
WIRING HARNESS DESIGN, CONNECTOR SELECTION, AND WIRING METHODS OF TWO-WHEELER EV

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ABSTRACT

The rapid growth of two-wheeler electric vehicles has increased the importance of reliable electrical interconnection systems. The wiring harness serves as the primary medium for distributing electrical power and transmitting control signals among various vehicle subsystems. Consequently, wiring harness design, connector selection, and wiring methods play a significant role in ensuring vehicle safety, reliability, and performance.

KEYWORDS: Electric Vehicle, Battery Technologies, Wireless Power transfer and Charging System

1. INTRODUCTION

The rapid growth of electric mobility has led to the widespread adoption of electric vehicles across the transportation sector. Among the various categories of electric vehicles, two-wheeler electric vehicles have emerged as an effective solution for urban transportation owing to their high energy efficiency, lower operating costs, reduced environmental impact, and compact design. As the level of electrification within vehicles continues to increase, greater dependence is being placed on electrical and electronic systems for vehicle propulsion, monitoring, control, communication, and safety functions.

A typical two-wheeler electric vehicle consists of several interconnected subsystems including the battery pack, battery management system (BMS), motor controller, traction motor, charging system, instrument cluster, lighting system, sensors, and auxiliary electrical loads. The operation of these subsystems is dependent upon the reliable transmission of electrical power and control signals throughout the vehicle. This requirement is fulfilled through the implementation of a wiring harness system.

The wiring harness is an organized assembly of conductors, connectors, terminals, protective coverings, and fastening elements that collectively establish electrical interconnections between various vehicle components. The wiring harness serves as the primary electrical distribution network of the vehicle and enables the transfer of power, control signals, and communication data among different subsystems. Consequently, the performance, safety, and reliability of the vehicle are significantly influenced by the quality of wiring harness design and implementation.

The design of a wiring harness involves several engineering considerations including conductor selection, current carrying capacity, voltage drop limitations, insulation requirements, routing constraints, thermal performance, mechanical protection, and serviceability. In addition, connector systems must be selected carefully to ensure reliable electrical contact under conditions involving vibration, temperature variations, moisture exposure, and mechanical stress. Appropriate wiring methods must also be adopted to protect conductors from abrasion, thermal damage, electromagnetic interference, and environmental degradation.

2. MODE OF TWO WHEELER ELECTRIC VEHICLES OPERATION

The transportation sector is undergoing a significant transformation due to increasing concerns regarding environmental sustainability, energy security, and reduction of greenhouse gas emissions. Conventional vehicles powered by internal combustion engines are associated with fossil fuel consumption and the emission of pollutants such as carbon dioxide, nitrogen oxides, and particulate matter. Consequently, electric vehicles have emerged as a viable alternative for achieving sustainable transportation.

Among the various categories of electric vehicles, two-wheeler electric vehicles have gained widespread acceptance because of their relatively low energy consumption, compact size, reduced maintenance requirements, and suitability for urban transportation. The advancement of battery technology, power electronics, and electric drive systems has further accelerated the adoption of electric two-wheelers in both developed and developing countries.

A two-wheeler electric vehicle utilizes electrical energy stored within a rechargeable battery pack to provide propulsion. The stored energy is converted into mechanical energy through an electric traction motor controlled by an electronic motor controller. Various electrical and electronic subsystems operate in a coordinated manner to ensure efficient vehicle performance, safety, and reliability. Therefore, a comprehensive understanding of electric vehicle fundamentals is required before studying the electrical architecture and wiring harness systems employed within the vehicle.

The adoption of WPT not only reduces reliance on cumbersome cables but also enhances the flexibility and scalability of power distribution systems, making it a compelling choice in modern engineering and technology landscapes. The roots of Wireless Power Transfer (WPT) systems can be traced back to the visionary concepts of Nikola Tesla in the late 19th century. Tesla, widely acknowledged as a genius in the field, envisioned utilizing the Earth as a conductor for transmitting power globally. Despite scepticism regarding the slow adoption of such technologies, Tesla conducted pioneering experiments in the 1900s, notably at Colorado Springs, employing a resonant transformer known as the Tesla coil. These early experiments demonstrated the feasibility of wireless power transmission, showcasing successful discharges up to 50 kilometres from the source. Although the study of WPT systems has been ongoing for over a century, it gained more momentum in recent years due to EV technology. In literature, Brown et al categorized WPT history into three timelines.

