6	4,38	4,64	42	54	67,8	69,6

400	6,94	82,3	3,87	4,59	45	58	65,9	68,9
450	3,26	6,52	2,05	4,12	45	58	65,5	67,4

Tests show that QS Motor is consistently better than Bosch in a wide range of parameters. For example, shown in Figure 2, at 350 rpm, the QS Motor produces 4.64 HP, while Bosch only produces 4.38 HP. In addition, the QS Motor can reach a maximum speed of 58 km/h at 40 rpm.

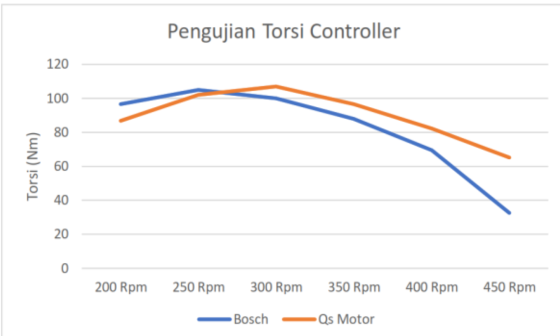

Figure 1. Comparison of torque of BLCD 1000-watt electric motor with BOSH and Qs Motor type controllers

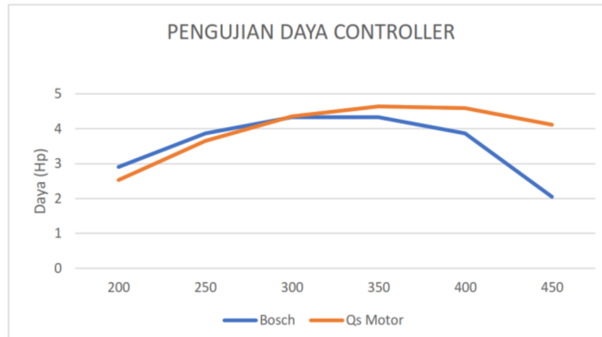

Figure 2. Comparison of 1000-watt BLCD electric motor power with BOSH and Qs Motor type controllers

Battery efficiency is one of the important aspects of this study, and the results are shown in Figure 3, that QS Motor is more efficient than Bosch. QS Motor can cover 60 km with an average speed of 59 Kph, while Bosch only reaches 51 km with an average speed of 48 Kph. The efficiency of QS Motor's battery reaches 63%, while Bosch only reaches 61%, indicating that QS Motor is more optimal in energy use.

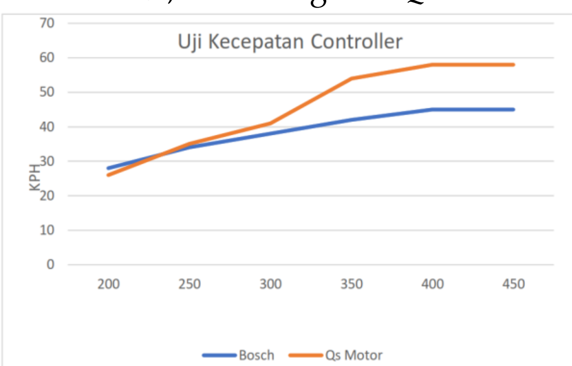

Figure 3. Speed comparison of 1000-watt BLCD electric motor with BOSH and Qs Motor type controllers

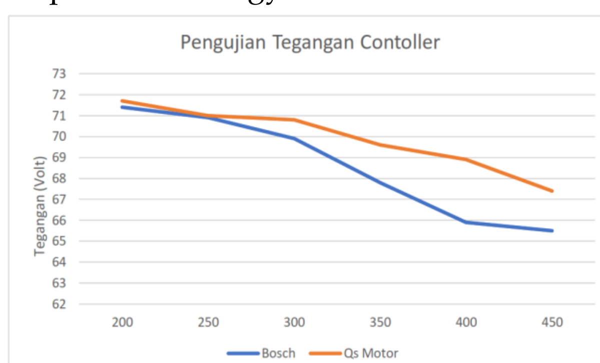

Figure 4. Comparison of voltage of BLCD 1000-watt electric motor with BOSH and Qs Motor type controllers

Voltage stability is also a critical factor in maintaining the performance of an electric motor. The test results show in Figure 4, that QS Motor produces a more stable voltage than Bosch. At 350 rpm, QS Motor produces a voltage of 69.6 Volts, while Bosch only reaches 67.8 Volts. At 450 rpm, the QS Motor remains ahead with a voltage of 67.4 Volts, while Bosch produces only 65.5 Volts. Overall, QS Motor improves voltage stability by 3% compared to Bosch, which contributes to more reliable electric motor performance.

