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Innovative Battery Swapping System for Electric Scooters

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Abstract - *The growing adoption of battery swapping systems for electric scooters marks a significant shift towards sustainable and efficient transportation solutions. This innovative technology promotes the use of renewable energy sources, such as solar and wind power, to generate electricity for charging batteries. By reducing reliance on fossil fuels, battery swapping systems contribute to a decrease in greenhouse gas emissions and mitigate environmental pollution.The benefits of battery swapping systems extend beyond environmental sustainability. These systems are designed to provide a seamless and efficient battery replacement experience, ensuring that users have access to a fully charged battery at all times. This is particularly important for individuals who rely on electric scooters for daily commuting or emergency services. The growth of battery swapping systems also supports the development of eco-friendly mobility solutions. By providing a convenient and reliable means of charging, these systems encourage the adoption of electric vehicles, reducing our dependence on fossil fuels and promoting a cleaner, healthier environment. As the demand for sustainable transportation solutions continues to grow, battery swapping systems are poised to play a critical role in shaping the future of urban mobility.*

Key Words: Renewable Energy Integration, Electric Scooter Charging Infrastructure, Subscription based Battery Swapping, Growing demand for Battery Swapping Systems, Battery Swapping System Component Diagram

1. INTRODUCTION

The Indian two-wheeler market is vast, catering to a wide range of consumers, from budget-friendly mopeds to high-end motorcycles. While commuter motorcycles and scooters dominate sales, there has been a growing demand for premium and electric two-wheelers, including models equipped with advanced battery-swapping technology.

Battery swapping is an innovative solution that allows electric scooter users to replace a depleted battery with a fully charged one in minutes, eliminating long charging times. Many electric vehicle manufacturers have introduced scooters with swappable battery technology, making EV adoption more convenient and efficient. Models like the Bounce Infinity E.1+ and Hero Electric Atria offer swappable lithium-ion batteries, providing a practical solution for urban commuting.

Swappable batteries are designed to be easily removed without requiring complex tools or modifications. They offer flexibility, allowing users to charge spare batteries at home or carry an extra pack for extended range. This plug-and-play approach enhances the usability of electric scooters, ensuring seamless and uninterrupted rides while promoting the growth of the EV ecosystem in India.

2. PROPOSED WORKED

The proposed battery swapping system for electric scooters aims to develop a cost-effective, efficient, and user-friendly infrastructure to address the limitations of conventional charging methods. This system will enable electric scooter users to replace depleted batteries with fully charged ones in a matter of minutes, reducing downtime and enhancing vehicle usability.

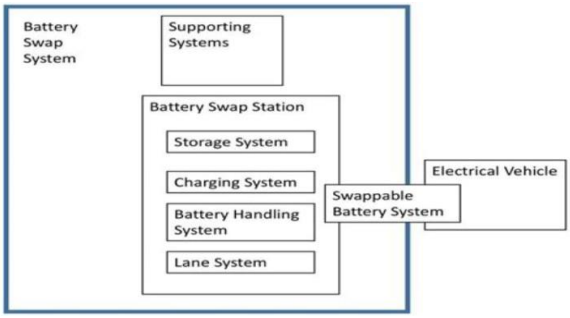

Fig.1: Working process of battery swapping system for electric scooter

Objectives of the Proposed Work

1. Development of a Modular Swapping Station:

Designing a battery swapping station that supports standardized lithium-ion batteries.

Ensuring interoperability between different electric scooter brands for seamless battery exchange.

2. Integration of Smart Monitoring Systems:

Implementing IoT-based smart meters to track battery health, usage, and availability in real- time.

Developing a user-friendly mobile application for locating nearby swapping stations and making payments digitally.

3. Payment and Subscription Model Implementation:

Introducing flexible subscription plans for users based on usage patterns.

Enabling secure digital transactions through a mobile application, enhancing convenience and accessibility.

4. Renewable Energy Integration:

Utilizing solar-powered charging infrastructure to charge swappable batteries, promoting sustainability.

Reducing dependency on conventional power grids and minimizing carbon emissions.

5. User Experience and Scalability:

Conducting pilot testing in urban areas to analyze system efficiency and user feedback.

Exploring scalability options for widespread adoption across cities, including partnerships with EV manufacturers.

