

Electrical Design of Two-Wheeler Electric Vehicle

G. Rajasekhhar Yadav^{1*}, Gautam Moni Patro¹, D. Anitha², S. K. V. Monish², N. Upendra Kumar²

¹Assistant Professor, Department of Electrical and Electronics Engineering, Avanathi Institute of Engineering & Technology, Makavarapalem, India

²UG Student, Department of Electrical and Electronics Engineering, Avanathi Institute of Engineering & Technology, Makavarapalem, India

Abstract: This paper presents an electrical design study of a two-wheeler electric vehicle, focusing on the major electrical and electronic subsystems required for propulsion, control, power conversion and rider interaction. The work covers the overall two-wheeler architecture, battery and electrical supply, wiring harness, brushless DC (BLDC) motor, motor controller, DC-DC converter, throttle and speed-control system. The design discussion follows the project implementation in which an electric two-wheeler uses a BLDC hub motor, an electronic controller, a DC-DC converter and a handlebar-mounted throttle. The electrical architecture is considered as an interconnected system in which the battery supplies the propulsion drive, the controller regulates motor operation, the converter supplies lower-voltage auxiliary loads, and the throttle provides the rider command. The project implementation reports a BLDC motor with a maximum speed of approximately 28 km/h and a mass of 2.1 kg, together with a 60 Vdc controller having a current limit of approximately 25±1 A and a 120° phase angle. The paper also discusses regenerative braking, protection, voltage regulation and the role of the wiring harness in reliable energy and signal distribution. The study demonstrates that coordinated selection and integration of these subsystems is essential for safe, efficient and practical electric two-wheeler operation.

Keywords: Electric vehicle, two-wheeler, BLDC motor, motor controller, DC-DC converter, wiring harness, throttle, speed control, regenerative braking.

1. Introduction

Electric vehicles are propelled by electric motors supplied from rechargeable energy-storage systems. In two-wheeler applications, the compact vehicle structure requires the electrical components to be lightweight, reliable and efficiently integrated. The source project describes a two-wheeler electric vehicle in which the battery, motor, controller, converter, throttle, wiring harness, wheels, brakes, deck and suspension form the principal subsystems. The electrical design is therefore not limited to the motor alone; it involves the complete energy path from the battery to the traction motor and the associated control and auxiliary circuits.

The development of electric motorcycles and scooters has progressed from early electric bicycle concepts to modern battery-powered scooters and motorcycles. Early patents for electric bicycles were filed by Ogden Bolton Jr. and Hosea W. Libbey in 1895 [1], [2]. Historical development subsequently included experimental electric motorcycles, high-performance electric racing vehicles and, more recently, commercial electric

scooter manufacturing. The source report documents this development and relates it to the present growth of two-wheeler electric mobility [3]–[6].

Modern electric scooters require coordinated control of motor speed and torque, battery energy, auxiliary voltage levels and rider commands. BLDC motors are particularly suitable for compact electric mobility because they eliminate mechanical brushes and use electronic commutation. Recent research has also demonstrated the use of hardware-in-the-loop modelling and controller tuning for BLDC-based electric scooters under varying operating conditions [7].

2. Two-Wheeler Electric Vehicle Architecture

The electrical architecture considered in the project consists of the battery, bidirectional power-conversion stage, inverter/controller, BLDC motor, throttle and vehicle load. Operating conditions such as road slope, vehicle mass and wind speed influence the torque and power demand. The controller receives the rider command and sensor feedback and regulates the power supplied to the motor. This arrangement corresponds to the project block diagram and provides the basis for the electrical design.

General Electrical Architecture of Two-Wheeler Electric Vehicle

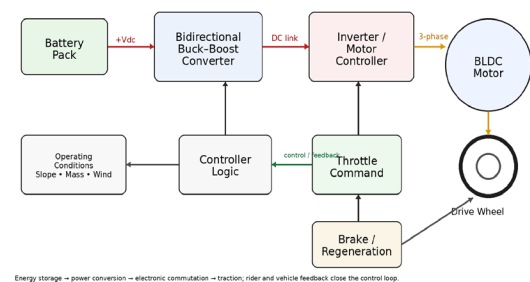


Fig. 1. General electrical architecture of the two-wheeler electric vehicle

The basic operating sequence begins with energy stored in the battery. The battery output is processed by the controller and power-conversion stages before being applied to the motor. The BLDC motor converts electrical energy into mechanical torque and drives the wheel. During braking, the motor can operate as a generator when the controller and battery conditions permit regenerative energy recovery. The architecture therefore combines energy storage, power electronics, electrical machines and feedback control [7].

