Journal of Mechatronics, Electrical Power, and Vehicular Technology 16 (2025) 233-243

Journal of Mechatronics, Electrical Power, and Vehicular Technology

e-ISSN: 2088-6985
p-ISSN: 2087-3379

mev.brin.go.id

Novel design of a simple control system for hybrid electric motorcycle

Didi Widya Utama [a, *], Hadian Satria Utama [b], Reno Wardy [b]

[a] Mechanical Engineering dept., Universitas Tarumanagara
Jl Let. Jend. S. Parman No.1., Jakarta Barat, 11440, Indonesia

[b] Electrical Engineering dept., Universitas Tarumanagara
Jl Let. Jend. S. Parman No.1., Jakarta Barat, 11440, Indonesia

Abstract

A hybrid system combines two or more propulsion systems, typically including electric motors and internal combustion engines. In this research, the motorcycle uses a 5.67 kW/8000 rpm gasoline internal combustion engine and a 1 kW/48 V DC brushless electric motor, both coupled to an in-wheel electric motor. The control system was designed to automatically manage two propulsion systems based on the rotation speeds of an internal combustion engine and an electric motor, along with readings from current and voltage sensors. It uses two ATmega16-based microcontrollers, a master and a slave, and is monitored via Bluetooth using an Android smartphone. An experimental setup was conducted to effectively operate the system, utilizing the motorcycle in three modes: engine mode, electric motor mode, and hybrid mode, which demonstrated successful functionality through automatic propulsion displacement.

Keywords: hybrid electric vehicle; brushless direct current; internal combustion engine; in-wheel motor; android smartphone.

I. Introduction

The transition to hybrid electric vehicles (HEVs) in Indonesia represents a critical step towards sustainable transportation and environmental conservation. As the Indonesian government seeks to reduce greenhouse gas emissions and promote energy security, hybrid vehicles serve as a practical intermediary between traditional internal combustion engines and fully electric vehicles (BEVs) [1][2]. HEVs combine an internal combustion engine with an electric motor, enabling improved fuel efficiency and reduced emissions, which is crucial in addressing the country's rising pollution levels [3][4]. Despite the potential benefits, consumer awareness and acceptance of HEVs remain low, largely due to concerns over maintenance costs and technological reliability [5][6]. The government's incentive policies and strategic partnerships within the automotive sector are vital for fostering a conducive environment for HEV adoption, aiming to position Indonesia as a key player in the Southeast Asian electric vehicle market [7][8].

The development of hybrid electric motorcycle (HEM) control systems has advanced significantly, driven by the need for enhanced energy efficiency and reduced emissions. Recent innovations include implementing sophisticated control strategies that optimize the interaction between the internal combustion engine and electric motor, thereby

* Corresponding Author. didiu@ft.untar.ac.id (D. W. Utama)

https://doi.org/10.55981/j.mev.2025.1077

Received 27 September 2025; revised 21 November 2025; accepted 24 November 2025; available online 26 December 2025; published 31 December 2025

How to Cite: D. W. Utama *et al.*, “Novel design of a simple control system for hybrid electric motorcycle,” *Journal of Mechatronics, Electrical Power, and Vehicular Technology*, vol. 16, no. 2, pp. 233-243, Dec., 2025.

improving overall performance and efficiency [9][10]. For instance, dynamic programming has been proposed to determine optimal operating points for power management, thereby minimizing energy consumption while maintaining drivability [11].

Moreover, integrating fuzzy logic and advanced algorithms has facilitated smoother transitions between energy sources, such as batteries and supercapacitors, which is crucial for maintaining performance under varying operational conditions [12][13]. The development of centralized fleet management systems also highlights the potential for hybrid electric motorcycles to contribute to sustainable urban transportation by reducing greenhouse gas emissions and improving energy utilization [14]. As technology matures, ongoing research continues to refine these control systems, enhancing responsiveness and adaptability to real-time driving conditions [15][16].

This research aims to design a simple control system that can operate automatically and eliminate pounding caused by manual shifting between the propulsions. The control system should function effectively in mobile conditions. To operate in automatic mode, the system utilizes sensors that monitor driving conditions, vehicle speed, and load conditions. The system is designed to automatically shift between the internal combustion engine and the electric motor, both of which are attached to the motorcycle's rear wheel. Motorcycle drivers can operate in three modes: internal combustion engine, electric, or hybrid. The driver can select among these operating conditions using a three-way switch button attached to the motorcycle handle, and the LCD will display the engine speed, vehicle speed, and vehicle load as indicated by the sensors.

A. Design of the system

Several key considerations regarding the system's design have been taken into account, including driving conditions, shifting threshold, vehicle load, vehicle speed, and ease of data collection from the system using wireless data logging. The driving condition is allocated to three modes of operation. The first mode is the internal combustion engine mode, which operates solely with the internal combustion engine, allowing the driver to experience a typical motorcycle ride. The second mode is the electric mode, which is fully powered by an electric motor to propel the vehicle; this provides the driver with an electric motorcycle experience that produces zero emissions. The third mode is a hybrid mode that operates entirely automatically in both propulsions. The shifting between these propulsions operates automatically

