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DEVELOPMENT OF ULTRA CAPACITOR BASED REGENERATIVE BRAKING SYSTEM FOR ELECTRIC VEHICLES

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ABSTRACT

Regenerative braking is a technique for converting a moving vehicle's kinetic energy into usable form while slowing it down. When an automobile brakes violently, it usually emits heat. If we could conserve energy rather than waste it, that would be amazing, right? That's where regenerative braking technology comes in handy, especially for electric vehicles. It stores the wasted energy in a battery or ultra-capacitor, so it can be used later to start or accelerate the vehicle. In our project, we looked at how effective regenerative braking is during both braking and starting modes. We compared starting the motor with a battery, ultra-capacitor, or a combination of both (HESS), and also analyzed how storing energy during braking works with these systems. Although not all of the regenerated energy is reinvested in the battery, the motor acts as a generator, charging the vehicle's battery. To move the vehicle forward, regenerative braking uses the kinetic energy it temporarily stores during deceleration. We used a lithium-ion battery and ultra-capacitor module energy storage system coupled to a BLDC motor via a converter. These brakes help batteries last longer without needing to be charged externally. They enable efficient power transfer during regenerative braking and acceleration. Our project discusses whether regenerative braking increases or decreases efficiency. of state of charge of battery and ultra- capacitor when starting and braking applied in discharging(in running of motor) and charging(in regenerative braking of motor). And also BLDC motor speed control in starting and braking mode. The model is simulated using MATLAB Simulink software.

Keywords: Regenerative braking, kinetic energy, electric vehicles, energy storage, battery, ultra-capacitor, starting mode, braking mode, Hybrid Energy Storage System (HESS), efficiency, motor generator

1. INTRODUCTION

The dawn of the 21st century has witnessed the passage provides a detailed examination of regenerative braking technology within the broader context of technological innovation in transportation, particularly focusing on the rise of electric vehicles (EVs) and the quest for environmental sustainability and energy efficiency. It begins by highlighting the unprecedented surge in technological innovation, especially in transportation, driven by concerns over environmental sustainability and energy efficiency. This sets the stage for discussing the pivotal role of regenerative braking in advancing the efficiency of EVs.

Regenerative braking is introduced as a revolutionary technology that captures and converts kinetic energy into electrical energy during braking manoeuvres, rather than dissipating it as heat. This fundamental principle, rooted in the laws of physics, forms the basis for enhancing the efficiency of electric vehicles.

The passage emphasizes the advantages of regenerative braking, including improved energy efficiency, extended driving range, reduced greenhouse gas emissions, and enhanced vehicle control and stability. It also underscores ongoing advancements in regenerative braking technology, fueled by research and development efforts in the automotive industry.

Furthermore, the integration of regenerative braking systems into electric and hybrid vehicles by major automotive manufacturers is highlighted as a significant milestone, showcasing the technology's potential to transform the future of transportation.

However, the passage acknowledges the challenges and limitations facing regenerative braking technology, such as technical complexities, cost considerations, and integration issues. Despite these hurdles, there is optimism about overcoming these challenges through continued innovation and collaboration. the passage underscores the importance of addressing these challenges and fully leveraging the potential of regenerative braking technology to accelerate the transition towards sustainable transportation solutions. It calls for further investment and collaboration to realize a cleaner, greener, and more efficient future of mobility powered by regenerative braking technology and beyond.

1.1 MOTIVATION

As the world moves towards clean energy due to climate change, the automotive industry is focused on making cars more efficient. Electric vehicles (EVs) are seen as a solution to the challenges we face. But a big question remains: how can we make EVs drive farther on a single charge? The answer lies in finding better energy sources like advanced batteries or fuel cells, and improving technologies like regenerative braking systems. In traditional cars, when you brake, the energy of motion is turned into heat. When driving in metropolitan settings, research shows that braking burns a significant amount of energy. This energy can be converted back into electricity and stored in batteries using regenerative braking. We can reuse it to power the vehicle, which saves energy, improves fuel efficiency, and reduces pollution. A recent study predicts that by 2030, all light vehicles sold in India could be electric. EVs are becoming more popular because they produce fewer emissions, are efficient, and operate quietly. Chemical batteries have been the go-tochoice for storing energy in many industries, including electric cars, and they continue to dominate the market.

