Enhanced Energy Recovery Using Regenerative Braking Techniques

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Abstract - Regenerative braking system is the system in which the kinetic energy of the vehicle is stored temporarily; during deceleration and is reused as kinetic energy. Regenerative braking is a step to reduce the use of fossil fuels. While braking, a large amount of energy is lost in the form of heat. A regenerative braking system aims to utilize this energy instead of getting it wasted. In this mechanism, the electric traction motor uses the vehicle's momentum to recover energy lost while braking. This contrasts with the conventional braking system, where the excess kinetic energy gets converted to unwanted heat and is wasted due to friction in the brakes, or with dynamic brakes.

Key Words: *Regenerative braking, Energy recovery, Deceleration, Fossil fuel reduction, Heat loss, Energy utilization.*

1. INTRODUCTION

Brakes are employed to stop or retard the motion of any moving body. In an automobile, brakes are equally important as the engine. In a conventional braking system, the motion is retarded or stopped by absorbing kinetic energy by friction; by making the contact of the moving body with a frictional rubber pad (called brake liner) which causes the absorption of kinetic energy. This energy dissipates as heat into surroundings. Each time brakes are applied, the momentum gets absorbed to re-accelerate, and the vehicle has to start from scratch, redeveloping it using power from the engine. Thus, it will ultimately result in the wastage of energy. A regenerative brake is an energy recovery mechanism that slows a vehicle by converting its kinetic energy into another form, which is used immediately or stored until needed.

Thus, the generated energy during the braking is sent back into the supply system (in the case of electric trains), whereas, in battery electric and hybrid electric vehicles, the energy is stored in a battery or bank of capacitors for later use. Energy can also be stored by compressing air or in a rotating flywheel. Process of braking is one of- if not the most important matter of motion. During braking energy of friction (mechanical) is converted to heat and thus wasted. Electric vehicles recover part of that energy by regenerative braking. Regenerative braking is a widely studied and known process found in traction of railways, trams and trolleybuses but appears as a nuance to automobiles. The process also benefits them by extension of their drive range or just by powering electrical accessories. EVs also incorporate a typical mechanical brake system used for emergency stops with shorter brake times.

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2.1 METHODOLOGY

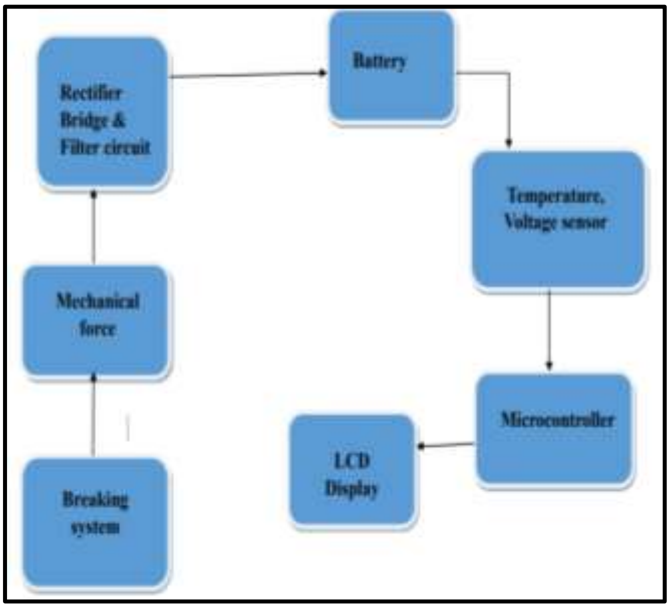

Figure 1: BLOCK DIAGRAM

When the braking system is activated, it generates mechanical force as a result of the deceleration process. Instead of allowing this energy to dissipate as heat, the system utilizes the mechanical force to drive a generator, thereby converting mechanical energy into electrical energy. This generated electrical energy, which is typically in the form of alternating current (AC), is then passed through a rectifier bridge circuit. The rectifier bridge converts the AC into direct current (DC), and a filter circuit is employed to smooth out any fluctuations, ensuring a stable DC output. The filtered DC power is then stored in a battery, which acts as the energy storage device for the recovered energy.

To monitor the health and performance of the battery, temperature and voltage sensors are connected to it. These sensors continuously measure critical parameters like battery voltage levels and temperature to ensure safe operation. The collected sensor data is fed into a microcontroller, which processes the information and makes decisions based on predefined conditions, such as halting the charging process if the voltage or temperature exceeds safe limits. Finally, the processed information is displayed on an LCD display, providing real-time feedback to the user regarding the battery's status, including voltage levels and temperature. This entire process enhances the overall energy efficiency of the system by recovering energy that would otherwise be wasted during braking.

One of the two motors is used as the main motor. This is connected to the gear using a spindle shaft. The motor's tip is connected to a gear which can be meshed with the braking gear. It has a capacity of 12v. The other motor is used as the dynamo. The motor tip is connected to another gear and when the gears mesh, the motor spindle rotates. The rotating spindle has kinetic energy and due electro-magnetic force the kinetic energy is converted into electrical energy. The motor has the capacity of 12v. LED are used in order to show the power generated from the regenerative brakes.

Regenerative energy can be produced only when the vehicle is in motion. The axles must have enough momentum which will be utilized by the system. The energy (electricity) produced using regenerative braking, should either be utilized immediately or be stored in a battery for future use. There must be a controller which turns ON or OFF the process of regeneration based on the requirement and availability. There must be a provision of frictional braking to stop the vehicle, which should be used when regenerators fail or during an emergency. Regenerative braking system may not suffice the basic requirement of braking system alone. This is because of limitation of energy dissipation at very high power.