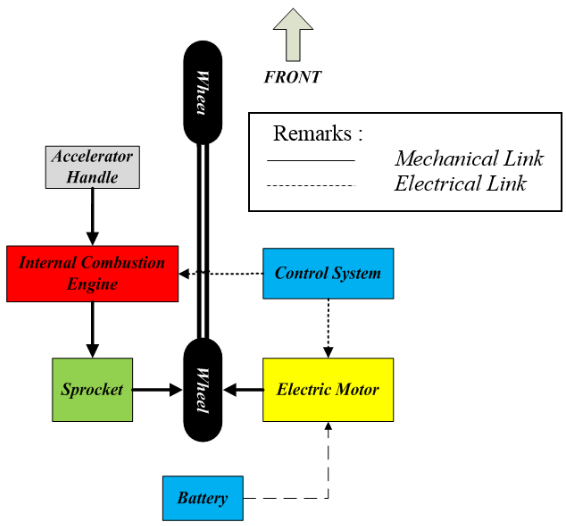


Figure 1. Hybrid system configuration.

according to predetermined traceholds derived from the combination of data collected from the vehicle's speed, engine speed, battery state of charge, vehicle load, and the electrical current sensor. These systems are controlled by microcontrollers and are divided into master control and slave control. The slave microcontroller receives sensor data and sends essential data to the master microcontroller and the data logger. The master microcontroller, in turn, handles the vehicle's operation mode and shifts the propulsion system.

The vehicle used in this experiment was a Honda-brand motorcycle equipped with a Revo-type automatic transmission. This motorcycle utilized a 4-stroke internal combustion engine, producing 5.73kW at 8000 rpm and 0.81 kgf·m at 5000 rpm, and featured a continuously variable transmission to ensure smooth shifting during operation. The electric motor used is a brushless DC motor with a power rating of 1kW at 600 rpm and 48V DC, utilizing an in-wheel system. This type of system couples the DC motor directly to the wheel, with the electric motor attached to the rear wheel [17]. The mechanical and electrical components are connected, as shown in Figure 1.

B. System control modules

To simplify the system, the hybrid system incorporates several small modules into it. The small module offers a compact design, easy troubleshooting, responsive data acquisition, ease of programming, and good overall system responsiveness. The innovative design of the simple control system prioritizes ease of programming while utilizing readily available, cost-effective hardware. In particular, we focus on the availability of components in the Indonesian market, ensuring that the control system can be easily replicated by common motorcycle modifiers within the

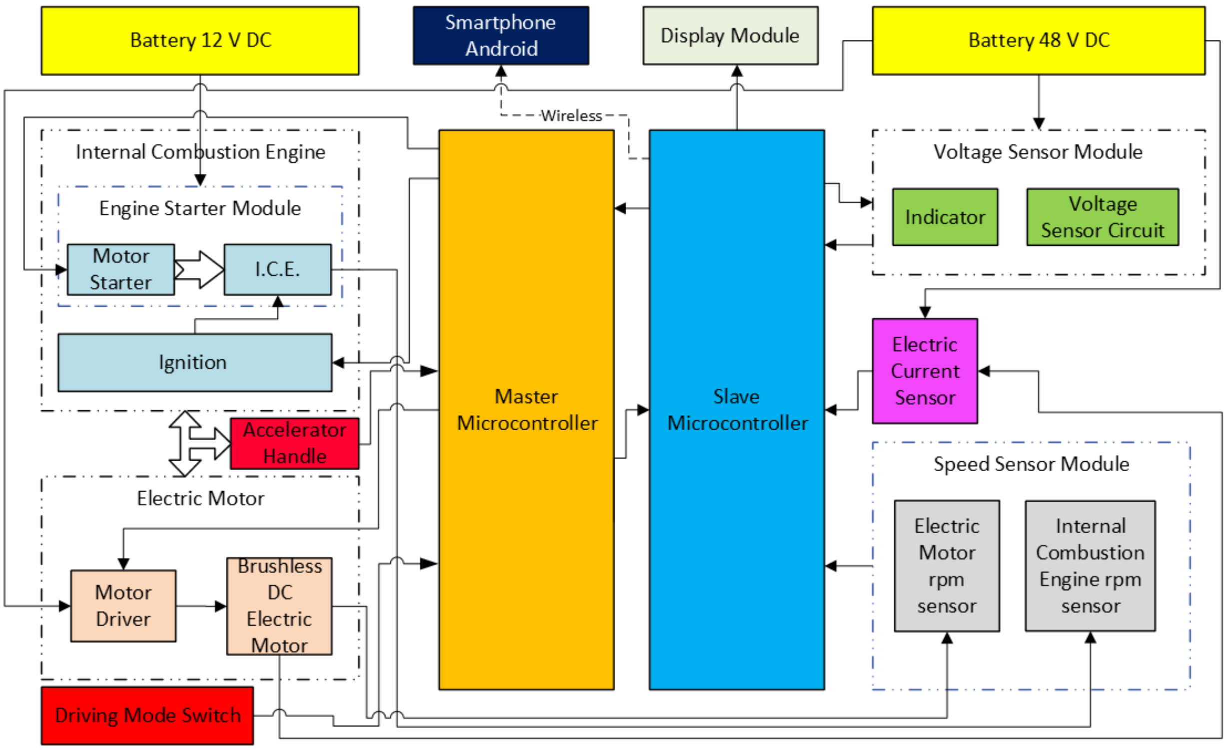


Figure 2. Simple hybrid control system block diagram.

community. This approach aims to democratize the technology nationwide. The control system consists of two main modules, each controlled by the microcontroller, as shown in Figure 2. And those controllers handle the algorithm's overall functionality as the master controller, while the slave controller handles the sensor input. This configuration ensures the system's responsiveness in this scenario. The comprehensive block diagram of the control system shows that the slave and master control system operates and communicate through general I/Os.