3. BLOCK DIAGRAM & COMPONENT DETAIL

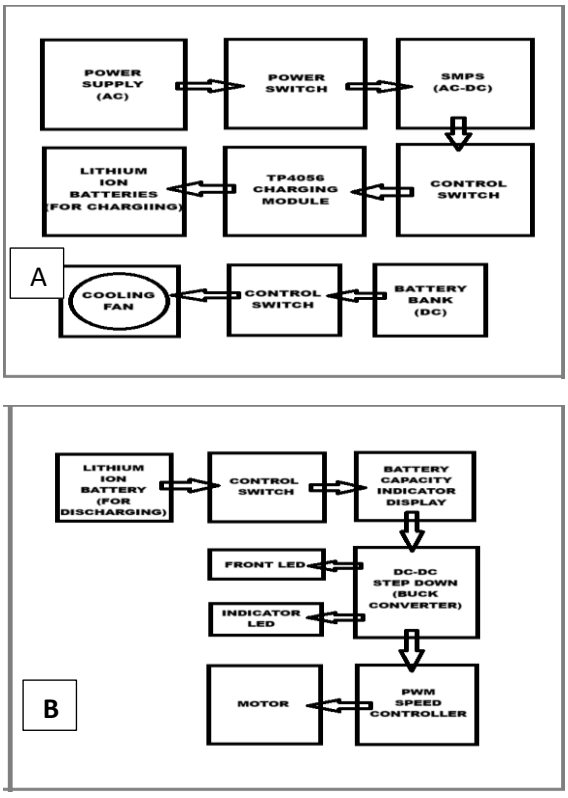

Fig.2: Block diagram of Charging station (A) and swapping scooter (B) -

Main Component

i. SMPS :

Fig.3: SMPS

The SMPS 5V 10A efficiently converts 100-240V AC to 5V DC with high efficiency (80-90%) and built-in protection, making it ideal for microcontrollers and LED strips.

ii. TP4056 charging module :

Fig.4: TP4056 charging module

The TP4056 module charges 3.7V lithium-ion batteries with 1A current and has protection features like overcharge and short-circuit prevention. It includes LED indicators for charging status

iii. Lithium-ion battery :

Fig.5: Lithium-ion battery

A 3.7V 1200mAh lithium-ion battery is a rechargeable power source with high energy density and up to 500 charge cycles, requiring a BMS or TP4056 for protection.

iv. Battery Capacity Indicator :

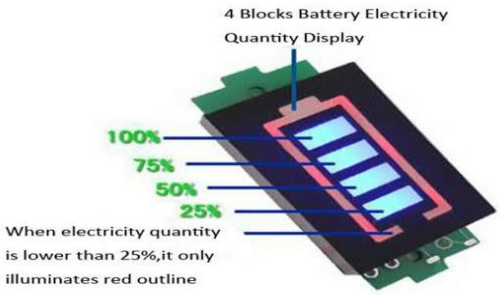

Fig.6: Battery capacity indicator

A battery capacity indicator visually displays battery status via LEDs or digital displays, useful for portable electronics and energy storage.

v. DC-DC step-down (buck) converter :

Fig.7: DC-DC step down converter

A DC-DC step-down (buck) converter efficiently reduces 6V-40V DC to lower voltages (e.g., 5V, 12V) with 90% efficiency, used in battery systems and solar controllers.

vi. PWM speed controller :

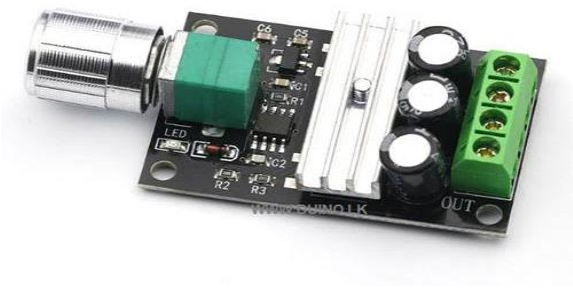

Fig.8: PWM speed controller

A PWM motor speed controller adjusts DC motor speed by modifying the duty cycle, providing smooth, efficient control for EVs, automation, and industrial applications.

