Design And Analysis of TAB Converter for Electric Two-Wheeler Applications

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***Abstract*—This paper presents a hybrid energy storage system for electric two-wheelers based on a Triple Active Bridge (TAB) converter. The system integrates a battery as the primary energy source and a supercapacitor to handle transient power demands and energy recovery during braking. A bidirectional TAB converter manages power exchange between the sources and the load using phase-shift control. The system is modeled and simulated using MATLAB/Simulink to evaluate performance under different operating conditions. Results show stable DC link voltage, smooth motor response, and efficient energy distribution. The proposed system improves efficiency and reduces stress on the battery.**

***Index Terms*—Electric Vehicle, TAB Converter, Hybrid Energy Storage, Supercapacitor, Induction Motor**

I. INTRODUCTION

The shift toward electric vehicles is driven by the need to reduce emissions and dependence on fossil fuels. Among various categories, electric two-wheelers are gaining popularity due to their affordability and efficiency.

However, relying solely on batteries creates challenges such as limited lifespan and poor response to rapid power variations. To address this limitation, hybrid energy storage systems are used. In such systems, batteries supply steady energy, while supercapacitors respond quickly to sudden load changes and store energy during regenerative braking. This combination improves overall system performance [1] – [3].

Conventional designs use multiple converters for different energy sources, which increases system complexity and reduces efficiency. A multi-port converter such as the TAB converter can overcome these drawbacks by integrating multiple sources into a single power conversion stage.

II. SYSTEM DESCRIPTION

The proposed system consists of a battery, supercapacitor, Triple Active Bridge (TAB) converter, DC link, inverter, and induction motor. The battery acts as the primary energy source and provides continuous power to the system. The supercapacitor functions as an auxiliary source that supplies high power during transient conditions such as acceleration and absorbs energy during regenerative braking.

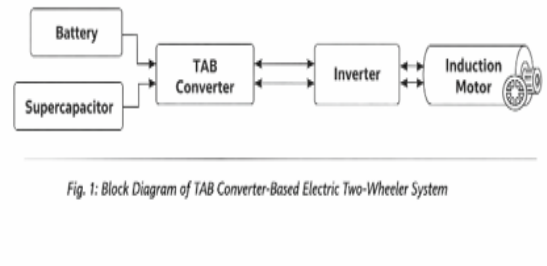

Fig. 1: Block Diagram of TAB Converter-Based Electric Two-Wheeler System

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The overall system configuration is shown in Fig. 1. The battery and supercapacitor are connected to the TAB converter, which controls the power flow between energy sources and the load. The DC link maintains a stable voltage, which is supplied to the inverter. The inverter converts DC power into AC to drive the induction motor. During regenerative braking, energy flows back from the motor to the energy storage devices through the TAB converter.

During normal operation, the battery supplies power to the load. Under sudden load demand, the supercapacitor assists the battery by providing additional power. During regenerative braking, the motor operates as a generator and the energy is transferred back to the battery or supercapacitor through the TAB converter. This configuration improves energy utilization and system efficiency.

III. METHODOLOGY

The proposed system is modeled and simulated using MATLAB/Simulink to evaluate its performance under different operating conditions. The TAB converter is controlled using a phase-shift modulation technique to regulate power flow between the battery, supercapacitor, and load.

The control process begins by sensing key system parameters such as voltage and current. These measured values are compared with predefined reference values to generate an error signal. This error is processed through a proportional–integral (PI) controller, which determines the required phase shift between switching signals.

The phase difference between the converter bridges controls the magnitude and direction of power transfer. By adjusting the phase shift, the system ensures efficient distribution of power between the battery and supercapacitor based on load requirements.

The system operates under different conditions such as normal operation, high load demand, and regenerative braking. During normal operation, the battery supplies power to the load. During sudden load changes, the supercapacitor provides additional support. During regenerative braking, energy from the motor is transferred back to the storage devices.

This control strategy ensures stable DC link voltage, efficient energy management, and improved dynamic response of the system.

IV. RESULTS AND DISCUSSION

Simulation outcomes demonstrate that the system maintains a stable DC link voltage even when operating conditions change. The motor exhibits smooth speed variation during both acceleration and braking. The DC link voltage is maintained around 300 V during operation.

The battery voltage shows minimal fluctuation, indicating reduced stress, while the supercapacitor supplies or absorbs power during transient conditions. During regenerative braking, energy is effectively redirected back to the storage elements. These observations confirm that the proposed system achieves efficient power sharing and improved dynamic response.

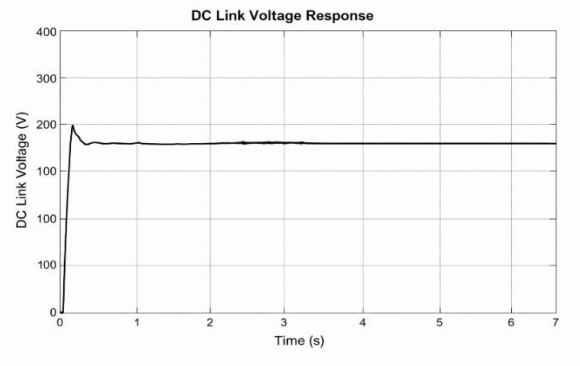

Fig. 2: DC Link Voltage Response of the Proposed System

Fig. 2 shows the simulated DC link voltage response of the system. The voltage quickly rises and stabilizes around 300 V with minimal fluctuations, indicating effective control and stable operation under varying conditions.

V. CONCLUSION

The proposed TAB converter-based hybrid energy storage system improves the performance of electric two-wheelers. It enables efficient power sharing between battery and supercapacitor and supports bidirectional energy flow. The system reduces losses, improves efficiency, and increases battery life.

Future work may include hardware implementation and the development of advanced control strategies for further performance enhancement.

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