1) Microcontroller

Both master and slave microcontrollers use the AT Mega 16 type; the slave gets inputs from the voltage sensor module, receives many sensor values such as electric current, electric motor rotation speed, and internal combustion engine rotation speed, displays the value through the LCD module, and also sends the information to an Android smartphone via Bluetooth. The master controller executes the programmed algorithm using data from the modules.

2) Voltage sensor module

Collect the battery voltage data and send it to the slave. The slave then uses this data and the current flowing through the system to count coulombs based on the state of charge [18]. The voltage sensor used in this module is a voltage divider that divides the battery voltage as an input and outputs 0-5 Vdc, connecting to the microcontroller slave.

3) Electric current sensor module

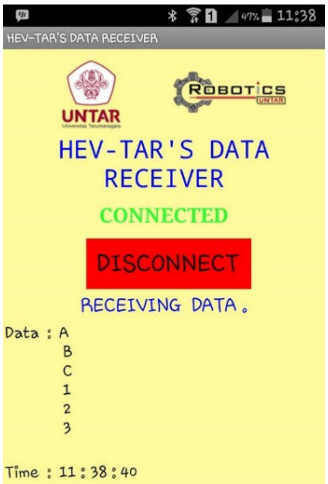
The electric current flowing to the electric motor is a crucial parameter measured in this system; it can be used to indicate the vehicle's traction load, energy consumption, and the threshold for propulsion shifting. The Allegro ACS712 is used in the sensing unit, and the sensor is measured using the Hall effect current sensor method [19].

4) Speed sensor module

This module consists of two measured parameters: the internal combustion rotation speed is measured using an internal magnetic pickup coil sensor attached built into the flywheel because the data from this sensor is a sinusoidal form, and the voltage level differences between the controller and the sensor, then an optocoupler is added to this module and then output data from optocoupler are sent to the master controller, and then the electric motor rotation speed also measured using the inductive proximity sensor attached to the in-wheel electric BLDC motor [20] at the rear wheel and an optocoupler used in this module.

5) Android smartphone

This module sends sensor data to the Android smartphone, enabling convenient data collection while the vehicle is in motion. The Bluetooth connection is



(a)

(b)

Figure 3. (a) user interface of the data receiver in Android apps; (b) visual representation of the modified accelerator handle.

used to transfer data wirelessly and in real time while the vehicle is running, with data sent 5 times per second. The smartphone application is designed for this function, and, as shown on the left side of Figure 3, the data is sent wirelessly via Bluetooth.

6) Electric motor module

The primary purpose of this module is to activate the electric motor and control its speed. The accelerator handle sensor is attached to the throttle accelerator handle of the internal combustion engine. This module can adjust the sensing value sent to the controller to accommodate the smooth transition between the propulsion systems.

7) Internal combustion engine module

The module used a relay to switch the motorcycle's internal combustion engine on and off. This module doesn't operate the engine on its own; it only cuts/off the ignition coil.

8) Engine starting module

This engine starter module operates the vehicle's crank starter motor to start the engine. However, if the engine fails to start, the system will repeat the process until it succeeds. This attempt was repeated only three times before the system indicated to the driver that the engine had failed to start and sent a failure indication to the driver.

9) Accelerator handle

It uses a modified motorcycle accelerator handle with an additional, coupled hall sensor at the end of the device to provide a signal to the microcontroller. The visual of this device is shown on the right side of Figure 3. This accelerator handle also mechanically pulls the throttle valve of the internal combustion engine (ICE). To give a synchronized signal on both the ICE and the electric motor, this device has been calibrated and synchronized.

C. Automatic hybrid control system operation

The operating system is divided into three main modes: Internal combustion engine, electric, and hybrid mode, controlled by the three-way switch attached to the left steering handle of the driver. The internal combustion engine mode operates as a typical motorcycle. The electric motor mode operates exclusively with the electric motor used to propel the vehicle, and additionally, the system can detect the battery's state of charge. If the battery doesn't have enough power, the low-battery indicator will illuminate, and the electric motor won't start.

The third mode is the hybrid mode, which is the most complex system. Before the system starts, the microcontroller checks the battery's state of charge. If the battery is below 30 % state of charge (SOC), the system will automatically start the engine, and the vehicle will run on an internal combustion engine. However, if the battery's SOC exceeds 30 %, the system will activate the electric motor. According to input from the accelerator handle sensors, the electric motor will rotate until the vehicle reaches the upper-speed threshold of 32 km/h. Then, the system automatically turns on the engine. After the engine has run, the sensor detects rotation within a specified period of time, indicating that the engine has started. The system automatically shuts off the electrical motor, and the vehicle continues to run with the engine. The vehicle runs with the engine at cruising speed until it decelerates/brakes, and the vehicle speed reaches a lower threshold of 18 km/h. Then, the system automatically shuts down the engine's ignition system