Discussion

This study shows that the use of motor QS controllers is always better than Bosch in terms of torque, power, speed, and voltage stability. For example, at 300 rpm, the QS controller produces 10.7 N.m of torque, up 40% from the Bosch 10.0 N.m. In addition, the QS controller also increases power. These findings are supported by Wang et al. (2022), which emphasizes that the ideal controller design is essential to improve the efficiency of the electric drive system. Therefore, the findings of this study suggest that the right settings can significantly affect the performance of light electric vehicles such as the Viar New Q1.

One of the important components that affect the performance of electric vehicles is battery efficiency. The results show that QS Motor's controller has a 63% higher battery efficiency than Bosch, with a 72V 23Ah battery, QS Motor can cover 60 km at an average speed of 59 km/h, while Bosch can cover 51 km at a speed of 48 km/h. These results answer the lack of research on the simultaneous relationship between controller variation and battery efficiency(Wei et al., 2020). and provides a practical understanding of the importance of setting up the ideal controller to improve battery efficiency.

The results of this study also show how user behavior affects battery damage. In tests, QS Motor was more stable than Bosch under load conditions and high temperatures. When used at an average speed of 58 km/h with a load of 90 kg, the QS Motor remains stable without overheating, while Bosch tends to experience significant performance degradation. For QS motors, a more stable battery temperature indicates that user behavior, such as speed and charging patterns, can greatly affect battery degradation. These results support previous research(Fioriti et al., 2023). which emphasizes that a holistic degradation prediction model is essential to include elements of user behavior such as charging patterns and driving habits. Electric vehicle manufacturers can use this relationship to create battery management algorithms that suit user behavior.

The optimization of energy losses in permanent magnetic synchronous motor drive systems (PMSM) is an important focus of this study. The test results show that QS Motor is more efficient in reducing energy losses than Bosch. For example, the voltage stability on the QS Motor is better than that of the Bosch, which experiences a more drastic drop voltage at high revs. The lower voltage drop in the QS Motor indicates that this controller can minimize energy losses due to uneven power distribution. These findings are supported by Zhang et al., (2017), which emphasizes the importance of optimal controller design to reduce energy loss. Thus, the results of this study provide practical insights into how energy losses can be minimized through more efficient controller configurations, particularly in the context of light electric vehicles such as the Viar New Q1 1000W.

The integration of energy and thermal management systems has a significant impact on the performance of light electric vehicles such as the Viar New Q1 1000W. Tests show that QS Motor is superior in integrating these two systems compared to Bosch. For example, QS Motor results in better voltage stability and higher battery efficiency, which indicates a more optimal integration between energy and thermal management. These findings support Wei et al. (2020), which highlights the importance of integrating both systems to improve the efficiency of light electric vehicles. Thus, the results of this study provide practical insights into how the optimization of both systems can be applied to improve the performance and reliability of light electric vehicles, which have different specific needs than large-sized vehicles.

Conclusion

This study successfully analyzed the relationship between control unit variation (UCU) and battery efficiency in the Viar EV1 1000W light electric vehicle, as well as optimizing the energy and thermal management system to improve vehicle performance. The results showed that the use of the QS Motor Controller significantly increased torque by 40%, power by 0.26%, average speed by 10%, and voltage stability by 3% compared to Bosch Controller. Battery efficiency has also increased to 63% with the QS Motor, which allows for longer mileage (60 km) than Bosch (51 km), demonstrating the importance of selecting an optimal controller for electric vehicle performance. This research provides practical insights into how the integration of energy and thermal management systems can be applied to improve power efficiency, battery operation stability, and predict battery degradation based on user behavior, which is highly relevant for the development of more reliable and sustainable EV technologies. Although the study provided significant findings, its focus was limited to the Viar EV1 1000W light electric vehicle, so the results may not be fully generalizable to electric vehicles of different capacities or designs.

Future research should expand this analysis to include various electric vehicle models with different motor capacities and battery configurations to ensure broader generalizability. Long-term durability testing under real-world driving conditions is also recommended to evaluate the prolonged impact of controller selection on battery degradation and thermal stability. Furthermore, investigating the integration of advanced Battery Management Systems (BMS) alongside optimized controllers could provide deeper insights into maximizing overall system longevity and energy efficiency.

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