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A Hybrid Model of Regenerative Braking for Operation and Control in Electric Vehicles

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Abstract: - The issue of charging electric cars has persisted throughout history. Deceleration is the process by which the drive train of the brakes converts kinetic energy to potential storage, as described in this paper. When the vehicle requires that energy, it is transformed back into energy and stored in the battery. Conservation power is affected by storage type, drivetrain efficiency, driving cycle, and inertia weight. When a brake is applied, the kinetic energy of a normal vehicle is transformed into heat by the friction between the brake pad and wheels. As this heat moves through the atmosphere, some of its energy is lost. The energy lost in this way depends on the length, force, and frequency of braking. An energy conversion procedure known as regenerative braking involves storing some of the vehicle's energy in a battery or some other kind of storage device. When compared to the possible energy savings, driving in a city results in a substantial amount of wasted energy due to the increased braking required. When it comes to vehicles used for public transportation, such delivery trucks, buses, taxis, and local trains, the possibility of energy regeneration is much greater.

Keywords: Regenerative braking, motor generator, Energy recovery, Electric Vehicles.

1. INTRODUCTION

Electrical car charging has always been a problem. This paper discusses how the drive train in the brakes transfers kinetic energy, which is then directed by a mechanical system to the potential storage during deceleration. That energy is retained until the car needs it, at which point it is converted back into energy and kept in the battery. The kind of storage determines how much electricity is available for conservation. You're squandering energy each time you apply the brakes. According to physics, energy cannot be annihilated. Therefore, the kinetic energy that was driving your automobile forward must go somewhere as it slows down. The majority of it just turns into heat and is no longer useful. It's basically a waste of energy that might have been put to use. Up to 30% of the power produced by the vehicle is wasted when this thermal energy evaporates into the atmosphere. The vehicle's fuel economy gradually decreases as a result of this cycle of friction and squandered heat energy. To make up for the energy lost by braking, more engine power is needed. It's an unavoidable consequence of braking in most automobiles, and you can't drive a car without periodically using the brakes. However, after considerable consideration, automotive experts have developed a type of braking system that can catch a large portion of the vehicle's kinetic energy and transform it into electrical energy that can be utilized to replenish the vehicle's batteries. Regenerative braking is the name of this system [1].

Brake pads and brake rotors provide friction in a conventional braking system, which slows or stops the car. Between the slowing wheels and the road surface, more friction is created. The kinetic energy of the automobile is converted to heat by this friction. However, with regenerative brakes, most of the braking is done by the vehicle's driving system. Electric or hybrid brakes slow down the wheels of the vehicle by putting the electric motor in reverse mode, which causes it to run backwards, when the driver presses the brake pedal. The engine also generates power while it runs backwards, which is then transferred to the car's batteries. The usage of batteries as the sole

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energy source is another significant drawback of fully electric vehicles. This leads to issues due to the vehicle's low specific power, lengthy charging periods, and incapacity to satisfy its short-term power needs. As a result, the motor's ability to accelerate, climb, brake, and recover energy is significantly impacted. The high energy density and great storage capacity of EV batteries, however, is a benefit. Furthermore, a longer service life is provided by upgraded battery technology. By recovering a portion of the braking energy, EVs' regenerative braking system (RBS) improves energy efficiency. However, the generator produces a significantly high feedback current under various braking circumstances. Excessive charging current might reduce the battery's cycle life. Furthermore, the constraints of the battery and motor characteristics may prevent the energy recovery rate from reaching the intended level. At some speeds, some brakes perform better than others. Actually, stop-and-go driving is where they work best. This is meant to rotate the wheel by means of a pedal that is attached to the DC dynamo shaft via a screw-bar link mechanism. Power is generated as the wheel turns and comes into contact with the brake drum, which instantly stops [2].

Age, inertia weight, driving cycle, and drivetrain efficiency. The friction between the brake pad and wheels causes the kinetic energy of a typical vehicle to be converted to heat when The brake is engaged. The vitality is lost when this heat travels through the atmosphere. The amount of energy lost in this manner is contingent upon the frequency, duration, and force of the brake application. Regenerative braking is an energy conversion process where a portion of the vehicle's energy is saved in a battery or other storage device. Driving in a city requires greater braking, which results in a significant energy waste compared to the potential for energy savings. There is even more potential for energy regeneration in the case of public transportation vehicles, such as delivery trucks, buses, taxis, and local trains.

