# ENERGY REGENERATION SYSTEM FOR ELECTRIC VEHICLES USING DC-DC CONVERTER WITH SUPER-CAPACITORS

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**Abstract:** In order to improve the effificiency of electric vehicles, energy regeneration systems using super-capacitors have been researched. In this paper, an energy regeneration system using two super-capacitors is proposed. This system can reduce the regenerative current to the battery by storing the regenerative power in the super-capacitor. In addition, it reduces the energy loss of the inverter and the motor by changing the input voltage of the inverter according to the rotation speed of the motor. In this paper, the voltage control method and capacitor utilization of the proposed circuit are described. The effectiveness of the bi-directional DC-DC converter in the proposed circuit is verified by the experiment.

***Key words: DC-DC converter, Super capacitor, EV, ERS, ZVS.***

## I INTRODUCTION

An Energy Regeneration System (ERS) for electric vehicles (EVs) using a DC-DC converter with super-capacitors is an advanced approach to improving energy efficiency and performance in EVs. The main objective of this system is to recover energy during braking or deceleration, a process known as regenerative braking. Unlike traditional vehicles that lose kinetic energy as heat through frictional braking, EVs equipped with this technology capture and store the energy, which can then be reused. The system utilizes a DC-DC converter to regulate the energy flow, ensuring that it is optimally stored in super-capacitors, which are highly efficient in capturing and discharging power quickly.

Super-capacitors are an ideal choice for energy regeneration due to their high power density, fast charge-discharge cycles, and long operational life compared to traditional batteries. They complement the slower charge-discharge behavior of lithium-ion batteries, making them particularly suitable for handling the short bursts of energy associated with braking. When paired with a DC-DC converter, the super-capacitors can quickly absorb the recovered energy, reducing the strain on the primary battery and improving the overall lifespan of the energy storage system. Additionally, this configuration enhances the vehicle's acceleration by providing an immediate power boost from the stored energy when needed.

The integration of the ERS with super-capacitors and a DC-DC converter provides several advantages, including increased energy efficiency, extended battery life, and improved driving range. By harnessing and reusing braking energy, the system reduces the vehicle's overall energy consumption, contributing to greener and more sustainable transportation. This technology is particularly important in urban environments, where frequent stops and starts occur, maximizing the opportunities for energy regeneration. As the electric vehicle market continues to grow, innovations like the ERS will play a crucial role in making EVs more energy-efficient, cost-effective, and environmentally friendly.

## II SURVEY OF RESEARCH

· F. Gao, B. Blunier, M. G. Simoes, and A. Miraoui (2012) - In their work titled "Energy Management in Electric Vehicles: Optimizing Energy Regeneration with Supercapacitors and DC-DC Converters," the authors explored how DC-DC converters improve energy transfer between super-capacitors and batteries in EVs. Their research emphasizes the high-power density and rapid charge-discharge properties of super-capacitors, which allow for better handling of regenerative braking energy. They also highlighted the importance of bidirectional DC-DC converters in efficiently managing energy flows between super-capacitors and the battery system. The study concluded that a hybrid energy storage system combining super-capacitors and batteries could extend battery life and improve vehicle efficiency.

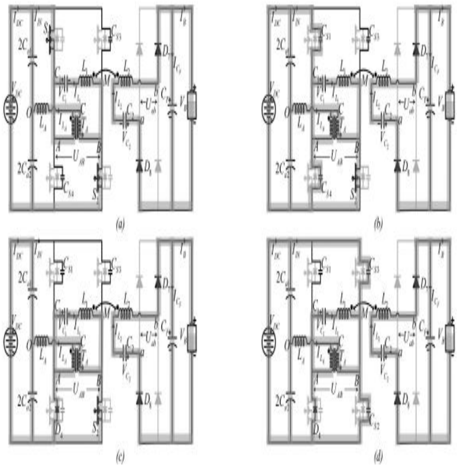
· · X. Yan, J. Liu, and L. Wang (2015) - In their paper, "Energy Regeneration in Electric Vehicles: The Role of Supercapacitors," the authors presented an in-depth analysis of how super-capacitors and DC-DC converters can enhance energy regeneration in EVs. Their study focused on optimizing the regenerative braking process to maximize the energy recovered. They found that the use of super-capacitors significantly reduces energy loss during braking and facilitates smoother energy recovery by mitigating power spikes that occur during sudden deceleration. Their work provided design guidelines for combining super-capacitors with a DC-DC converter to improve energy management in EVs.

· · A. Khaligh and Z. Li (2010) - In their research titled "Battery, Ultracapacitor, Fuel Cell, and Hybrid Energy Storage Systems for Electric, Hybrid Electric, Fuel Cell, and Plug-In Hybrid Electric Vehicles: State of the Art," Khaligh and Li conducted a comprehensive review of hybrid energy storage systems (HESS) in electric vehicles, which included the combination of batteries and super-capacitors. Their analysis detailed how DC-DC converters enable efficient energy flow between energy storage components. The study highlighted the advantages of super-capacitors in regenerative braking applications, especially in urban driving conditions where frequent braking occurs. They also discussed the economic and environmental benefits of integrating such systems into EVs, which lead to higher efficiency and longer battery life.