1.2 AIM OF THE PROJECT

This project delves into studying a regenerative braking system utilizing ultra-capacitors to optimize energy reuse. While conventional chemical batteries exhibit drawbacks like limited lifespan, low power density, and high cost, ultra-capacitors, also known as Electric Double Layer Capacitors (ELDC) or supercapacitors, offer distinct advantages such as heightened power density, extended longevity, and versatility across temperature ranges. However, due to their comparatively lower energy density and potential reliability issues, ultra-capacitors cannot singularly serve as the primary energy storage system. To harness the complementary strengths of both technologies, the concept of a Hybrid Energy Storage System (HESS) is proposed. This approach presents several benefits: ultra-capacitors efficiently capture kinetic energy during braking, assist batteries in managing peak power demands to enhance longevity and vehicle acceleration, and enable the effective storage of braking energy, thereby significantly extending the vehicle's driving range.

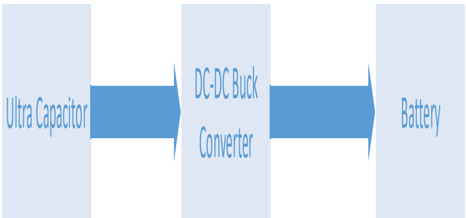

Fig 1. Block Diagram of HESS

1.3 OBJECTIVE

Regenerative braking in EVs redirects kinetic energy back to the battery, extending driving range by up to 40%. Goals include optimizing performance with Hybrid Energy Storage Systems and refining control strategies for hybrid systems. This technology reshapes EV efficiency, paving the way for a sustainable transportation future.

2. LITERATURE REVIEW

Title 1: "Regenerative Braking System Using Ultra Capacitorfor Electric Vehicles

Author &Year:Akash Kothari,Akshay Patel,Komal Koli, Shabbir Governor, International Journal of Recent Trends in Engineering & Research (IJRTER) Volume 04, Issue 03; March- 2018"

This essay highlights the significant energy loss that occurs during braking and proposes the use of regenerative braking technology to capture and store this energy for later use, particularly in electric vehicles (EVs). The technology utilizes ultracapacitors to store the energy generated during braking, which is then converted into electrical energy and stored for future acceleration. This innovative approach promises to enhance the energy efficiency and range of EVs by minimizing energy waste and reducing reliance on conventional friction brakes. By increasing the driving range and addressing concerns like range anxiety, this technology offers a practical solution to real-world challenges in EV adoption while also contributing to environmental benefits by cutting emissions.

"Title 2:Modelling and Simulation of BLDC Motor using MATLAB/SIMULINK Environment"

Author & year: Sudhanshu Mitra1, R. Saida Nayak, Ravi Prakash, International Research Journal of Engineering and Technology Volume: 02 Issue: 08 | Nov-2015

This paper focuses on the use of Brushless DC Motors (BLDC) in a range of industrial applications such as traction drives, electric vehicles, and heating ventilation systems. BLDC motors are preferred for these applications because they offer higher efficiency, greater torque, and compact size. One of the key aspects in using BLDC motors is positioning control, which is crucial for their operation.

"Title 3: Regenerative Braking System in Electric Vehicles"

Author & year: Soniya. K. Malode, R. H. Adware, International Research Journal of Engineering and Technology (IRJET) Volume: 03 Issue: 03 | Mar-2016

Regenerative braking revolutionizes electric vehicles (EVs) by converting kinetic energy into electrical energy during braking, storing it in the vehicle's battery or ultracapacitors. This technology enhances energy efficiency, eliminates traditional braking methods, and reduces energy waste, thus minimizing pollutants and extending EVs' operating range. Now a standard feature in modern EVs, regenerative braking significantly influences their efficiency and environmental impact, countering the drawbacks of hydraulic braking systems that waste energy as heat. The paper concentrates on optimizing regenerated brake energy to make EVs more energy-efficient and sustainable.

"Title 4: Regenerative Braking for an Electric Vehicle Using Ultra capacitors and a Buck-Boost Converter"

Author & year: Juan W. Dixon, Micah Ortúzar and Eduardo Wiechmann, 2017

Regenerative braking, crucial in electric vehicle technology, harnesses braking kinetic energy to improve range and efficiency. Incorporating ultracapacitors and a buck-boost converter enhances efficiency, ensuring compatibility with the vehicle's electrical system. With these advancements, electric vehicles are set to gain popularity due to increased efficiency, prolonged battery life, and superior performance.

Title 5:"Ultra Capacitors Charging by Regenerative Braking in Electric Vehicles

Author & year: Nikolay Lyuboslavov Hinov, Dimitar Nikolov Penev, Gergana Ilieva Vacheva, 2016"

Regenerative braking in electric vehicles (EVs) converts kinetic energy into electrical energy during deceleration. Ultracapacitors amplify this process due to their high-power density and rapid charge-discharge cycles, preventing energy loss as heat and extending the lifespan of braking components. Controlled charging through a robust power electronics system ensures compatibility with the vehicle's electrical design. This integration significantly boosts EV

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efficiency and sustainability, advancing electric mobility alternatives.