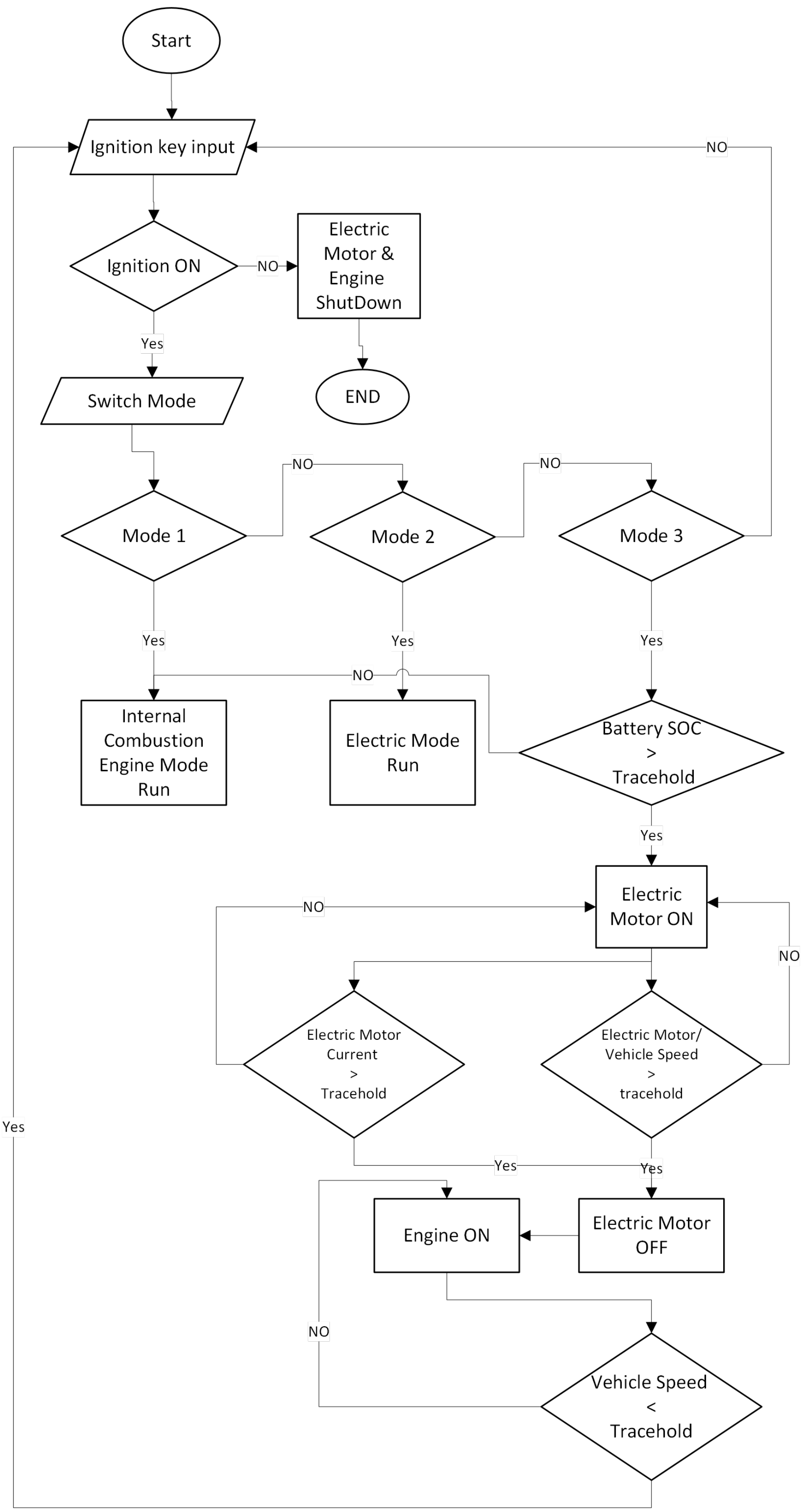


Figure 4. Automatic hybrid algorithm.

and continues with the electric motor. The algorithm of the automatic hybrid control system is shown in detail in the algorithm flowchart in Figure 4.

In order to enhance vehicle stability and ensure smoother performance during propulsion changes, a time-dependent algorithm has been implemented. This sophisticated algorithm effectively minimizes the vehicle's responsiveness to shifts in propulsion as it nears either the upper or lower threshold. The primary purpose of this system is to prevent unnecessary or erratic shifting between propulsion modes, particularly in the event of any data anomalies that may arise during operation. By doing so, the algorithm contributes to a more reliable and seamless driving experience, safeguarding against potential disruptions that could affect overall vehicle performance. In such a condition, if the internal combustion engine fails to start as controlled by the system, the electric motor will continue running. Meanwhile, the system will indicate engine failure to the driver. The other condition, which occurs when the vehicle is running using the electric motor and the vehicle load is increasing, as indicated by the electric current sensor, triggers the increased vehicle load signal. Consequently, the system starts the internal combustion engine. However, when the upper vehicle speed threshold has not been reached, the engine provides torque assist to the vehicle.

II. Experimental Methods

The assessment process for the hybrid electric motorcycle involves two primary phases. Initially, the emphasis is on testing the functionality of individual modules, including the battery management system, electric motor, internal combustion engine, power electronics, and control unit. Each module undergoes extensive testing to evaluate performance metrics, including performance, power consumption, and system reliability.

After successfully validating each module, the next step is to integrate the modules and test the entire system on a testbed. The motorcycle will undergo various simulated riding conditions to assess its overall performance, including power output, energy efficiency, and the effectiveness of the control system. The data gathered from these tests will be carefully analyzed to evaluate the system's stability, reliability, and possible areas for improvement. The experiment will conclude with an evaluation of the hybrid system's functionality and recommendations for further enhancements.