3. ELECTRICAL ARCHITECTURE OF TWO WHEELER ELECTRIC VEHICLES

The performance, efficiency, safety, and reliability of a two-wheeler electric vehicle are primarily determined by its electrical architecture. The electrical architecture represents the arrangement and interconnection of various electrical and electronic subsystems responsible for energy storage, power conversion, propulsion, monitoring, protection, communication, and auxiliary functions. Unlike conventional internal combustion engine vehicles, where mechanical systems dominate vehicle operation, electric vehicles rely extensively on electrical and electronic components to perform essential functions.

A modern two-wheeler electric vehicle consists of several integrated subsystems including the battery pack, Battery Management System (BMS), motor controller, traction motor, charging system, DC-DC converter, instrument cluster, lighting system, sensors, communication networks, and auxiliary loads. These subsystems operate in coordination to ensure efficient power delivery, vehicle control, fault protection, and user interaction.

Electrical power generated or stored within the vehicle must be distributed reliably among various subsystems. Simultaneously, control signals and communication data must be transmitted accurately between electronic modules. Consequently, the design of the electrical architecture directly influences the complexity of the wiring harness, connector systems, and wiring methods employed within the vehicle.

A thorough understanding of the electrical architecture is therefore essential before examining the design and implementation of wiring harness systems. The major electrical subsystems employed in a typical two-wheeler electric vehicle are discussed in this chapter.

The electrical architecture of a two-wheeler electric vehicle is designed to facilitate efficient power flow and communication among different vehicle subsystems. The battery pack serves as the primary energy source and supplies electrical power to the traction system and auxiliary loads. The Battery Management System continuously supervises battery operation to ensure safe and reliable performance.

The motor controller receives electrical power from the battery pack and regulates the voltage and current supplied to the traction motor. Based on rider inputs and operating conditions, the controller adjusts motor speed and torque to achieve the desired vehicle performance. The traction motor subsequently converts electrical energy into mechanical energy, which is transmitted to the drive wheel.

Additional subsystems such as the charging system, DC-DC converter, instrument cluster, lighting circuits, and communication modules support vehicle operation. The charging system replenishes battery energy from an external electrical source, while the DC-DC converter provides regulated low-voltage power for auxiliary circuits. Information related to vehicle speed, battery state of charge, fault conditions, and operating parameters is displayed through the instrument cluster.

The interconnection of these subsystems is achieved through the wiring harness system, which distributes both electrical power and communication signals throughout the vehicle. Figure 1 illustrates the typical electrical architecture of a two-wheeler electric vehicle.