*Corresponding author: rajasekharyadav.g@gmail.com

3. Electrical Power and Wiring Harness

The wiring harness acts as the electrical interconnection network of the two-wheeler. It carries power and, where required, control and sensor information between the battery, controller, motor, throttle, switches and auxiliary loads. The project describes the harness as a collection of wires, connectors, terminations and protective elements arranged into a cohesive electrical system.

For an EV harness, conductor selection must consider current-carrying capacity, insulation, temperature, mechanical vibration and routing. Connectors must provide reliable electrical contact and suitable protection against environmental exposure. Protective sheathing helps isolate conductors from abrasion, moisture and mechanical damage. Proper routing and clamping reduce the likelihood of chafing, loose connections and electrical faults.

- Power conductors distribute battery and auxiliary electrical power.
- Signal conductors carry throttle, Hall-sensor and control information.
- Connectors provide removable and reliable electrical interfaces.
- Protective sheathing reduces exposure to vibration, abrasion and moisture.
- Correct routing and colour identification support installation and maintenance.

The project also discusses colour classification for power, control, lighting, charging and safety circuits. In practical implementation, the exact colour convention should follow the applicable vehicle and wiring standard rather than relying only on a generic colour scheme.

4. BLDC Motor for Electric Two-Wheeler

The project identifies the BLDC motor as the main traction motor. A BLDC motor uses permanent magnets on the rotor and electronically switched stator windings. Hall-effect feedback can be used to determine rotor position, while the electronic controller energizes the appropriate phase sequence. This eliminates the mechanical commutator and brushes used in a conventional brushed DC motor.

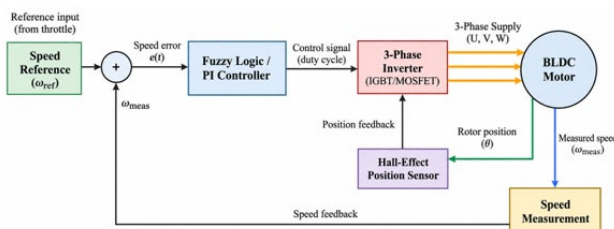


Fig. 2. BLDC motor control block diagram

The principal advantages described in the source are high efficiency, high torque capability, compact construction, low maintenance and suitability for propulsion. BLDC motors can also operate in regenerative mode during deceleration when the controller and battery are designed for bidirectional power flow. These characteristics make BLDC drives appropriate for

lightweight electric two-wheelers [7].

The motor used in the project is reported as a hub-type BLDC motor with a maximum speed of 28 km/h and a mass of approximately 2.1 kg. The reported shaft information includes a D-type shaft, 50 mm shaft length and approximately 16 mm round-side diameter with a 14.5 mm flat-side dimension.

A. Motor Controller

The motor controller is the principal power-electronic control unit between the battery and traction motor. It interprets the throttle and other control inputs and regulates motor voltage, current, speed and torque. The source project describes the controller as combining power electronics and embedded control functions. Depending on the architecture, the controller can also support regenerative braking, protection and thermal supervision.

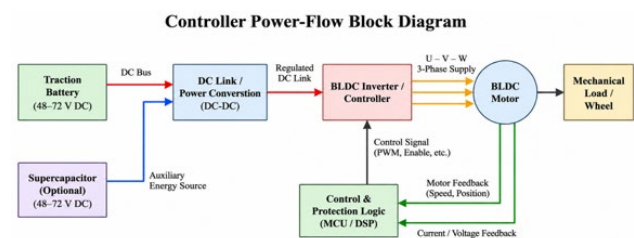


Fig. 3. Controller power-flow block diagram used in the project

The project discusses AC and DC controller classifications and identifies brushed-DC, BLDC, hybrid, field-oriented-control and inverter-less controller approaches. For the implemented two-wheeler, the BLDC controller is the relevant choice. The controller specification reported in the project is approximately 60 Vdc operating voltage, 25 ± 1 A current limit and 120° phase angle.

Controller functions include throttle interpretation, current regulation, speed and torque control, regenerative braking, battery protection and thermal protection. In a practical vehicle, these functions must be coordinated with the battery management system and motor sensors to prevent overcurrent, excessive temperature and abnormal operating conditions.

B. DC-DC Converter

The DC-DC converter provides voltage conversion between the traction battery and lower-voltage vehicle electronics. Although the traction battery supplies the motor drive at a relatively high voltage, auxiliary components such as lighting, instrumentation, sensors and communication circuits may require lower and regulated voltage levels. The converter therefore improves electrical compatibility and allows auxiliary loads to operate without a separate battery.