A. Module testing

To ensure each module is functioning correctly, it must pass the test. Each module was tested and calibrated during the experiment. The experimental types of equipment used in these tests are:

- Digital multimeter brand Sanwa, type CD800A
- DC amperemeter brand Yokogawa model 2011 37
- Digital tachometer brand Ono Sokki, type HT-4100
- Oscilloscope

The voltage sensor module was tested by comparing the output voltage from the module with the reading in the multimeter, and the current sensor module was tested in a circuit. The reading between the module and the ampere meter reading was then compared; both the speed control module was tested by comparing the reading from the tachometer and the speed rotation data from the module at any speed level, the last electric motor module was tested by giving the motor a pulse width modulator signal to the motor and measure the rotation speed, current flowing and the signal voltage.

B. System testing

The integrated system controls were tested in a test bed; after all hardware components had been installed, the vehicle was connected to the test bed. The system is tested in three operating modes: internal combustion engine mode, electric motor mode, and hybrid mode. In the first mode, the driver manually started the engine, and the throttle handle's speed control accelerated until the speed limit was reached, then maintained that speed for some time. Then, the throttle handle speed control decelerated until the vehicle's wheels stopped, and the collected data included engine rotation speed, battery voltage, electrical current, and vehicle speed.

The second mode was the electric motor mode. The vehicle is driven using the electric motor in a testbed. The accelerator handle controlled the acceleration, cruising speed, and deceleration. All the data captured were battery voltage level, electric motor rotation speed, engine rotation speed, and electrical current.

The third mode was the hybrid mode. This similar method was implemented, but with both propulsion systems activated using a hybrid control system. The data collected were engine rotation speed, electric motor rotation speed, electric current, and voltage level. All methods were conducted, and data were collected using the data logger sent by the microcontroller to the Android app at a rate of 5 times per second.

III. Results and Discussions

1) Results of the module testing

The voltage sensor module has undergone multiple testing iterations to ensure accuracy. Measurements are taken by comparing the data obtained from measured voltages with voltage readings from the microcontroller. The results of the voltage sensor module data are depicted in Figure 5, which shows the data between the measured value and the reading, with an average error of 0.05 %. This finding indicates that the voltage sensor can be considered acceptable. This error originates from the component sensor tolerance, as the resistor is used in the sensor as a voltage divider. Each resistor has

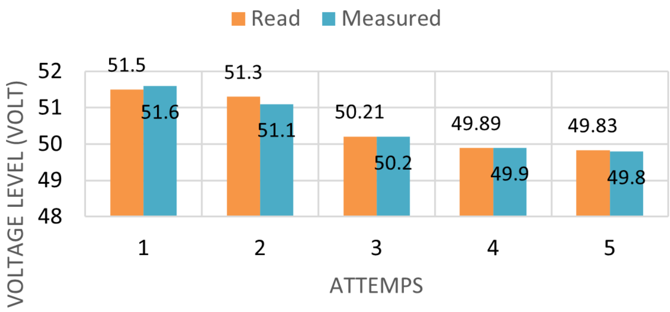


Figure 5. Voltage sensor module test results.

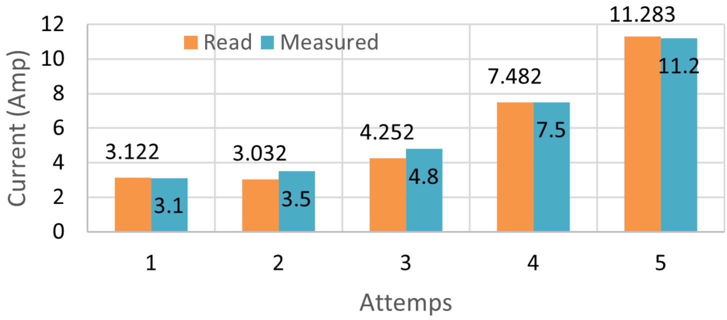


Figure 6. Electric current sensor module test results.

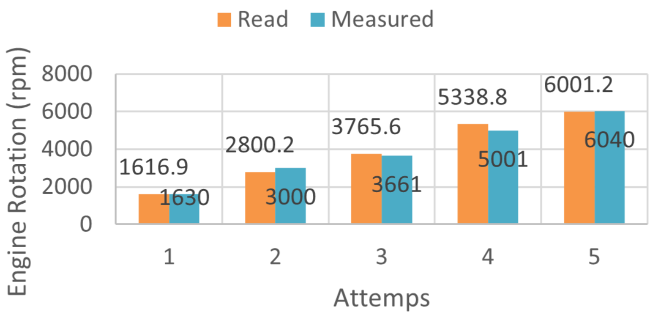


Figure 7. Engine rotation speed sensor module test results.

a tolerance of resistive value, so this tolerance affects the overall result read by the microcontroller.

The electrical current module involved running an electric motor at different speeds and measuring the current with an ammeter. The readings from the sensor are compared with those from the ammeter, and the results are presented in Figure 6.

Based on the chart above, the electric motor runs at a low speed of 100 rpm to 500 rpm, showing a total of five attempts. Then, the calculated average error is 4.715 %, which is considered acceptable. The trends in this data indicate a linear relationship between the increasing rotation speed of the motor and the corresponding increase in electrical current, a characteristic of DC motors. The next module to be tested was the speed sensor module. The engine rotation speed module was tested by comparing the measured value with the reading value at the display; the results of the data are shown in Figure 7.