2. LITERATURE REVIEW

Regenerative braking systems (RBS) greatly enhance electric vehicles' (EVs') energy efficiency by converting the kinetic energy lost during braking into usable electrical energy. Unlike conventional braking systems, which wastefully dissipate this energy as heat, RBS can store and repurpose it, enhancing overall vehicle effectiveness as well as extending the life of the battery. There has been a lot of study on many parts of regenerative braking, including how it works, the efficiency benefits it provides, and the technological advances in the field. This approach reuses energy that would have been lost due to friction by capitalizing on the fact that When velocity is squared, kinetic energy rises ($E = m \cdot v^2$). One possible use of regenerative braking technology is the use of an electric motor to convert mechanical motion into electrical energy. The flywheel may furthermore transform the vehicle's kinetic energy into mechanical energy if that becomes required. Much study in the years following the energy crisis focused on the practicality and practicability of combining hybrid power trains with regenerative braking to improve the fuel efficiency of vehicles used in urban driving conditions. This section presents a literature review that draws on the primary findings from the uploaded document as well as other research pieces [4].

The paper lays out the basics of regenerative braking to show how an electric motor may be used as a generator during braking, converting mechanical energy into electrical energy that can be stored in the vehicle's battery. This method, which involves storing or feeding back into the power supply system, is widely used in electric train systems as well as hybrid and electric vehicles. There are a lot of factors that influence the efficiency of regenerative braking, such as the capacity of the energy storage system, the design of the motor, and the driving conditions. The study also highlights the need for extra friction brakes for comprehensive vehicle stopping and safety, as well as the fact that efficiency decreases at lower speeds. Even while regenerative braking systems improve energy efficiency by collecting braking energy, batteries may have a shorter cycle life if the feedback current is too high when braking. In addition, energy recovery is usually limited by the battery and motor specifications [3].

There have been a number of investigations on how to improve regenerative braking systems for maximum energy recovery. Studies have shown that front-wheel-drive electric vehicles can benefit from fuzzy control systems, which optimize the distribution of deceleration forces, improve energy recovery, and guarantee that braking needs are met. In reaction to real-time circumstances, these strategies use AI methods to dynamically alter braking characteristics. Game theory, which offers a multi-objective framework, has also been used to improve RBS. This framework finds a middle ground between comfort, braking stability, and energy recovery. As power is stored in the accumulator, the vehicle's acceleration decreases. The hydraulic system's mode of operation was regenerative braking. When the vehicle is in pump mode, the secondary component uses the vehicle's kinetic energy to pressurize the oil in the reservoir, which then flows into the accumulator. In order to maximize EV drivable range and minimize energy waste, these models determine the optimal distribution of braking torque [5].

The linked document also discusses the use of regenerative braking in electric train systems. Historical applications of this technology to reduce operational costs and energy consumption include regenerative braking in high-speed trains and trams. Modern rail systems continue to employ regenerative braking, which allows for the recycling of unused energy into the grid for use by other trains or other electrical equipment. Formula One and high-performance vehicles rely on kinetic energy recovery systems (KERS) for regenerative braking. These systems store braking energy in flywheels or capacitors for immediate reuse. Both performance and acceleration are enhanced as a result. When a hybrid or electric car brakes, the effect is magnified by the electric motor that drives the wheels. When you press down on the brake pedal, the engine's regenerative braking circuit changes its operation such that it now works in reverse, counteracting the wheel bearings. Due to its inverted design, it produces electrical vitality in a manner similar to that of a dynamo or power generator [6].