4. CONNECTION DIAGRAM

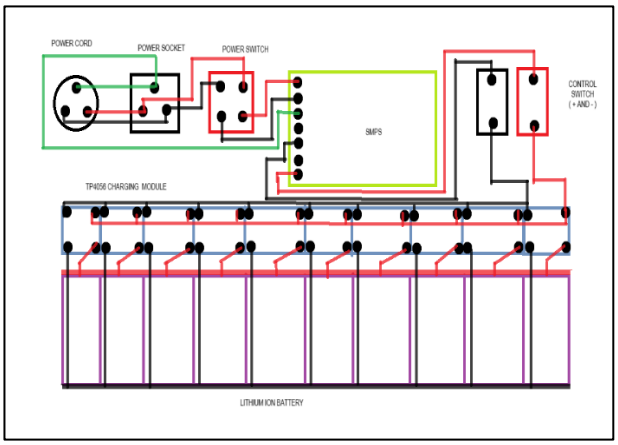

Fig.9: Charging station

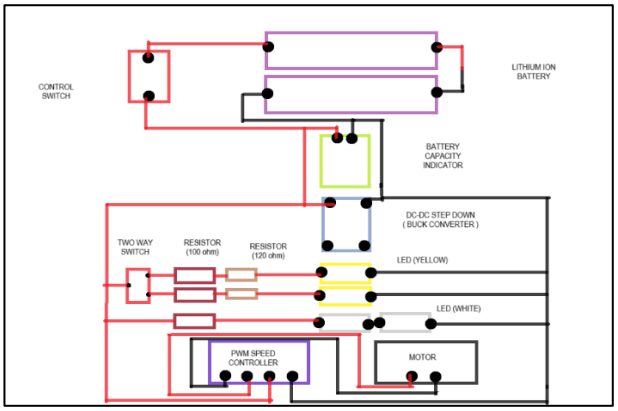

Fig.10: Swapping scooter

Explanation

Firstly, I will connect the power cord to the power socket and then I will connect to the supply board and I will ON the power switch which is connected in between supply power (230V 50Hz) and (5V 10Amp) SMPS by which the AC power is converted into DC power with requirement.

After that I will plug in all lithium ion batteries in the case which is connected with TP4056 charging module in parallel and also the coming DC supply is connected in parallel with TP4056 charging module to fixed the 5V supply and distribute 10Amp (1Amp to each) and between them positive and negative control switch is present which I will ON after ensuring that all batteries are connected and then red light indicates batteries is charging and green light indicates the batteries is charged which I can use.

The usable charged batteries I will plug in the case storage of swapping scooter after ON the switch it goes to battery capacity indicator and DC-DC step down converter which control all supply requirement in

system such front light and indicating light and motor speed is controlled by PWM speed controller.

5. ADVANTAGES

A. Fast Charging: Swap a depleted battery with a fully charged one in minutes.

B. Longer Battery Life: Centralized charging prevents overcharging and extends battery lifespan.

C. Lower Cost: Reduces upfront costs with pay-per-use or subscription-based models.

D. User Convenience: Easy access to swapping stations via mobile apps.

E. Better Energy Efficiency: Controlled charging and integration with renewable energy.

F. Standardization: Compatible batteries for different scooter models.

G. No Range Anxiety: Always have access to a fully charged battery.

6. THE RISING DEMAND FOR BATTERY SWAPPING SYSTEM

The demand for battery swapping systems in India has been growing rapidly, driven by the increasing adoption of electric two-wheelers and government initiatives to enhance EV infrastructure. Companies like Gogoro have introduced battery-swapping pilots in collaboration with delivery service providers, while large-scale investments, such as the $2.5 billion partnership between Belrise Industries and the Maharashtra government, are accelerating infrastructure development.

The Indian battery-swapping market for electric two-wheelers is expected to witness a significant growth rate, with a projected CAGR of 18% in the coming years. While the COVID-19 pandemic initially slowed EV sales due to manufacturing disruptions, the sector rebounded strongly as demand surged post-lockdown. The expansion of battery-swapping stations across major cities has played a crucial role in supporting this growth, addressing the challenges of long charging times and high vehicle costs by offering a flexible and cost-effective solution.

Government policies have further propelled the adoption of battery swapping, with plans to integrate swapping stations along highways and encourage the use of Battery-as-a-Service (BaaS) to lower upfront EV costs. Additionally, rising consumer awareness and improved battery technology are fueling market expansion. Despite challenges like variations in battery designs and high setup costs, the increasing penetration of electric two-wheelers and advancements in battery-swapping models are expected to drive sustained growth in the industry.

7. INTEGRATING BATTERY SWAPPING SYSTEM WITH RENEWABLE ENERGY

As the world shifts towards sustainable mobility solutions, battery swapping systems are emerging as a game-changer for electric vehicles. According to Ketan Mehta, CEO and founder of HOP Electric Mobility, growing environmental concerns and climate awareness are driving the demand for efficient and eco-friendly transportation. Electric scooters have already proven to be a renewable and economical alternative to traditional fuel-powered vehicles, and integrating them with a robust battery-swapping network enhances their efficiency.

