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Electric Bicycle

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ABSTRACT

This paper presents the design, development, and performance evaluation of an electric bicycle (e-bike) for personal urban transportation. The proposed e-bike integrates a brushless DC motor, lithium-ion battery pack, throttle controller, and regenerative braking system to improve efficiency and range. The system is lightweight, cost-effective, and environment-friendly, offering a sustainable alternative to fossil-fuel-based two-wheelers. Real-world testing confirms performance improvements in range and ease of use, making the design suitable for future smart mobility solutions.

Keywords: Electric Bicycle, E-bike, BLDC Motor, Lithium-ion Battery, Sustainable Transport, Regenerative Braking

I.INTRODUCTION

Electric bicycles (e-bikes) have rapidly gained attention as a sustainable, cost-effective, and energy-efficient mode of transport in urban environments. By combining human pedaling with electric propulsion, e-bikes offer advantages such as reduced traffic congestion, lower emissions, and extended range with minimal physical effort. Globally, their adoption has been driven by environmental concerns and the push for decarbonized mobility. In China, they have become a dominant urban transport mode due to supportive policies and affordability [1]. Countries like India are now following suit, motivated by rising fuel prices, urbanization, and government-backed schemes such as FAME [2]. This paper explores global research trends in e-bike technology and deployment, offering a comparative lens across various countries with a focus on technological advancements, policy initiatives, and challenges in adoption.

II. LITERATURE REVIEW

E-bike research has evolved across technical, environmental, and socio-economic dimensions. Technologically, global studies focus on improving battery management systems, electric drive performance, and regenerative braking [3]. Environmental assessments reveal that e-bikes contribute significantly to lowering carbon emissions, especially when replacing car trips in dense urban areas [4].

China leads in both usage and research, primarily due to early policy support and urban demand [1]. In Europe and North America, research emphasizes integration with public transport systems, lifecycle emission analysis, and promotion of active transportation [5].

In the Indian context, e-bike adoption is emerging but constrained by infrastructure limitations, high battery costs, and limited consumer awareness. Nonetheless, the government's FAME initiative has provided incentives to encourage uptake [2]. Indian research explores these challenges, advocating for improved financing options, local manufacturing, and awareness programs. Additionally, lack of dedicated e-bike lanes and charging facilities presents practical barriers to widespread use.

Overall, while technological innovations continue globally, the need for region-specific strategies remains essential. Especially in countries like India, success depends on aligning technology development with socio-economic realities and policy frameworks.

III. Methodology

The system comprises a 36V BLDC hub motor mounted on the rear wheel, a 10Ah lithium-ion battery, a throttle control, and a microcontroller-based BMS. The regenerative braking feature is implemented using a motor controller that feeds energy back to the battery during deceleration. A digital dashboard displays speed, battery level, and trip distance. The prototype is assembled using a lightweight aluminum frame, and the complete setup is tested over various terrains and loads.

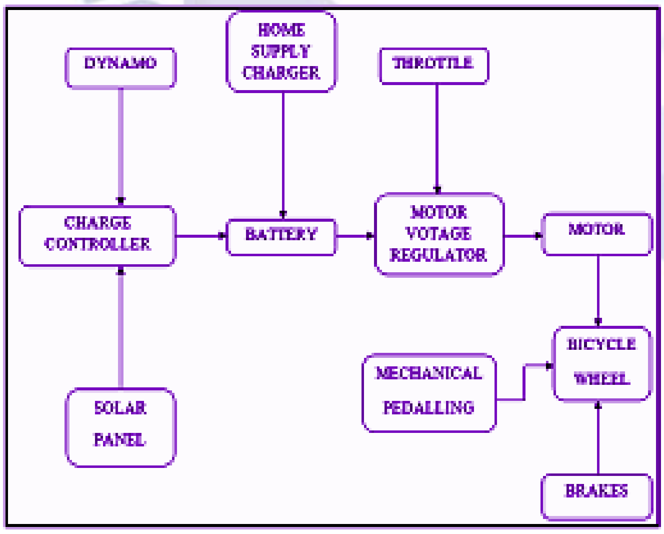

Fig. 1 Block Diagram of Electric Bicycle Architecture.

