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A Study on On-Board, Off-Board Chargers and Smart Locking System

Srinivasa Rao Tegala[1*], M. Navya Kantha[2], P. Lohitha[3], R. Santosh Dileep[3], Y. Navya Ganga Mani Devi[3]
[1]*Professor & HoD, Department of Electrical and Electronics Engineering, Avanthi Institute of Engineering & Technology, Makavarapalem, India*
[2]*Assistant Professor, Department of Electrical and Electronics Engineering, Avanthi Institute of Engineering & Technology, Makavarapalem, India*
[3]*UG Student, Department of Electrical and Electronics Engineering, Avanthi Institute of Engineering & Technology, Makavarapalem, India*

***Abstract*: This paper presents a study of on-board and off-board charging systems for electric two-wheelers together with a smart locking system for vehicle security. The charger study examines the conversion of electrical energy, charger classifications, charging functionality, safety considerations, battery management, thermal management and charging infrastructure. An on-board charger is integrated into the vehicle and converts external AC into controlled DC suitable for the battery, while an off-board charger is a standalone unit installed at a charging location. The work also considers a remote keyless smart locking arrangement using a 433 MHz communication link, microcontroller-based control and servo-operated locks. The study brings together charger architecture, battery management, charging infrastructure and vehicle-security functions to provide a practical overview of technologies relevant to electric two-wheelers.**

***Keywords*: Electric vehicle, two-wheeler, on-board charger, off-board charger, battery management system, DC-DC converter, charging infrastructure, remote keyless system, smart locking.**

1. Introduction

An electric vehicle is powered by an electric motor that draws electricity from a battery and can be charged from an external source. Electric motorcycles and scooters are plug-in electric vehicles with two or three wheels, in which a rechargeable battery supplies one or more electric motors. The transition to two-wheeler EVs is driven by concerns over air pollution, greenhouse-gas emissions and fossil-fuel dependency [1].

For an electric two-wheeler, charging is a central part of the operating cycle. Battery range, charging infrastructure, performance, cost-effectiveness, charging time and safety influence practical adoption. Improvements in battery technology, fast-charging networks, battery swapping and smart connectivity are helping address range and convenience requirements [1]-[3].

The present study focuses on the charger subsystem and a complementary smart locking arrangement. The charger part covers standard, fast, portable and smart chargers, followed by a detailed examination of on-board and off-board charging. The security part considers remote keyless operation, microcontroller control and vehicle-side locking hardware [1], [2].

2. Literature and Technology Overview

Electric-vehicle charging systems have evolved from basic regulated chargers to integrated power-electronic systems containing rectification, filtering, DC-DC conversion, battery management and monitoring. For two-wheelers, charger selection is influenced by battery voltage, current requirement, charging time, portability, protection features and cost [1]-[3].

The project study identifies four broad charger categories: standard on-board chargers, fast chargers, portable chargers and smart chargers. Standard chargers provide steady charging for routine use. Fast chargers reduce charging time by providing higher charging power when the battery and vehicle support it. Portable chargers provide flexibility where fixed charging infrastructure is limited. Smart chargers add connectivity and monitoring features [1], [2].

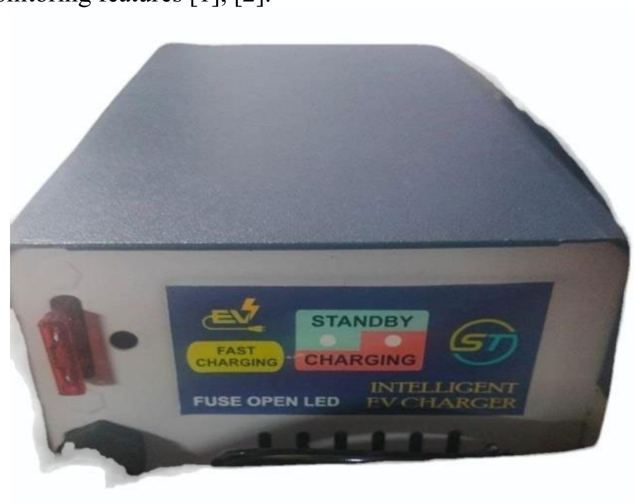

Fig. 1. Fast charger

*Corresponding author: srinivasarao.tegala@gmail.com

Fig. 2. Portable charger

Fig. 3. Smart charger

3. Electric Two-Wheeler Charging System

A. Basic Charging Function

The charger forms the interface between the electrical supply and the vehicle battery. The input AC supply is converted and regulated so that the battery receives the required charging voltage and current. Protection against overcharge, overcurrent, short circuit and excessive temperature is important for safe operation [2], [3].