The comparison chart above shows the rotation speed of the internal combustion engine sensor and the measured values. The test results indicate some discrepancy between the measured data and the data read by the module. However, the average error is only 3.548 %, which is considered acceptable.

Proceeding with testing the electrical motor module, which regulates the rotation speed of the electric motor. The tests were conducted by activating the motor driver with a 10-bit pulse width modulation (PWM) signal from the controller, ranging from 200 to 1000 at intervals of 50. The recorded data includes the PWM output voltage level, electric current, and rotation speed, as well as the rotation speed measured with a tachometer. The results of the data are displayed in Figure 8.

The Voltage signal and Current value vary between 0 and 5, while the read and measured values are between 0 and 500 rpm, as indicated on the right side of the Y-axis in Figure 8. The test results indicate that the rotation speed value displayed on the unit and the measured value have an error of approximately 0.42 %, which is considered acceptable.

2) Results of the system testing

To ensure the system operates effectively, it needs to be tested across various scenarios. This section addresses three specific scenarios. The experimental data presented reveal a relationship between engine and motor speeds, both of which are transformed into vehicle speed by accounting for the vehicle's wheel diameter. This conversion allows us to express speed in kilometers per hour (km/h), providing a clear, standardized measure of how the vehicle is traveling. By understanding these dynamics, we can gain insights into the vehicle's overall performance characteristics. The first scenario involves the internal combustion engine mode, where the vehicle control system operates the engine independently. The driver manually starts the engine using the switch button after selecting the internal combustion engine mode on the selector switch. Following this, the driver continuously accelerates the engine using the accelerator handle until reaching a certain speed, holds it for a period, and then decelerates until the engine stops. This test was repeated several times, and the resulting data are displayed in Figure 9.

The data presented in Figure 9 illustrates the performance of the engine as it accelerates, ultimately achieving a peak speed of 97 km/h. Notably, throughout this process, the electric motor shows no signs of activity, remaining completely stationary. This occurs due to the in-wheel one-way coupling activated during the engine mode. This device prevents the electric motor from overcharging the battery during high-speed wheel rotation. The voltage level consistently remains stable at 52 volts, indicating no voltage drop while the engine is running. Additionally, the electrical current remains steady, with no fluctuations or signals detected.

Despite the engine's rotation speed displaying some instability, it is important to highlight that the control system mode operates without any issues, functioning as intended. This erratic behavior in the engine's rotation speed can be attributed to the specific conditions of the testbed: the wheels are allowed to spin freely, avoiding any friction that would normally occur on a road surface.

The second scenario test mode is the motorcycle operating only on an electric motor, with the internal combustion engine off; in this mode, it mimics the driving conditions of an electric vehicle. The result of this mode test is shown in Figure 10.

Figure 10 clearly shows a significant correlation between motor current and motor speed, indicating a direct relationship in which current increases proportionally with speed. This pattern indicates that the electric motor module is functioning optimally. During the experimentation phase, as the motor approached its maximum speed, minor voltage drops were observed, a phenomenon likely linked to the higher energy demand from the battery. The testbed showcased the electric motor's reaching a peak speed of 42 km/h under no-load conditions, while the maximum electrical current recorded was 9.3 Amperes. It is worth noting that a voltage drop occurred at both the motor’s peak speed and the maximum current draw, highlighting the dynamic nature of electrical performance. Since the engine was not operating in this mode, there was no rotational speed of the engine. The overall results show that the electric motor is indeed operating within the expected parameters, confirming its reliability and performance capabilities.

The last test mode is hybrid; this mode operates both propulsion systems, an electric motor, and an internal combustion engine in combination so that the vehicle can operate efficiently. Test results are shown in Figure 11.

Figure 8. Electric motor driver module test results.

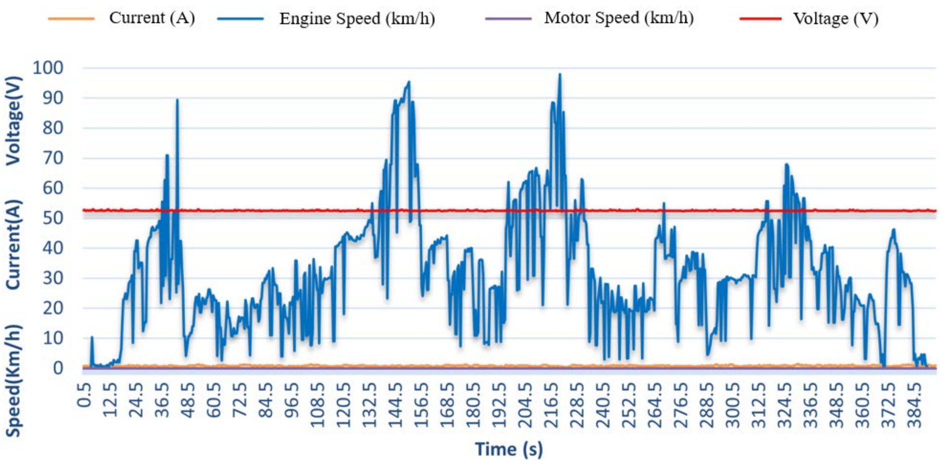


Figure 9. Result data on internal combustion engine mode test.