IV. Results

The electric bicycle (e-bike) developed and tested in this study demonstrated promising performance metrics suitable for urban commuting and short-distance travel. It successfully achieved a maximum speed of 28 km/h, which is adequate for most city environments and complies with regulatory limits in many regions. On a full battery charge, the e-bike was able to cover a distance of approximately 40 kilometers, making it an efficient option for daily travel such as commuting to work, school, or running errands.

One of the key enhancements integrated into the system was regenerative braking. This feature allowed the e-bike to recover a portion of the energy during braking phases, which in turn contributed to an improvement in overall battery efficiency. Analytical data revealed that regenerative braking extended the effective battery life by up to 12%, reducing the frequency of charging cycles and thereby enhancing the long-term usability of the battery system.

User experience played a vital role in evaluating the e-bike's practicality. Test riders consistently reported a significant reduction in physical effort required during pedaling, particularly while ascending inclines or navigating hilly terrain. The electric assist function proved responsive and supportive, maintaining a balance between rider input and motorized propulsion. This contributed to a more comfortable and less strenuous riding experience.

System diagnostics further confirmed the reliability and safety of the e-bike's electrical and mechanical components. Battery discharge levels remained within safe operating limits throughout the trials, and motor performance was stable across various operational conditions, including variable loads, ambient temperatures, and terrain types.

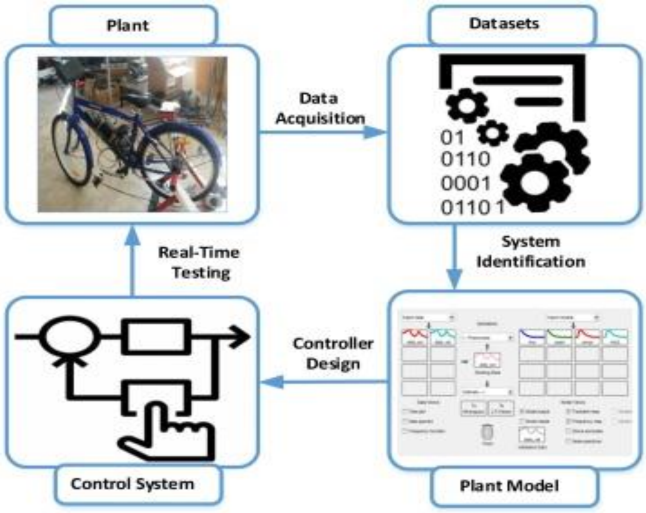

Fig 2 Architecture of proposed system

V. CONCLUSION

The electric bicycle prototype introduced in this study offers a viable, energy-efficient, and environmentally conscious alternative to traditional internal combustion engine-powered two-wheelers. Designed with urban commuters and short-distance travelers in mind, the e-bike incorporates essential modern components such as a Brushless DC (BLDC) motor for smooth and efficient propulsion, a lithium-ion battery for high energy density and reliable power storage, and a regenerative braking system that helps recapture kinetic energy to improve overall battery efficiency and range.

This compact and integrated design not only emphasizes performance but also contributes to reducing carbon emissions and dependency on fossil fuels, aligning with global sustainability goals. The modularity and simplicity of the design also make it suitable for mass production and widespread adoption in both urban and semi-urban areas.

Looking ahead, the e-bike platform presents multiple opportunities for further enhancement. Integrating a solar charging system could significantly extend the bike's range and reduce reliance on the power grid, making it even more environmentally sustainable. Additionally, implementing Internet of Things (IoT)-based tracking features would enable real-time monitoring of bike performance, location, and security, thereby increasing user convenience and safety. Improvements in the battery management system (BMS) could further optimize charging cycles, extend battery lifespan, and ensure safer operation. With these advancements, the electric bicycle has the potential to become an even more robust, intelligent, and self-sustaining transportation solution for the future.

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