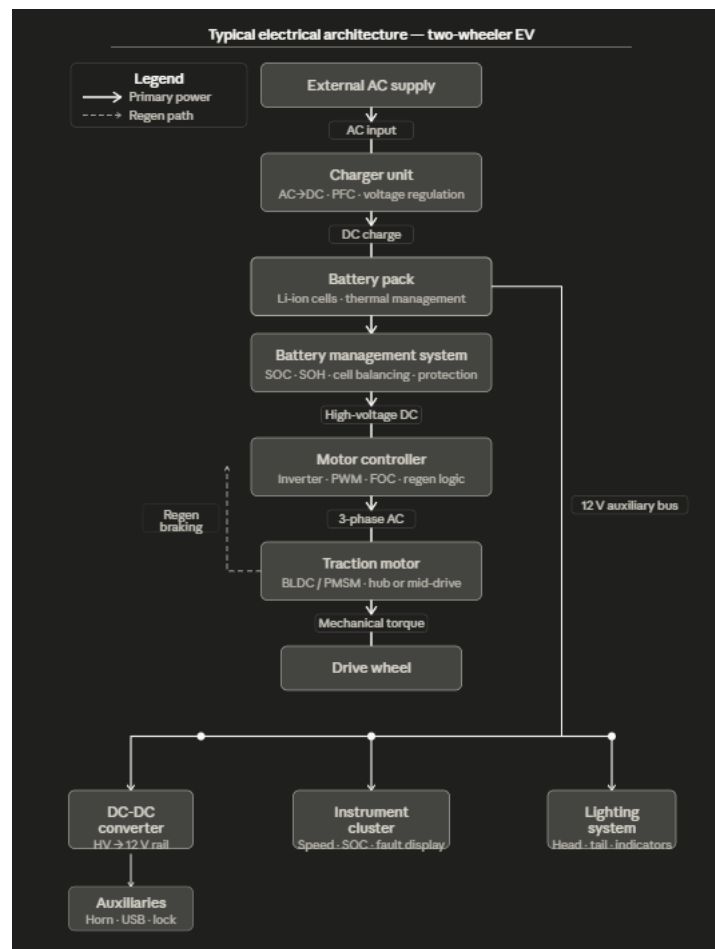


Figure 1: Typical Electrical Architecture of a Two-Wheeler Electric Vehicle.

The architecture shown above represents the primary electrical power flow path and the major auxiliary electrical branches commonly employed in modern two-wheeler electric vehicles.

4. DESIGN CONSIDERATIONS IN WIRING HARNESS DEVELOPMENT

Electrical design represents the foundation of wiring harness development. The conductor size, connector ratings, protection devices, and routing methods must be selected according to the electrical requirements of the vehicle.

Current carrying capacity, commonly referred to as ampacity, represents the maximum current that a conductor can safely carry without exceeding its permissible operating temperature. The conductor selected for a circuit must be capable of carrying both continuous and transient currents expected during vehicle operation.

In a two-wheeler electric vehicle, the highest currents are typically associated with the battery-to-controller connection and the controller-to-motor connection. These circuits may experience substantial current flow during acceleration, hill climbing, and high-load

operating conditions. If the conductor size is insufficient, excessive temperature rise may occur, resulting in insulation degradation, increased resistance, reduced efficiency, and potential failure.

The ampacity of a conductor is influenced by several factors including conductor cross-sectional area, conductor material, insulation type, ambient temperature, bundling conditions, and installation environment. Consequently, conductor selection is performed with adequate safety margins to ensure reliable operation under all anticipated operating conditions.

Proper current carrying capability is one of the most important considerations in wiring harness design because it directly affects system reliability and safety.

Voltage Drop Considerations

Voltage drop occurs whenever current flows through a conductor possessing finite electrical resistance. Although conductor resistance is generally small, significant voltage reductions may occur in high-current circuits if conductor sizing and routing are not properly designed.

Excessive voltage drop can adversely affect the performance of several vehicle subsystems. Reduced voltage supplied to the motor controller may limit available motor torque and decrease vehicle performance. Similarly, inadequate voltage levels supplied to sensors, communication systems, and electronic control units may result in inaccurate operation or communication failures.

Voltage drop is influenced by conductor length, conductor cross-sectional area, conductor material, and circuit current. Therefore, conductor lengths are minimized wherever possible, and appropriate conductor sizes are selected to maintain voltage drop within acceptable limits.

For electric vehicle applications, voltage drop considerations are particularly important because battery energy must be utilized as efficiently as possible to maximize vehicle range and overall system performance.

Conductor Sizing

Conductor sizing involves the selection of an appropriate conductor cross-sectional area capable of satisfying electrical, thermal, and mechanical requirements.

The selected conductor must carry the required current while maintaining acceptable voltage drop and temperature rise. Larger conductors generally provide lower resistance and improved electrical performance. However, excessive conductor size increases harness weight, cost, and installation complexity.

Smaller conductors reduce weight and cost but may experience excessive heating and voltage loss. Consequently, conductor sizing represents a balance between electrical performance and practical design considerations.

In two-wheeler electric vehicles, different conductor sizes are employed according to circuit requirements. High-current propulsion circuits utilize larger conductors, whereas communication and sensor circuits generally require much smaller conductors. Proper conductor sizing contributes significantly to system efficiency, reliability, and safety.

5. CONCLUSIONS

The industrial training program successfully provided practical exposure to the electrical systems of two-wheeler electric vehicles. Knowledge regarding vehicle electrical architecture, wiring harness design, connector selection, and wiring methods was acquired through observation and study of industrial practices. The relationship between theoretical engineering concepts and practical implementation was clearly understood.

Through the completion of this project, a comprehensive understanding of wiring harness development for two-wheeler electric vehicles was achieved. The design considerations, engineering calculations, protection requirements, and reliability aspects associated with wiring harness systems were studied and analyzed

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