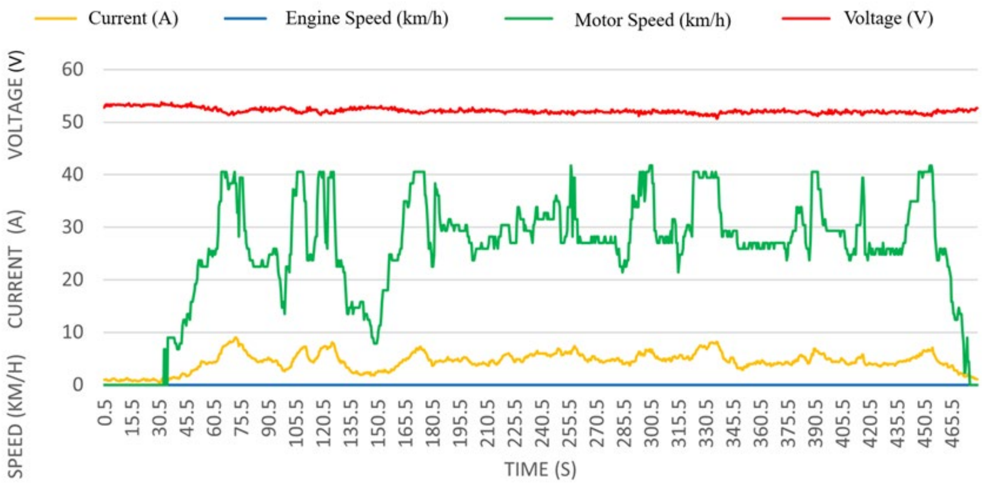


Figure 10. Result data on electric motor mode test.

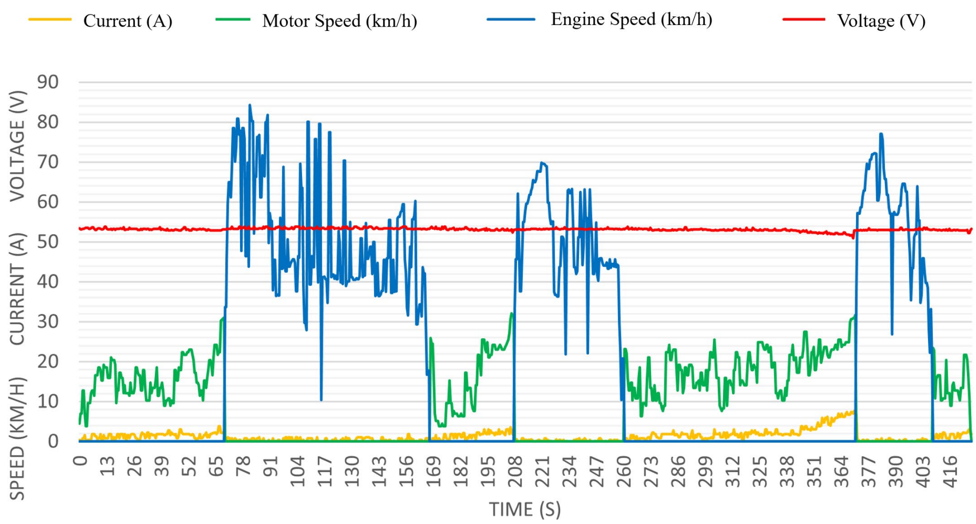


Figure 11. Result data on hybrid test mode.

Figure 11 illustrates that the electric motor accelerates up to 32 km/h. At the 69th second, the internal combustion engine automatically takes over. The electric motor then shuts down, and the vehicle continues with the engine until it reaches a maximum speed of about 82 km/h. At the 115th second, there is a sudden decrease in speed, but the system can handle this without shifting the propulsion, thanks to the time-dependent algorithm implemented in the control system. The engine continues to run smoothly without interruption. At the 170th second, the engine decelerates to 18 km/h. The electric motor takes over propulsion at this point, causing the engine to shut down automatically, and the system runs on the electric motor only. This cycle repeats as indicated in the graph, showcasing the system's ability to perform smooth propulsion shifting at the 69th, 207th, and 368th seconds. Also, the various attempts show that the propulsion shift is highly consistent at both the upper and lower speed thresholds, as shown in Figure 11. The engine handles the speed take-off seamlessly. From the set of operation test scenarios, the simple hybrid control system demonstrates its operational performance and works correctly as expected.

IV. Conclusion

The design system's control has demonstrated commendable performance, with each module operating within acceptable parameters and the overall control system functioning effectively. The design effectively utilizes common components available in the market, showcasing its reliability. Additionally, this approach indicates significant potential for developing a hybrid motorcycle. The various driving modes are also performing well, as evidenced by the accompanying graphs for each mode, which show the control algorithm's performance as intended. In hybrid mode, the propulsion shifting is functioning as intended on every attempt of the driving scenario. Nevertheless, it is essential to consider that the threshold for propulsion switching may need to be adjusted in future research, as it significantly affects the smooth transition between propulsion systems. To gain deeper insights into the hybrid vehicle's performance and energy consumption, conducting real-world driving tests on the road will be beneficial.

Acknowledgements

The researchers would like to thank the Institute for Research and Community Service (LPPM) of Universitas Tarumanagara for their financial support through the research grant. Their funding was essential to the successful completion of this project. We would also like to thank P.T. Astra Honda Motor for providing the motorcycle unit as research equipment.

