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The Experimental Study on Lead Acid Battery Driven E-Rickshaw Performance Using Capacitor Bank

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ABSTRACT

This experimental study investigates the performance of Lead Acid Battery driven Electric Rickshaws (E-Rickshaws) enhanced with a Capacitor Bank. With a growing demand for sustainable urban transportation solutions, E-Rickshaws have emerged as a promising option. However, challenges such as limited battery life and variable performance under different load conditions persist. In this research, we explore the application of a Capacitor Bank circuitry to mitigate these challenges. The study involves a series of performance tests conducted on E-Rickshaws equipped with the proposed hardware model. Key parameters, including charging current, charging time, and discharging current under varying load conditions, are rigorously analyzed. Our experimental results reveal substantial improvements in E-Rickshaw performance when compared to conventional Lead Acid Battery-driven models. Notably, reductions in starting current and minimized power fluctuations, especially under full load conditions, lead to a smoother and more efficient driving experience. Crucially, the extended battery life resulting from these hardware enhancements demonstrates the economic viability of the modified E-Rickshaw prototype. This research contributes valuable insights into the sustainable transformation of urban transportation, with implications for both performance optimization and economic feasibility in the E-Rickshaw industry.

1. INTRODUCTION

Auto rickshaws, once manually pulled by individuals for transportation, have evolved significantly over time to become a crucial mode of conveyance in Asia, serving both passengers and cargo needs [1]. The journey of these three-wheeled vehicles through history is fascinating. In 1914, recognizing their potential for citizen transport, authorities began to regulate rickshaws. However, it was in the 1930s when cycle-based rickshaws gained immense popularity in India, ultimately becoming the dominant means of transport by 1935. The transition to motorized rickshaws, powered by fossil fuels, occurred in 1957.

These auto rickshaws hold a unique position in the bustling traffic landscape of India. Their affordability and ability to navigate congested roads make them indispensable. Yet, their widespread use has also given rise to a significant environmental concern: pollution resulting from inadequate maintenance and the use of low-quality fuel [2]. Recognizing the critical role these rickshaws play in local transportation, electrification emerged as a compelling solution [3,4].

Electric Rickshaws (E-Rickshaws) have emerged as a promising and eco-friendly mode of urban transportation in many parts of the world, particularly in densely populated urban areas. With their compact size, zero emissions, and affordability, E-Rickshaws offer a viable solution to the challenges of urban mobility while addressing environmental concerns.

The advent of electric rickshaws marked a transformative shift. Unlike their conventional counterparts that relied on Internal Combustion Engines (ICE), electric rickshaws harnessed the power of electrical motors for propulsion [5]. However, despite their numerous advantages, E-Rickshaws powered by Lead Acid Batteries face certain limitations, notably in terms of battery life and performance consistency, which have hindered their widespread adoption and economic viability.

In the pursuit of enhancing the performance and sustainability of E-Rickshaws, innovative solutions are continuously sought. One such solution under investigation is the integration of a Capacitor Bank circuitry into the E-Rickshaw's electrical system. This experimental study delves into the promising prospect of augmenting Lead Acid Battery-driven E-Rickshaws with a Capacitor Bank, with the overarching goal of extending battery life and improving overall performance.

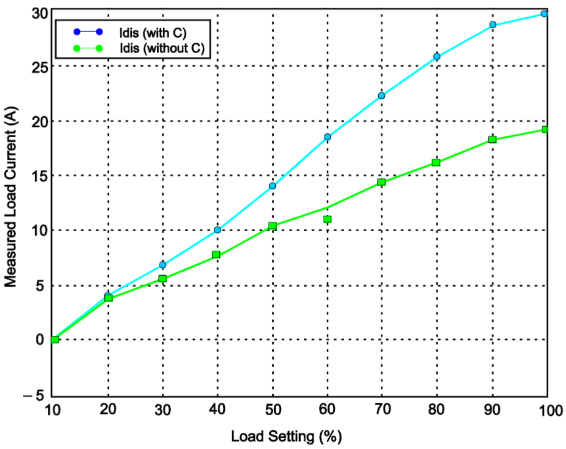

Figure □ Discharging Current with load D+4

SOC serves as a crucial indicator, offering insight into the battery's current condition, and facilitating the safe and optimized charging and discharging processes to extend the battery's lifespan.

Table 5. SOC of Battery with and without capacitor bank (Running condition)

Loading Type (D + 0 ,1, 2,3,4) D= Driver				% SOC improvement of Battery
D+0	00	70<SOC <75%	45<SOC <50%	36.9%
D+1	00	65<SOC <70%	45<SOC <50%	40%
D+2	00	60<SOC <65%	30<SOC <35%	46.7%
D+3	00	55<SOC <60%	25<SOC <30%	50%
D+4	00	50<SOC <55%	SOC <25%	53.8%

In Table 5, we observe a significant enhancement in the State of Charge (SOC) of the battery over a total runtime of 5.5 hours, with and without the use of a capacitor bank, as the load profile varies. When the capacitor bank is employed, there is a remarkable improvement in the SOC compared to scenarios where it is not utilized. This improvement underscores the positive impact of integrating a capacitor bank in stabilizing and optimizing the battery's SOC across different load profiles.

Figures 1□1□1□and 1□depict the State of Charge (SOC) of the system as it evolves over time while the proposed model is subjected to various load conditions. These figures provide a show how the SOC changes in response to different loads, both with and without the incorporation of a capacitor bank.