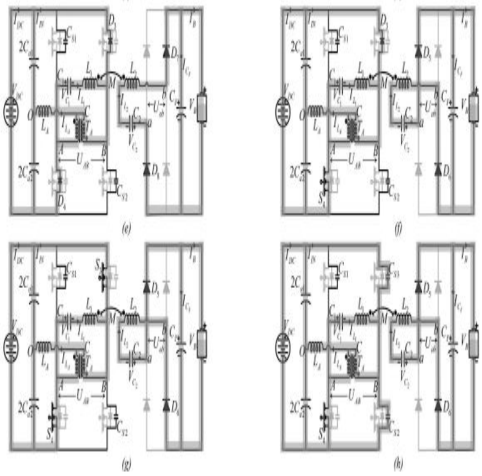
· · M. Ehsani, Y. Gao, S. Gay, and A. Emadi (2005) - In "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design," the authors explored the integration of super-capacitors with batteries using DC-DC converters in electric vehicles. Their research provided a theoretical background on energy regeneration, focusing on the role of super-capacitors in absorbing and releasing energy quickly during braking and acceleration. They discussed how DC-DC converters are crucial for matching the voltage levels between the battery, super-capacitor, and electric motor, ensuring optimal energy utilization. The study underlined the potential of super-capacitors to increase overall system efficiency in electric and hybrid vehicles.

## III WORKING METHODOLOGY

The working methodology of an Energy Regeneration System (ERS) for electric vehicles (EVs) using a DC-DC converter with super-capacitors revolves around capturing and reusing energy that would otherwise be lost during braking. This process begins during the regenerative braking phase, where the vehicle's electric motor acts as a generator. When the driver applies the brakes, the kinetic energy of the moving vehicle is converted into electrical energy. Instead of being dissipated as heat in traditional braking systems, this electrical energy is directed towards the energy storage system, where the DC-DC converter comes into play.



The DC-DC converter is a key component that regulates the energy flow between the electric motor, the super-capacitor, and the battery. Since the super-capacitor operates at a lower voltage compared to the vehicle's main battery, the DC-DC converter ensures that the recovered energy is efficiently transferred to the super-capacitor. The converter adjusts the voltage levels to optimize energy storage in the super-capacitor, which is capable of handling quick bursts of energy due to its high power density and rapid charge-discharge cycles. This reduces the strain on the main battery by absorbing the high-power surges during braking.



Once stored in the super-capacitor, the energy can be used during the vehicle's acceleration phase or when extra power is needed, such as during hill climbs or sudden speed increases. The DC-DC converter again plays a vital role by regulating the discharge of energy from the super-capacitor back to the vehicle's electric motor. This immediate release of energy reduces the load on the primary battery, enhancing overall energy efficiency and vehicle performance. The system not only improves energy utilization but also extends the lifespan of the battery by reducing frequent high-power demands, making the EV more efficient and sustainable over time.

## IV SIMULATION RESULTS

The working principle of the proposed converter topology is validated by performing modeling, simulation, and hardware testing. The circuit parameters in simulation and hardware are tuned to an operating point to understand the behavior of the converter. A. Simulation Results The simulation of a proposed topology has been done in MATLAB/Simulink by using principal components, as shown Fig. ZVS turn-ON for S1 − S4. in Fig. 4 and Table I. The ideal dc source is placed in series with resistor (nΩ) and inductor (nH). MOSFET switches from SimPowerSystem Library with 0 Ω resistance and 870 pF capacitance as snubber have been used to simulate H-bridge part of dc–dc converter.

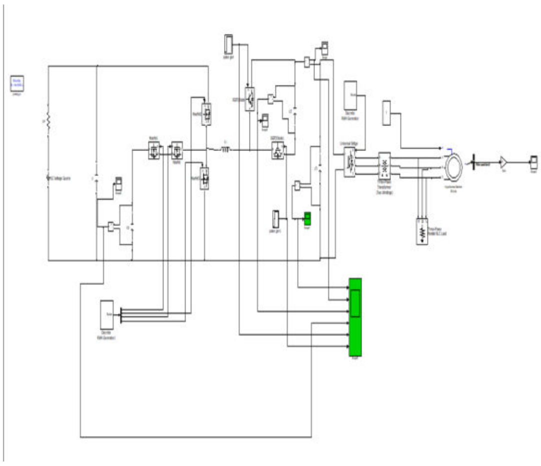


**Fig.1. Simulation circuit.**

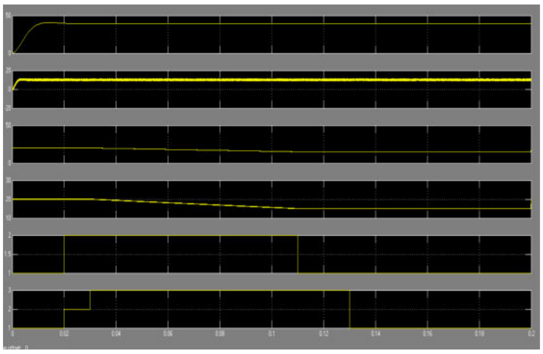


**Fig.2. Output results**

## CONCLUSION

In this article, the voltage fed series compensation based ZVZCS topology and its tuning method for wireless electrical vehicle battery charger have been proposed. Suitable modifications were presented for the full-bridge dc–dc converter, and enhanced performance with a wide range of input variation is achieved. The need for a high-power processor is eliminated, which further reduces the overall cost. The theoretical analysis and modeling have been presented to obtain ZVZCS with reduced control complexity. The simulation results verified the ZVZCS condition of the proposed topology for a full load range. The offered solution produced less ripple in input/ output voltage and current while utilizing a low value of dc link, and filter capacitance values, respectively. An acceptable efficiency of 91.26% has been achieved for both battery and resistive loads.

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