The project identifies voltage regulation, efficiency, compactness, protection and, where required, galvanic isolation as important converter characteristics. Protection functions may include overvoltage, undervoltage and short-circuit protection. The implemented converter is reported with an input range of approximately 36–72 V and a 12 V-class output.

C. Throttle and Speed-Control System

The throttle provides the primary rider command for vehicle

acceleration. In the project, the throttle is described as a handlebar-mounted input that may use a potentiometer or Hall-effect sensing element. Rotation of the throttle changes the sensor output, producing an electrical signal proportional to the requested power or speed. The controller processes this signal and adjusts the motor power accordingly.

Throttle Connection and Signal-Generation Arrangement

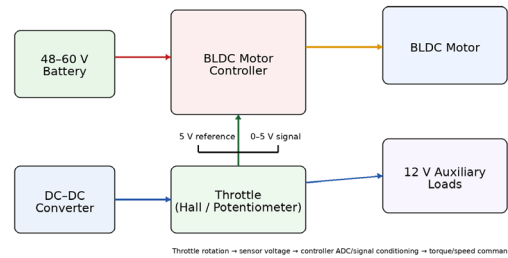


Fig. 4. Basic throttle connection and signal-generation arrangement

The throttle signal is an analogue input that can be sampled by an analogue-to-digital converter and processed by the controller. Filtering and signal conditioning can be used to obtain a stable response. The controller can additionally impose a maximum-speed limit and shape the acceleration response so that small throttle changes produce predictable vehicle behaviour.

The project also discusses the speedometer. Vehicle speed can be obtained from wheel-speed or motor-related sensing and processed by an electronic control unit before being displayed to the rider. In addition to speed indication, an advanced instrument cluster can provide trip distance, battery information, energy consumption and diagnostic warnings.

5. Integrated Electrical Design and Implementation

The electrical design can be viewed as an energy-and-information chain. The battery is the primary energy source; the controller determines the power delivered to the BLDC motor; the motor converts electrical power into traction torque; and the DC-DC converter supplies auxiliary electrical loads. The throttle provides the rider command, while sensors provide feedback to the controller. The wiring harness links these elements and must be designed for both electrical performance and mechanical reliability.

- Battery-to-controller connections must be sized for the maximum expected current.
- Three-phase motor conductors and Hall-sensor wiring must be securely routed and protected.
- Throttle wiring should be isolated from high-current switching conductors as far as practical.
- The DC-DC converter should provide a regulated auxiliary supply over the battery operating range.
- Controller protection should address overcurrent, abnormal voltage and overheating.
- Regenerative braking should be enabled only when battery and controller conditions permit energy recovery.

6. Results and Discussion

The project implementation demonstrates the integration of the major electrical subsystems in a two-wheeler platform. The selected BLDC hub motor provides propulsion, while the electronic controller manages motor operation from rider inputs and sensor feedback. The reported motor maximum speed is 28 km/h and motor mass is 2.1 kg. The controller is reported as a 60 Vdc unit with a current limit of approximately 25 ± 1 A and a 120° phase angle.

The converter provides a lower-voltage interface for auxiliary electrical equipment, while the throttle converts rider input into a control signal. The wiring harness provides the interconnection path for power, control and sensor circuits. Taken together, these elements form a compact electrical system suitable for a two-wheeler application. The source project emphasizes that efficiency, protection, reliability and correct subsystem matching are essential for practical operation.

The design also illustrates the importance of coordinated control. Increasing throttle demand requires the controller to increase motor torque while remaining within current and thermal limits. During deceleration, regenerative braking can recover part of the kinetic energy when the electrical system can safely accept the returned power. This coordinated behaviour is consistent with the control architecture discussed in the source material and with published work on BLDC electric-scooter control [7].

A. Advantages and Limitations

- BLDC propulsion provides high efficiency, compact construction and reduced mechanical maintenance.
- Electronic control enables precise speed and torque regulation and supports regenerative braking.
- A DC-DC converter allows high-voltage battery power to be used by lower-voltage auxiliary systems.
- A structured wiring harness improves maintainability and protects electrical interconnections.
- The compact two-wheeler architecture supports low-emission urban transportation.
- Electrical performance depends on correct battery, controller, motor and converter matching.
- Thermal management and protection are necessary under high-current or demanding operating conditions.
- Harness routing, connectors and insulation must withstand vibration, moisture and mechanical stress.