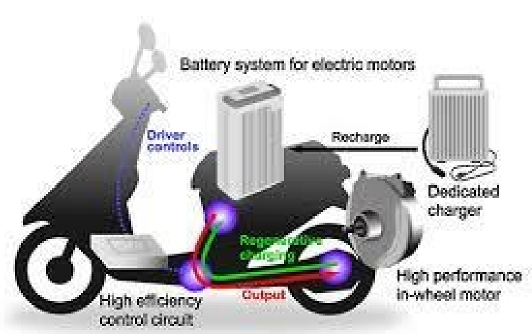

Fig. 4. Working of an electric vehicle

B. Battery and Charging Considerations

The project discusses battery development from earlier lead-acid systems toward lithium-ion batteries. Battery choice affects range, weight, charging performance and vehicle cost. Correct charger voltage and current ratings are essential because incompatible charging conditions can reduce efficiency or damage the battery [2].

C. Charger Selection Factors

- Battery compatibility and correct output voltage/current rating.
- Charging speed and acceptable charging time.
- Safety protection, thermal management and reliable operation.
- Portability and ease of installation or use.
- Connectivity and monitoring capability for smart charging.

4. On-Board Chargers

A. Architecture

An on-board charger is integrated into the electric vehicle. Its function is to convert electrical energy from an external AC source into controlled DC energy suitable for the traction battery. The charger architecture includes the input rectifier and filter, DC-DC conversion stage, battery management system, cooling system and control/monitoring circuitry [2].

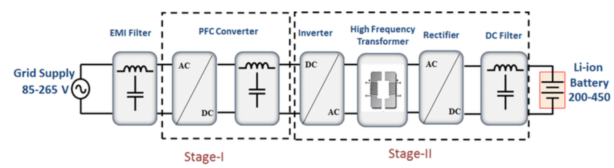

Fig. 5. Block diagram of on-board charger stages

B. Input Rectifier and Filter

The input rectifier converts the external AC supply into DC. The filter smooths the rectified waveform and reduces ripple and electrical interference, providing a more stable input for subsequent power-conversion stages [2], [3].

C. DC-DC Converter

The DC-DC converter regulates the DC voltage to the level required by the battery. The project includes a bi-directional DC-DC converter circuit as part of the charger study. Controlled conversion provides compatibility between the charger output and the battery voltage requirement [2].

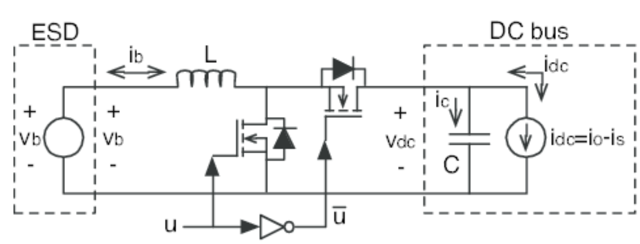

Fig. 6. Circuit diagram of bi-directional DC-DC converter

D. Battery Management System

The battery management system monitors and manages charging parameters such as voltage, current and temperature. It helps prevent overcharging, overdischarging and overheating and provides feedback to the charger control system. This feedback supports adaptive charging and real-time adjustment of charging parameters [3].

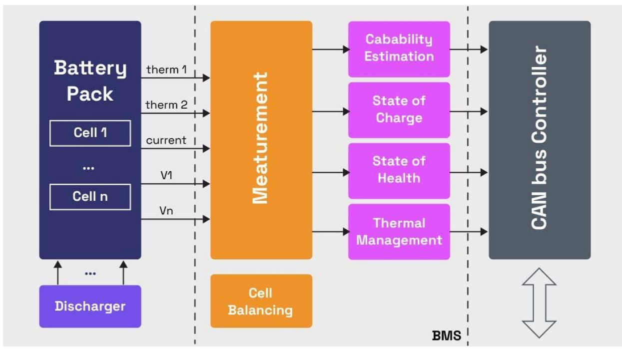

Fig. 7. Architecture of battery management system

E. Cooling and Thermal Management [2], [3].

Cooling is required to maintain suitable operating temperatures for batteries and power-electronic components. Thermal monitoring is important because excessive temperature can reduce battery life and create safety risks.

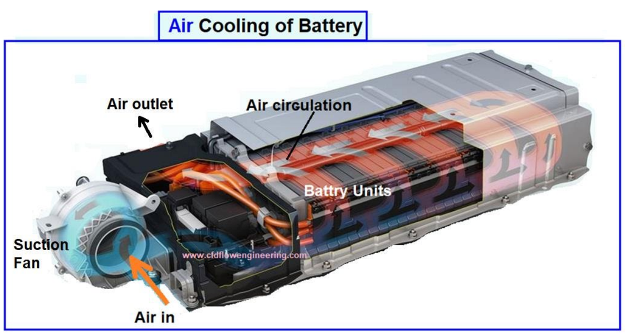

Fig. 8. Cooling system of EV battery

F. Control and Monitoring

Control and monitoring circuitry includes electronic components, sensors and microcontrollers that oversee charger operation. The controller can adjust charging parameters using feedback from the BMS and other sensors and can monitor the charging status and fault conditions [3].