Problems with regenerative braking persist despite these advancements. The effectiveness of energy recovery is affected by factors like as road conditions, braking effort, and battery quality. Vehicle safety in emergency braking conditions is ensured by using friction-based braking. Also, hybrid drivers need to make sure that their regenerative and conventional braking systems are in sync for a safe and comfortable ride. When a hybrid or electric car brakes, the effect is magnified by the electric motor that drives the wheels. When you press down on the brake pedal, the engine's regenerative braking circuit changes its operation such that it now works in reverse, counteracting the wheel bearings. Research on brake controllers that can intelligently switch between regenerative and friction braking in response to vehicle circumstances is continuing [7].

When it comes to environmental friendliness, driving efficiency, and power savings, regenerative braking systems are head and shoulders above the competition. Maximizing electric vehicle energy recovery is being challenged by a mix of machine learning algorithms, advanced control systems, and ideal braking profiles. Following the steps outlined before, the regeneration mechanism will begin to work. If you have a gearing setup, the traction motor (M) and generator (G) are linked in parallel. That is why the generator-to-variable-speed motor ratio is important [8].

3. BLOCK DIAGRAM OF REGENERATIVE BRAKING SYSTEM

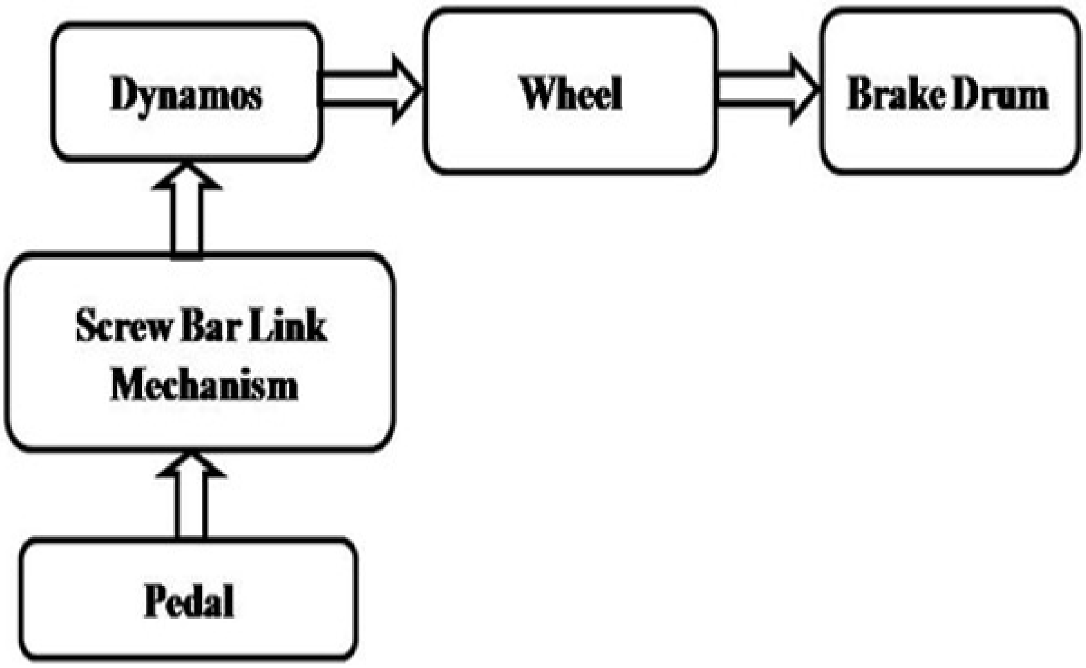

Fig1. Block Diagram of Regenerative Braking System.

Battery pack

The battery pack is made up of four 12V, 12AH batteries that are linked in series to deliver power to a 48V, 12AH circuit. In the driving mode, this battery supplies electricity, and in the regeneration mode, it serves as an energy storage device.

Motoring Block

Power MOSFETs, gate driver integrated circuits, and a controller make up this circuit block, which drives the motor in the first stage, accelerates it to the desired speed, and regulates its speed.

Regenerative Block

This block is made up of diodes that, when forced into forward conducting mode, store energy back into the battery pack.

4. PAPER OVERVIEW

Santos et al. provided solutions for the creation of an electric traction system by demonstrating its power converter and control features. The focus was on the converter's building techniques and issues, such as controllers, vehicle control, and protection. The study's vehicle was powered by 500W, 48V BLDC motors. Because this motor required a high current value of 20 A, it was crucial to take safety issues into account when designing the suggested architecture. In order to reduce heat generation and shield delicate components from harm during high-load operations, thermal management techniques were investigated. Additionally, it was stressed that the control algorithm should be optimized in order to improve overall motor performance and system dependability [9].