Fig.11. Power generation capacity

HOP Electric Mobility's energy network enables users to save both time and money by providing fast and seamless battery replacements. Equipped with advanced technology, their charging stations allow users to swap batteries within 30 seconds, eliminating long waiting times for recharging. Few companies offer such a high level of convenience, making battery swapping a revolutionary step toward mass EV adoption.

To further enhance sustainability, integrating battery-swapping stations with renewable energy sources such as solar and wind power can significantly reduce dependence on fossil fuels. Solar-powered charging stations, for example, can harness clean energy to charge swappable batteries, making the entire system greener and more cost-effective. By combining battery-swapping technology with renewable energy infrastructure, the EV ecosystem can achieve greater energy independence, lower emissions, and accelerate the transition toward a cleaner future.

8. PAYMENT & SUBSCRIPTION NETWORKS FOR CUSTOMERS FOR BATTERY SWAPPING

Battery swapping services offer a convenient and cost-effective solution for electric vehicle users, with a single swap priced between ₹100 and ₹150, providing a range of over 60 km. To enhance user experience, subscription plans are available, allowing EV owners to choose options that best suit their commuting needs. Smart meters installed in vehicles notify users when a swap is needed, and the entire process—from locating the nearest station to making payments—can be seamlessly

managed through dedicated mobile applications like the Battery Smart app.

Fig.12. Battery swapping

The batteries used in these systems are designed to be smart and interoperable, ensuring compatibility across various electric two-wheelers and three-wheelers. While sourced from multiple lithium-ion battery manufacturers, they maintain uniform specifications and dimensions, allowing for seamless swapping. This standardized approach ensures reliability and ease of use for customers, making battery swapping an efficient alternative to traditional charging methods. By leveraging digital platforms for payments and subscriptions, the battery-swapping ecosystem is becoming increasingly accessible and user-friendly, driving further adoption of electric mobility solutions.

9. INFRASTRUCTURE DEVELOPMENT FOR BATTERY SWAPPING SYSTEMS

Battery swapping is an innovative solution that allows electric vehicle (EV) users to replace a depleted battery with a fully charged one, ensuring minimal downtime. This method, supported by government guidelines, aims to establish a robust swapping ecosystem by promoting the Battery-as-a-Service (BaaS) model. The regulations apply to all battery swapping station (BSS) and battery charging station (BCS) operators, outlining essential components such as Battery-to-Grid (B2G) systems, battery providers, and swappable batteries. B2G enables stored energy from EV batteries to be supplied back to the grid when required, enhancing energy efficiency.

Fig.13. Actual charging/swapping station

To facilitate infrastructure expansion, the guidelines permit BSS and BCS operators to use existing electricity connections for charging swappable batteries, with an option to increase the connected load if needed. Additionally, the deployment of liquid-cooled swappable batteries is encouraged for larger vehicles such as buses and trucks. However, despite the advantages, the adoption of battery swapping remains limited due to infrastructure accessibility challenges. As of December 2024, India had approximately 25,000 public EV charging stations, whereas battery swapping stations stood at just 2,500.The key challenges slowing infrastructure growth include high capital investment requirements and the lack of standardization in battery sizes across different vehicle models. Since various automakers use distinct battery chemistries and sizes, achieving a universally compatible swapping system remains complex. This issue is evident in the case of Yulu's battery swap stations, which are exclusive to the company's vehicles, restricting broader accessibility. While efforts are underway to expand battery-swapping infrastructure, the sector requires significant investments and collaboration among automakers, battery providers, and government agencies to ensure widespread implementation.

10. RESULT

The implementation of a battery swapping system has demonstrated significant improvements in electric vehicle efficiency and usability. The system effectively reduces charging downtime by enabling instant battery replacement, ensuring a seamless riding experience. By eliminating the need for prolonged charging, users experience increased convenience, leading to greater adoption of electric mobility solutions.

Cost-effectiveness is another key outcome, as the swapping model lowers the initial investment required for electric scooters. Subscription-based and pay-per-use models have made EVs more affordable, encouraging a wider consumer base to transition from conventional fuel-powered vehicles.

11. CONCLUSIONS

The implementation of a battery swapping system offers a practical and efficient solution for overcoming the challenges of long charging times and high upfront costs in electric vehicles. By enabling quick battery replacements, this system enhances the convenience and adoption of electric mobility. Additionally, integrating renewable energy sources can further improve sustainability and reduce dependence on conventional power grids. With continuous advancements in battery technology and growing infrastructure support, battery swapping has the potential to revolutionize the EV

ecosystem, making electric transportation more accessible, cost-effective, and environmentally friendly.

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