5. Working Principle of On-Board Charging

During AC charging, the external AC source is supplied to the vehicle's on-board charger. The rectifier and filter create a controlled DC link, after which the DC-DC conversion stage regulates the voltage and current delivered to the battery. The BMS continuously monitors battery voltage, current and temperature. The control system uses this information to maintain safe charging conditions [1]-[3].

Charging is therefore a coordinated process rather than a simple AC-to-DC conversion. Regulation, protection, thermal management and feedback are required to achieve reliable charging. The integrated nature of the on-board charger provides convenient charging wherever a compatible AC supply is available, although the charger adds weight, volume and thermal requirements to the vehicle [1], [2].

6. Off-Board Chargers and Charging Infrastructure

A. Introduction

Off-board chargers are standalone units located outside the vehicle. They can be installed in homes, workplaces, commercial areas and public charging locations. They complement fixed charging infrastructure by providing additional charging options and can support higher charging power where suitable [1], [4], [5].

B. Charging Infrastructure

Accessible charging infrastructure is important for reducing range anxiety and supporting electric-scooter adoption. A well-developed network provides charging opportunities at residential areas, workplaces, commercial districts and public spaces. Off-board chargers also provide flexibility where dedicated charging stations are scarce [1], [4].

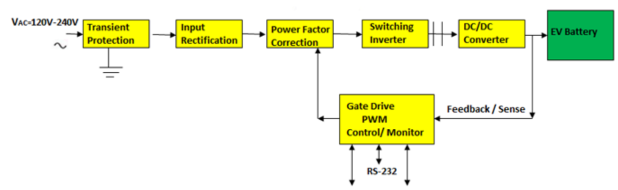

Fig. 9. Block diagram of charger infrastructure

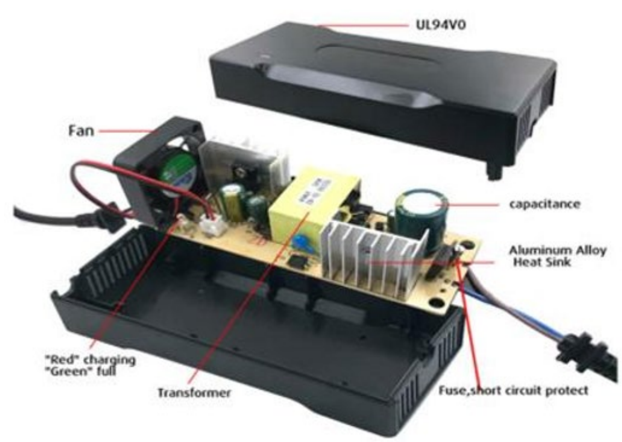

Fig. 10. Components of charger

C. Off-Board Charger Considerations

- Charging time and required charging power.
- Compatibility with battery voltage and charging characteristics.
- Safety, protection and thermal considerations.
- Installation requirements and accessibility.
- Suitability for home, workplace and public charging applications.

Table 1
Comparison of on-board and off-board chargers

Parameter	On-board Charger	Off-board Charger
Location	Integrated into vehicle	Installed outside vehicle
Charging flexibility	Can charge from compatible external AC supply	Depends on availability of charging unit
Vehicle impact	Adds weight, volume and thermal requirements	Less charger hardware carried by vehicle
Infrastructure	Useful for routine AC charging	Suitable for fixed/public charging infrastructure
Power level	Typically constrained by vehicle-integrated design	Can support higher-power installations where applicable

7. Smart Locking System

A. Proposed Security Arrangement

The project also studies a smart locking system intended to provide secure and convenient access control for a two-wheeler. The arrangement combines a remote keyless system, a microcontroller-based hardware module and servo-operated locks. The vehicle-side controller receives a command from the remote and performs the corresponding locking or unlocking sequence [6], [7].