2.2 WORKING PRINCIPLE

Regenerative braking is a braking method that utilizes the mechanical energy from the motor by converting kinetic energy into electrical energy and fed back into the battery source. Theoretically, the regenerative braking system can convert a good fraction of its kinetic energy to charge up the battery, using the same principle as an alternator. In regenerative braking mode, it uses the motor to slow down the motor. When the user applies force to the brake pedal, the electric motor works in reverse direction. Once user applied the breaker, the generator part will rotate with mechanical force. This power will pass through rectifier and filter circuit. This circuit will convert generated power to pure DC output. After that this power will get store in the power battery bank. We are interfacing voltage and temperature sensor and microcontroller for reading the voltage and temperature. User will able to see in LCD display the generated voltage by system and temperature of battery.

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One of the two motors is used as the main motor. To monitor the health and performance of the battery, temperature and voltage sensors are connected to it. These sensors continuously measure critical parameters like battery voltage levels and temperature to ensure safe operation. The collected sensor data is fed into a microcontroller, which processes the information and makes decisions based on predefined conditions, such as halting the charging process if the voltage or temperature exceeds safe limits. LED are used in order to show the power generated from the regenerative brakes.

2.3 RESULTS

The system was designed to measure and display both temperature and generated voltage using an Arduino Uno, an LCD screen, and relevant sensor modules. The following figures illustrate the results obtained during different conditions of the system.

Figure 2. shows the system in an idle state, where the main battery pack provides a voltage of approximately 11.91V, displayed on the LCD screen. This represents the input voltage available from the battery side, and at this stage, the regenerative system is not yet active. The temperature reading is 31.0°C, indicating the ambient or system temperature at the time of testing.

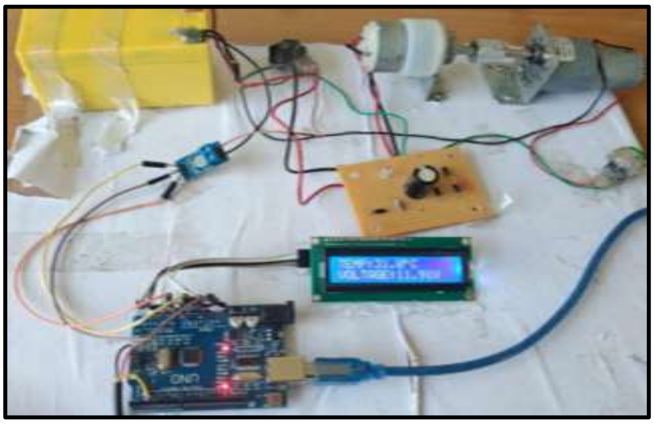

Figure 2: Battery Side Voltage with temperature

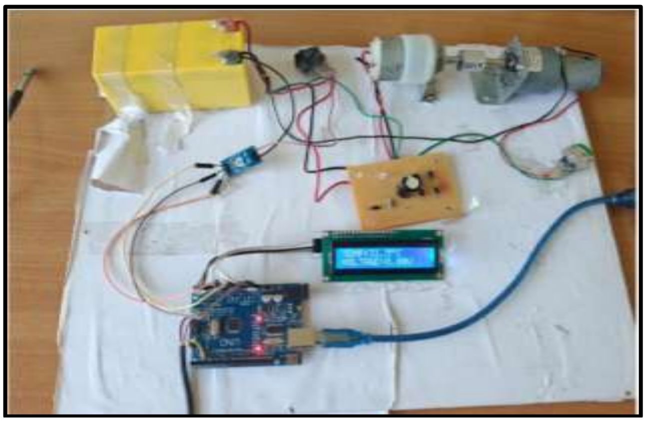

Figure 3: Initial Stage Voltage with Temperature

Figure 3 represents the initial condition where the regenerative braking system is at rest. The voltage shown on the LCD is 0.00V, indicating no energy is being recovered. The system is in a non-generative state, with the braking mechanism not yet applied. However, the temperature has slightly increased to 31.5°C, likely due to minor electrical activity or ambient conditions.

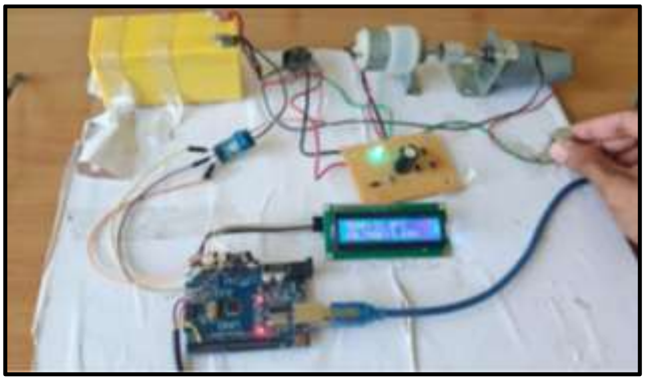

Figure 4: Regenerative Stage Voltage with Temperature

Figure 4 demonstrates the active regenerative state. In the braking condition a voltage of 5.69V is successfully generated and displayed on the LCD. This confirms the effectiveness of the regenerative braking technique in recovering energy. Additionally, a green LED on the circuit board is illuminated, signifying that the energy recovery circuit is active and functioning correctly. The temperature remains stable around 31.0°C, ensuring that the system operates within safe thermal limits.

3. CONCLUSION

The regenerative braking system used in vehicles satisfies the purpose of saving a part of the energy lost during braking. The regenerative braking system is designed to partially recover the battery charge wasted in braking of the vehicle. The energy is converted into heat by friction brakes which are dissipated to the environment. This Energy is utilized to rotate the rotor of generator converting mechanical energy of wheels into useful charge of battery. The regenerative braking system cannot be used as main braking system of vehicle as it cannot bring the vehicle to rest.

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