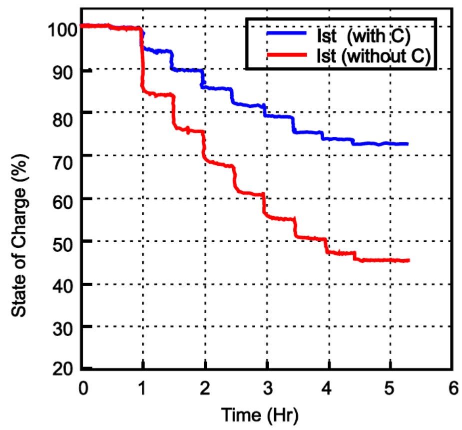

Figure 1□ SOC of battery for load D+0

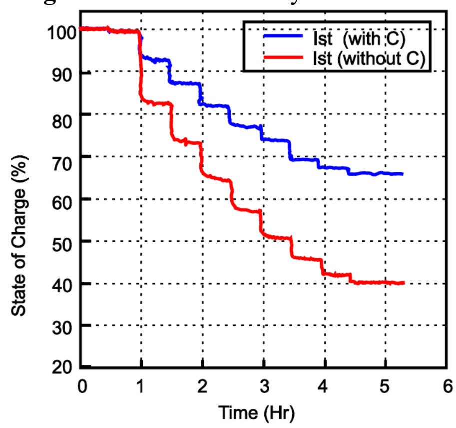

Figure 1□ SOC of battery for load D+1

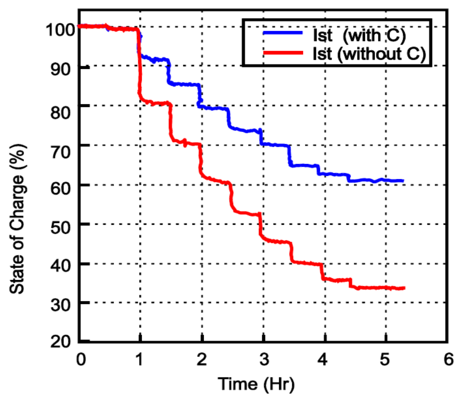

Figure 1□ SOC of battery for load D+2

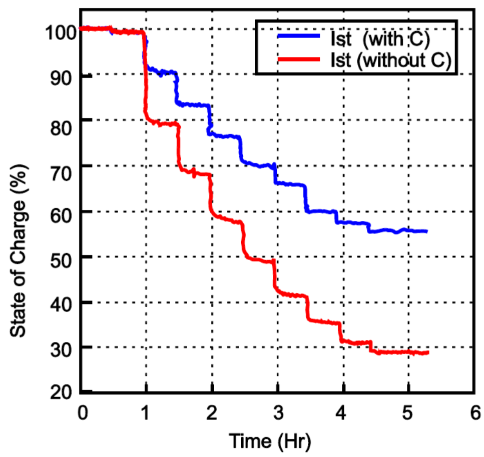

Figure 1□ SOC of battery for load D+3

The employed drain current refers to the rate at which electric current is drawn from the battery during the operation of the E-Rickshaw. In this study, the drain current used is significantly higher, specifically two orders of magnitude larger, than the current specified in the battery datasheet. The battery datasheet specifies a current of 0.2 mA, and the battery's rated capacity is indicated as 240 mAh at this current. Due to the extremely high drain current, the effective capacity of the battery is drastically reduced. The battery might discharge rapidly, and its voltage may drop more quickly than expected. This can affect the overall performance of the E-Rickshaw and could potentially lead to reduced operational range and a shorter battery lifespan.

At the current drain levels utilized in this study, the battery capacity is significantly lower, approximately two orders of magnitude smaller than its rated capacity, measuring around 5mAh. To bolster the study's findings, additional experiments should be conducted at discharge currents more commonly encountered in practical applications.

Figures 9, 10, and 11 provide insights into how each of the three examined factors impacts battery capacity. Notably, the discharge rate exerts the most substantial influence and is a well-established phenomenon. A lower peak current corresponds to a higher effective battery capacity, with this effect being particularly pronounced at lower drain currents.

5. CONCLUSIONS

In this study, we conducted simulations to analyze the behaviour of the battery under various load scenarios. We focused on assessing key parameters such as starting current, accelerator throttle load, and fluctuations in discharge current across these different load modes. The objective was to comprehensively evaluate the performance of our proposed system, which incorporates a capacitor bank, and compare it with conventional systems.

The results obtained from our simulations unequivocally demonstrate the advantages of our proposed system. Even when subjected to heavy load conditions, our system exhibited a significant reduction in the starting current. This reduction not only contributes to smoother driving experiences but also indicates an improved power delivery efficiency.

Furthermore, our findings suggest that the inclusion of a capacitor bank in our hardware model has led to enhancements across all evaluated parameters. This indicates that our system, with the capacitor bank as a critical component, performs notably better than conventional systems in terms of starting current reduction, throttle load optimization, and minimizing discharge current fluctuations.

As the e-rickshaws typically rely on batteries for power, incorporating the capacitors serve the purpose of buffer power delivery to the motor. This potentially reduces the stress on the battery, resulting in longer battery life extends to more than double & hence the system with capacitor has twice the life time.

In summary, our study showcases the superior performance of our proposed hardware model, highlighting the positive impact of the capacitor bank on various crucial parameters. This research contributes valuable insights into the optimization of electric vehicle systems, particularly in the context of E-Rickshaws, ultimately leading to enhanced efficiency and a more pleasant driving experience.

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