Declarations

Author contribution

D.W. Utama: Supervision; conceptualization; experimental design; data analysis; and writing of the original draft of the manuscript, Funding acquisition. **H.S. Utama**: Experimental supervision; experimental setup and equipment calibration; and data analysis. **R. Wardy**: Conducting the experiments; equipment calibration; installation of experimental apparatus; and data collection. All authors contributed equally as the primary contributors of this paper. All authors read and approved the final paper.

Funding statement

This research is fully funded by the Institute of Research and Community Engagement of Universitas Tarumanagara under the regular grant scheme.

Competing interest

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

The use of AI or AI-assisted technologies

During the preparation of this work, the authors used **Grammarly** to do a grammar check of this article. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Additional information

Reprints and permission: information is available at https://mev.brin.go.id/.

Publisher's Note: National Research and Innovation Agency (BRIN) remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

[1] M. Yuniza, I. Pratama, & R. Ramadhaniati, "Indonesia's incentive policies on electric vehicles: The questionable effort from the government", *International Journal of Energy Economics and Policy*, vol. 11, no. 5, p. 434-440, 2021.

[2] K. Sukra, "Effects of battery state of charge on fuel economy of hybrid electric vehicles: An analysis using the un ece r101 method", *Evergreen*, vol. 10, no. 3, p. 1770-1775, 2023.

[3] M. Fajratama, "Interfirm partnerships and organizational innovation for indonesian automotive component manufacturers facing the transition to battery electric vehicles", *Journal of Law and Sustainable Development*, vol. 12, no. 3, p. e3265, 2024.

[4] R. Riyanto, S. Riyadi, C. Nuryakin, & N. Massie, "Estimating the total cost of ownership (TCO) of electrified vehicle in indonesia", *2019 6th International Conference on Electric Vehicular Technology (ICEVT)*, 2019.

[5] M. Saputra, "Analysis of factors influencing intention to adopt battery electric vehicle in indonesia", *Adi Journal on Recent Innovation (Ajri)*, vol. 5, no. 2, p. 100-109, 2023.

[6] J. Balinado *et al.*, "Consumer perception and purchase intention on the transition to hybrid and electric vehicles for sustainable mobility and transportation in the philippines", 2023.
[7] B. Budiono, "Indonesia's movement to become the main player in the electric vehicle (EV) market in southeast asia", *AJESH*, vol. 3, no. 4, p. 866-882, 2024.
[8] M. Maghfiroh, A. Pandyaswargo, & H. Onoda, "Current readiness status of electric vehicles in indonesia: Multistakeholder perceptions", *Sustainability*, vol. 13, no. 23, p. 13177, 2021.
[9] P. Chen, D. Shen, C. Yang, & K. Huang, "Development of a hybrid electric motorcycle that accords energy efficiency and controllability via an inverse differential gear and power mode switching control", *Applied Sciences*, vol. 9, no. 9, p. 1787, 2019.
[10] P. Iodice, E. Fornaro, & M. Cardone, "Hybrid propulsion in si engines for new generation motorcycles: A numerical-experimental approach to assess power requirements and emission performance", *Energies*, vol. 15, no. 17, p. 6312, 2022.
[11] Y. Tian, J. Liu, Q. Yao, & K. Li, "Optimal control strategy for parallel plug-in hybrid electric vehicles based on dynamic programming", *World Electric Vehicle Journal*, vol. 12, no. 2, p. 85, 2021.
[12] R. Nurdiansyah, N. A. Windarko, R. Rakhmawati, and M. A. Haq, "State of charge estimation of ultracapacitor based on equivalent circuit model using adaptive neuro-fuzzy inference system," *Journal of Mechatronics, Electrical Power, and Vehicular Technology*, vol. 13, pp. 60–71, 2022.
[13] M. Suthar, "Enhancing electric vehicle performance with a hybrid PI-sliding mode controller for battery supercapacitor integration", *International Journal of Energy Research*, vol. 2024, p. 1-13, 2024.
[14] Y. Lashin, "A centralized fleet management system for electrified transportation", *Journal of Physics Conference Series*, vol. 2811, no. 1, p. 012025, 2024.
[15] H. Li, Y. Zhou, H. Xiong, B. Fu, & Z. Huang, "Real-time control strategy for CVT-based hybrid electric vehicles considering drivability constraints", *Applied Sciences*, vol. 9, no. 10, p. 2074, 2019.
[16] L. Timilsina, "A real-time prognostic-based control framework for hybrid electric vehicles", *IEEE Access*, vol. 11, p. 127589-127607, 2023.
[17] Ratih M. S., Fahrul F., Adhika K., Irwan M. "Implementation of modified trapezoidal commutation scheme for speed control of 1 kW BLDC motor," *Journal of Mechatronics, Electrical Power, and Vehicular Technology*, vol. 14, no. 2 (2023).
[18] T. Girijaprasanna and C. Dhanamjayulu, "A review on different state of battery charge estimation techniques and management systems for EV applications," *Electronics*, vol. 11, no. 11:1795, 2022.
[19] Current Sensing in Motor Drives, Copyright 2023, Allegro MicroSystems, LLC. (Allegro Microsystem) Retrieved 11, 2025.
[20] A. Ulinuha and Agita Cahya Ramadhany, "The comparison of electric motor performance in powering electric motorcycle," in *E3S Web of Conferences*, vol. 500, p. 03011, 2024.