3. Purposed methodology

3.1 WorkingPrinciple

Regenerative slowing down is a bleeding edge slowing mechanism that uses the mechanical energy created by the motor. It returns the electrical energy it produced from active energy to the battery. At the point when the brake pedal is applied, the engine switches bearing and works as a generator, easing back the vehicle and charging the battery. At the point when the vehicle is habitually determined, the engine utilizes the energy put away in the battery to drive it ahead. Regenerative slowing down in electric vehicles gives a few benefits, including lower fuel costs, further developed eco-friendliness, and lower outflows. This braking system is especially effective in urban driving, where there are many stops and starts. The controller and braking system are necessary for controlling the motor's operation. The controller calculates the torque and electricity required to generate rotational force based on wheel speed monitoring and feeds the results back into the batteries. When you hit the brakes, the controller recycles the motor's electrical energy back into the batteries.

3.2 Proposed Model

Current slowing mechanisms, for example, regenerative slowing down, utilize the mechanical energy of the engine to change over active energy into electrical energy, which is in this manner got back to the battery. During regenerative slowing down, the engine utilizes its motor energy to slow the vehicle downhill. At the point when the brake pedal is discouraged, the engine goes about as a converse generator, dialing back the vehicle. At the point when the engine is backward, it produces electrical energy, which is utilized to re-energize the battery. At the point when the engine is turned on, the battery produces the energy expected to drive the vehicle ahead. The energy change and utilization cycle adds to the supportability and proficiency of electric vehicles. In electric vehicles, regenerative braking offers several advantages. It reduces emissions, lowers fuel costs, and improves fuel efficiency. Regenerative braking enhances the overall sustainability and environmental friendliness of electric vehicles by efficiently using the kinetic energy generated during braking.