B. Remote Keyless System

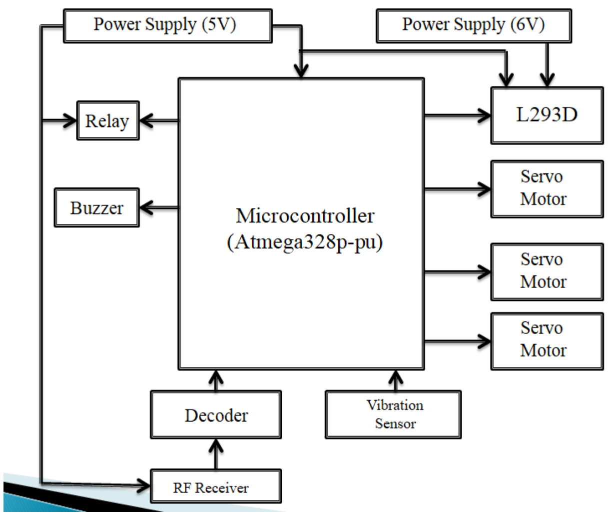

Fig. 11. Block diagram of TWVSS hardware module installed in the vehicle

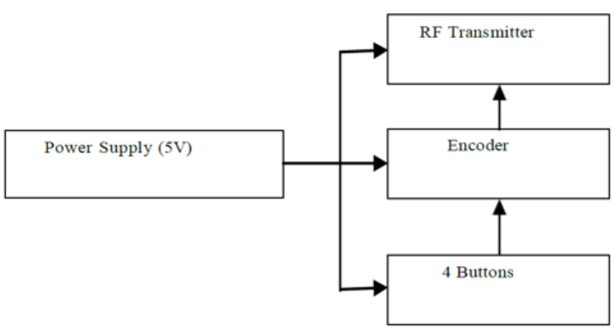

Fig. 12. Block diagram of RKS transmitter/receiver module

The remote keyless system operates at 433 MHz using a half-duplex communication link. The remote contains a transmitter, encoder, power supply and loop antenna. The receiver module contains a 433 MHz receiver, decoder, power supply and loop antenna and is interfaced with the microcontroller. The transmitted data contains address and command information; the receiver validates the address before making the command available to the MCU [6], [7].

The project reports an approximate maximum communication range of 100 m under standard conditions. The system is intended to provide low-cost remote operation while supporting vehicle locking and unlocking functions [6].

C. Operating Sequence

The operating sequence begins when a command is issued from the remote. The receiver decodes the serial information and checks the local address. After successful validation, the microcontroller activates the corresponding lock or unlock operation. The project also considers vehicle monitoring functions associated with the security system [6], [7].

8. Results and Discussion

The charger study shows that reliable EV charging requires coordinated power conversion, battery management, thermal control and monitoring. The on-board architecture provides integrated charging functionality, while off-board chargers extend charging accessibility through fixed infrastructure. The selection of either arrangement depends on vehicle design, battery characteristics, charging power and the intended operating environment [1]-[3].

For the smart security arrangement, the project describes hardware testing on different two-wheeler vehicles. The module was placed under the seat and servo-motor-operated locks were installed at the respective locations. The 12 V vehicle battery was used as the module power source. The remote keyless system transmitted commands to the receiver, and the microcontroller was interfaced with a computer through an Arduino Uno R3 for serial monitoring [6].

The reported RKS communication range was approximately 100 m under standard conditions. The serial interface was used to observe locked and unlocked states and associated system actions. These observations demonstrate the feasibility of combining remote access control with microcontroller-based vehicle security [6].

9. Advantages and Limitations

A. Advantages

- Integrated on-board charging provides convenient charging from compatible AC sources.
- Off-board infrastructure can provide flexible charging locations and higher-power options [1], [4], [5].
- BMS and thermal monitoring improve battery safety and charging reliability.
- Smart charging can support monitoring, connectivity and controlled charging.
- Remote keyless locking improves convenience and

provides an additional security layer.

B. Limitations

- On-board chargers increase vehicle weight, volume and thermal-management requirements [1], [2].
- Charging infrastructure availability can limit the practical use of off-board charging [4], [5].
- Charging performance depends on battery chemistry, voltage and allowable current.
- Remote keyless performance depends on communication range and system conditions.
- Proper protection, insulation, alignment and maintenance are required for reliable operation [8].

10. Conclusion

The study demonstrates the complementary roles of on-board and off-board chargers in electric two-wheeler applications. On-board chargers integrate the charging function into the vehicle and combine rectification, filtering, DC-DC conversion, battery management, cooling and control. Off-board chargers provide flexible external charging infrastructure and can support higher-power charging arrangements where appropriate.

The smart locking study demonstrates a practical microcontroller-based remote keyless approach for two-wheeler security. A 433 MHz communication link, receiver/decoder, MCU and servo-operated locks provide remote locking and unlocking. Overall, the combination of efficient charging technology and smart security functions supports safer, more convenient and more reliable electric two-wheeler operation.

11. Future Scope

Future development can focus on improving charging efficiency, reducing charging time, integrating more advanced battery-management algorithms and expanding smart charging connectivity. Charging infrastructure can be extended through public and workplace charging. On the security side, the system can be enhanced through mobile-phone integration, improved authentication, location monitoring and additional sensing. Further optimization can also address thermal management, reliability and cost [1]-[5], [8].

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