7. Conclusion

This paper presented the electrical design of a two-wheeler electric vehicle based on the project source. The design integrates a battery-powered BLDC traction motor, motor controller, DC-DC converter, throttle, speed-control system and wiring harness. The BLDC motor provides compact and efficient propulsion, while the controller regulates motor operation and can support regenerative braking. The DC-DC converter supplies regulated auxiliary power, and the throttle

provides the rider interface for acceleration and speed control. The reported implementation values provide a practical reference for the selected vehicle configuration.

Overall, reliable two-wheeler EV operation depends on the coordinated design of power delivery, electrical-machine control, auxiliary power conversion, sensing and wiring. Future development can focus on improved battery management, higher-efficiency power converters, advanced motor-control algorithms, improved thermal management, connectivity and more comprehensive vehicle diagnostics.

References

- [1] O. Bolton, Jr., "Electrical bicycle," U.S. Patent 552 271, Dec. 31, 1895.
- [2] H. W. Libbey, "Electric bicycle," U.S. Patent 596 272, Dec. 28, 1897.
- [3] M. Partridge, *Motorcycle Pioneers: The Men, the Machines, the Events 1860–1930*. London, U.K.: David & Charles, 1976.
- [4] "Electric motorcycle," *Popular Mechanics*, vol. 16, no. 4, Oct. 1911.
- [5] E. Tragatsch, *Alle Motorräder 1894–1981: Eine Typengeschichte*. Stuttgart, Germany: Motorbuch Verlag, 1997.
- [6] Grace's Guide, "Ransomes, Sims and Jefferies: Motorcycles." [Online]. Available: <https://www.gracesguide.co.uk/>
- [7] L. E. Moreno-Suarez, L. Morales-Velazquez, A. Y. Jaen-Cuellar, and R. A. Osornio-Rios, "Hardware-in-the-loop scheme of linear controllers tuned through genetic algorithms for BLDC motor used in electric scooter under variable operation conditions," *Machines*, vol. 11, no. 6, Art. no. 663, Jun. 2023.
- [8] Smithsonian Institution, "Alkali fuel cell history." [Online]. Available: <https://americanhistory.si.edu/>
- [9] "Post 1953 Indian motorcycle history." [Online]. Available: <https://www.indianmotorcycle.com/>
- [10] "Electric motorcycle history and development," *Cycle World*, vol. 31, no. 4, pp. 108–111, Apr. 1992.
- [11] AMA Motorcycle Hall of Fame, "Mike Corbin." [Online]. Available: <https://www.motorcyclemuseum.org/>
- [12] L. A. Noeth, *Bonneville: The Fastest Place on Earth*. Minneapolis, MN, USA: MotorBooks International, 2002, p. 136.
- [13] Gizmag, "Peugeot's incredibly frugal electric E-Vivacity scooter," *New Atlas*, Jan. 25, 2010. [Online]. Available: <https://newatlas.com/>
- [14] U.S. National Electric Drag Racing Association, "The Roger Hedlund 150 mph club." [Online]. Available: <https://www.nedra.com/>
- [15] Guinness World Records, "Fastest electric motorcycle (prototype)." [Online]. Available: <https://www.guinnessworldrecords.com/>
- [16] Wired, "Lightning's electric motorcycle and Pikes Peak development." [Online]. Available: <https://www.wired.com/>
- [17] "Electric motorcycle land-speed record / Lightning motorcycle," *Los Angeles Times*, Jul. 2, 2013. [Online]. Available: <https://www.latimes.com/>
- [18] S. Rai, "500-acre Bengaluru campus for world's largest e-scooter factory," *NDTV*, Mar. 8, 2021. [Online]. Available: <https://www.ndtv.com/india-news/ola-founder-bhavish-aggarwal-plans-worlds-largest-e-scooter-factory-near-bengaluru-2385922>
- [19] L. Mathai, "Meet Odysse Electric: India's first on-sale sportsbike-inspired electric bike maker," *The Financial Express*, Nov. 19, 2020. [Online]. Available: <https://www.financialexpress.com/auto/electric-vehicles/meet-odysse-electric-manufacturer-of-indias-first-sportsbike-inspired-electric-bike-on-sale/2131924/>
- [20] TechSci Research, "Electric two wheeler & its manufacturing," *TechSci Research*, Jun. 2021. [Online]. Available: <https://www.techsciresearch.com/blog/manufacturing-electric-two-wheeler/92.html>
- [21] BENLG, "Electric scooter." [Online]. Available: <https://www.benlg.com/product-category/electric-scooter/>