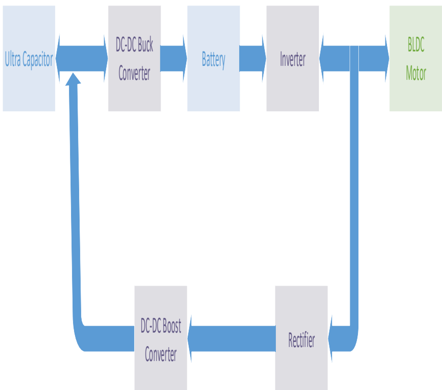

Figure 2 Simple Block Diagram of Regenerative Braking System

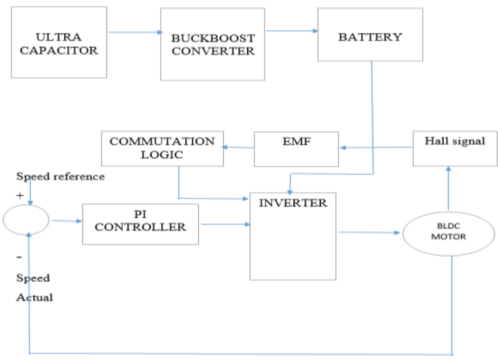

Figure 3 Block diagram for Simulink model in starting mode

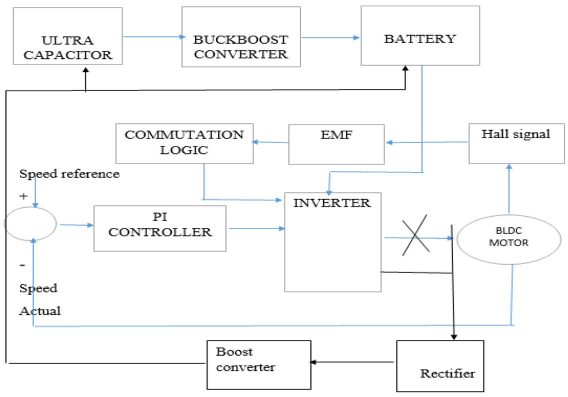

Figure 4 ultra capacitor diagram

4. RESULTS

4.1 Simulations

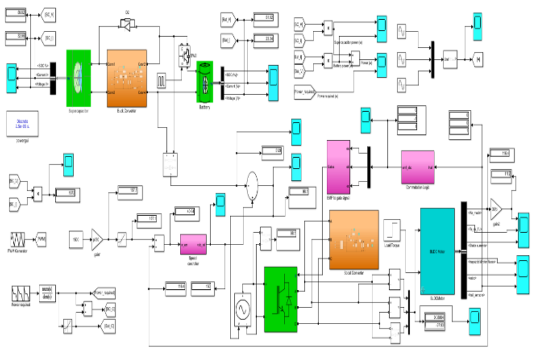

Figure 5 Simulation ModelResults Battery as a source

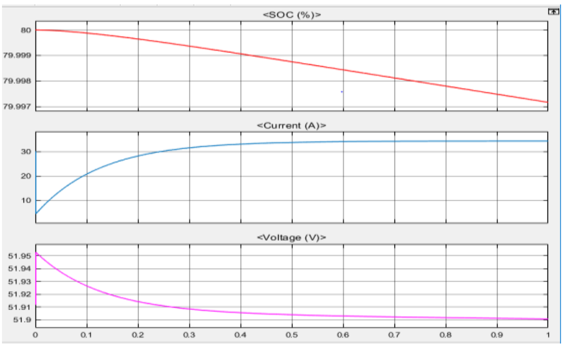

Figure 6 SOC, Current and voltage response when only Battery as a source

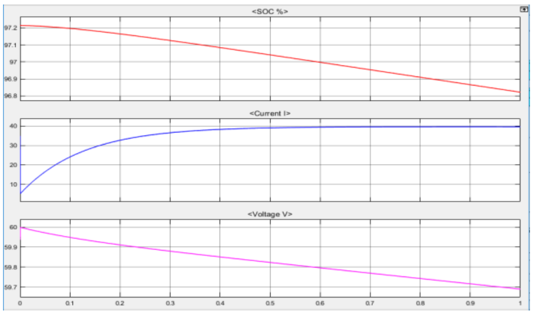

Figure 7 SOC, Current and voltage response when only ultra-capacitor as a source

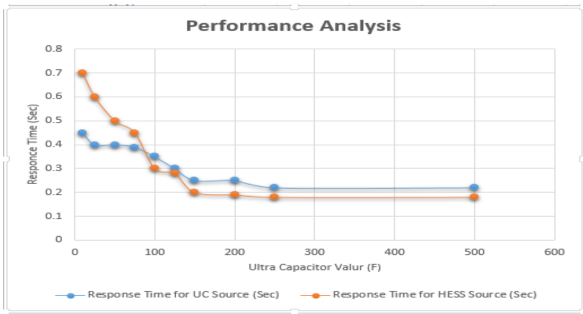

Figure 8 SOC, current and voltage of UC when HESS is energy source

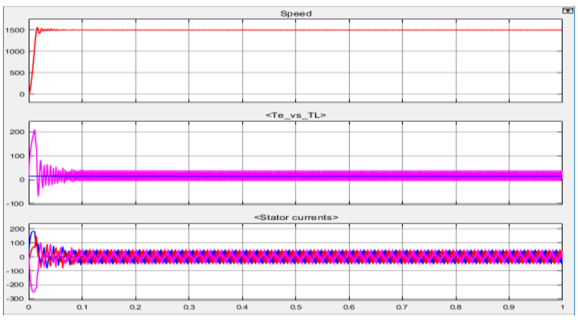

Figure 9 10kW Motor starting speed, Torque and Stator Current when source is HESS

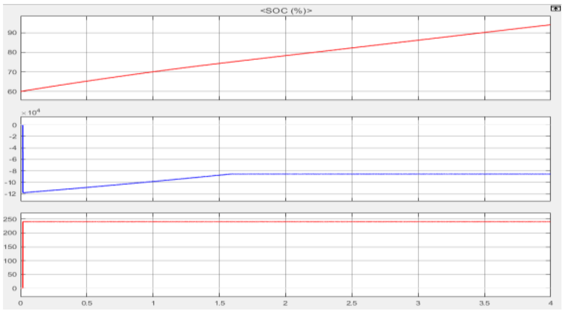

Figure 10 SOC, Current and voltage response when regenerative braking with Battery

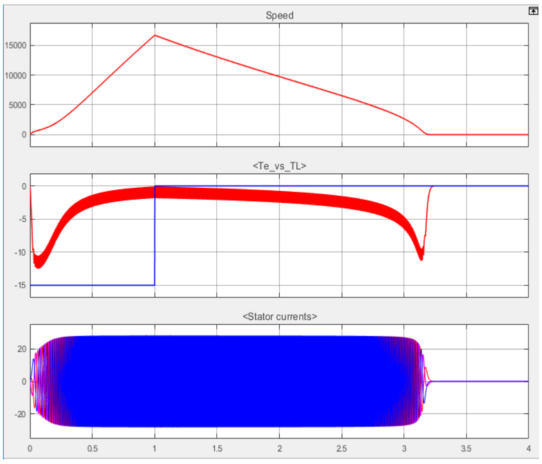

Figure 11 Motor braking speed, Torque and Stator Current when regenerative braking with Battery