In order to accomplish power conservation and minimal energy dissipation based on the motor operational requirements, a chopper, or DC to DC power converter, was briefly examined for both forward and backward vehicle operation. In order to protect and ensure the safety of the motor, controller, and various electrical and mechanical components, this paper explained the rationale, significance, and necessity of controlling the converter's variable output current, or controller, as opposed to voltage control, under the built-in relationship between throttle control and torque developed with regard to internal combustion engines. Methods to reduce power losses and maximize switching frequency were investigated. In order to optimize energy recovery during deceleration, the integration of regenerative braking was also examined [10].

There have also been systems that suggest using regenerative braking to conserve more energy, such as the Panagiotis et al. method. Conversely, Dixon et al. proposed a system that uses an IGBT buck boost converter power electronic device connected to the main batteries at the buck side and a bank of ultra-capacitors at the boost side. This allows for additional vehicle acceleration and deceleration with the least amount of energy loss and battery deterioration. Furthermore, sophisticated energy management algorithms have been put into place to maximize power distribution between the battery and ultra-capacitors, enhancing system efficiency overall. Additionally, thermal management strategies were included to guarantee a longer system lifespan by preventing overheating during high-current operations [11].

According to Chetana Kumar et al., who reviewed the possible need for India to design and develop a small electric concept vehicle that is competitive on a global scale, EVs are the answer to reducing urban pollution, and the adoption of HEVs and EVs would have significant positive effects on the economy and society. the braking method that transforms the motor's kinetic energy into electrical energy, which is then returned to the battery supply. Theoretically, the regenerative braking system may transfer a substantial amount of its kinetic energy to battery charge using the same principle as an alternator [12].

The research also described how governments and communities throughout the world might support and accelerate the use of electrical vehicles. According to the application of HEVs and EVs would have significant economic and societal benefits in addition to reducing pollution in cities. These benefits are outlined in detail, along with the necessity for framework development, challenges, and opportunities for design and deployment of emerging frameworks related to Plug-in Electric Vehicles (PEV). From battery production to communication and control between the vehicle and the electric power grid to supply safe and clean electricity, the initiator had solved the crucial issue of increasing revenues from the potential to reduce fuel use.

5. OUTPUT RESULTS:

A pedal that is attached to the shaft of the DC dynamo via a screw-bar link mechanism is used in the project **"A HYBRID MODEL OF REGENERATIVE BRAKING FOR OPERATION AND CONTROL IN ELECTRIC VEHICLES"** to rotate the wheel. Power is generated when the wheel turns and comes into contact with the brake drum, which instantly stops. The purpose of the regenerative braking system is to partially restore the lost battery charge. in relation to vehicle braking. The energy is converted into heat by friction brakes and released into the atmosphere. By spinning the generator rotor, the wheels' mechanical energy is transformed into a useful battery charge. In order to enhance braking performance in automobile transportation, regenerative braking system implementation is crucial.

Fig2. Experimental Setup of Regenerative Braking in EV.

Fig3. A Close View of Circuit Connections of Regenerative Braking in EV.

6. CONCLUSION

It was designed with features that include every piece of hardware. The placement of each module has been carefully thought out in order to optimize the unit's performance. Second, with the help of emerging technology, the article has been successfully implemented using very sophisticated ICs. Consequently, the design and testing of the project were successful.

6.1: Future Scope

To improve energy efficiency and prolong battery life, regenerative braking systems can be added to bicycles, electric bikes, scooters, and electric vehicles (EVs). In bigger applications, it can be used in conjunction with a battery management system (BMS) to further optimize energy use.

IoT-based real-time monitoring for braking pattern analysis and predictive maintenance is one potential future development that might lead to more economical and environmentally friendly transportation options. Furthermore, this technology may be modified for self-driving cars, enhancing system performance and encouraging more environmentally friendly transportation.

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