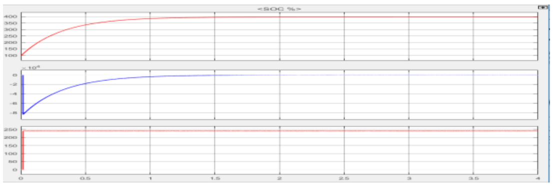

Figure 12 SOC, Current and voltage response when regenerative braking with UC

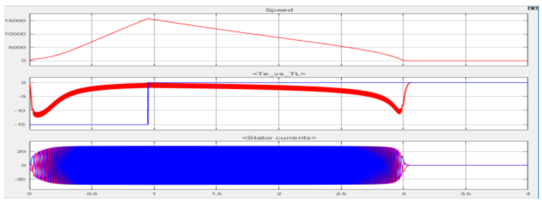

Figure 13 Motor braking speed, Torque and Stator Current when regenerative braking with UC

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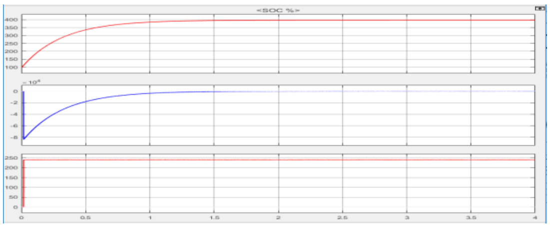

Figure 14 SOC, Current and voltage response of UC when regenerative braking with HESS

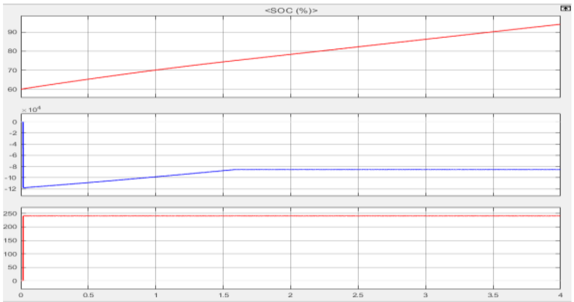

Figure 15 SOC, Current and voltage response of Battery when regenerative braking with HESS

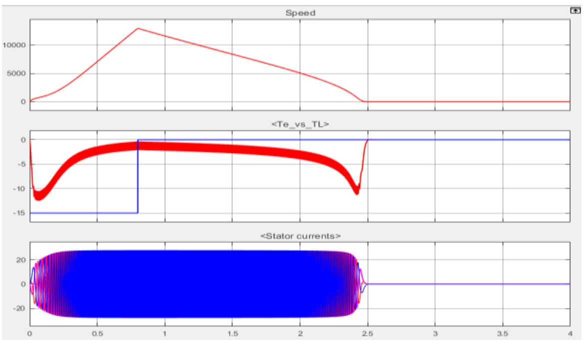

Figure 16 Motor braking speed, Torque and Stator Current when regenerative braking with HESS

We see the all required result which is strongly related to this project which shows that how speed varies in staring as well as in braking mode and how the state of charge (SOC) increase and decrease in braking and starting mode of vehicle.

5. CONCLUSION AND FUTURE SCOPE

The proposed regenerative braking system, incorporating a hybrid energy storage system (HESS) for electric vehicles (EVs) with brushless DC (BLDC) motors, presents a promising solution for boosting energy efficiency and extending driving range. By capturing kinetic energy from the vehicle during braking, this system stores it in an ultracapacitor, enhancing efficiency and safety during deceleration. The HESS, comprising an ultracapacitor, a DC-DC buck converter, and a battery, efficiently manages power distribution during acceleration and braking phases, ensuring smooth operation and reliable performance across diverse driving conditions.

Looking ahead, the future of regenerative braking technology holds vast potential for further advancements and refinements. Continued technological evolution is expected to significantly enhance the efficiency and effectiveness of regenerative braking systems. Areas of future research and development include exploring energy regeneration using AC/DC converters to enhance system efficiency and performance, investigating road load and traction forces affecting EVs to optimize regenerative braking strategies, and developing advanced control strategies to maximize energy recovery and improve vehicle dynamics.

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