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Regenerative braking for electric vehicles and industrial drives by using super-capacitor

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Abstract
The aim of this paper is to present the implementation of regenerative brake system in electric vehicle operated on battery. Regenerative braking improves the efficiency of vehicle by recovering Kinetic Energy energy feedback to the energy storage system. The energy lost during deceleration period which is now recovered, stored in battery and super capacitor and then used in other applications. Regenerative brakes allow batteries to be operated for longer periods of time without the need of plugging charger. Thus the energy consumption reduces because of recovery and reutilization kinetic energy which leads to the increase in energy stored and improves efficiency with extending the driving range (Km/h).
At the same time battery combine with the super capacitors will increasing the life expectancy and fuel economy of the battery and whatever energy stored in deceleration period is first feed to the motor in acceleration period. The system is used to MOSFET operated as buck-boost converter; this MOSFET is connected to super-capacitor. When the electric bike runs of high speed, the controller keeps the super-capacitor discharge. If the bike is not running the SC, remains charged as full voltage. The electrical braking system not only improves the comfort of riders but also increase safety of rider and electric vehicle as well. The proposed hardware model is implanted and simulated in MAT-lab Software.

Keywords: motor, power electronics controller, dc to dc converters, energy storage device, regenerative braking

1. Introduction
In recent years electrical bike plays a vital role within the facility so human life goes simple. If compare electrical vehicle and that I.C.E the E.V. receiving abundant attention to the I.C.E. At we tend to see worldwide state of affairs, currently each country to specialize in the electrical vehicles attributable to heating and conjointly raising the worth of gasoline and diesel. Regenerative braking during which mechanical energy of motor is come to power provides system. This regenerative braking is feasible once motor driven load force run at higher speed then its no-load speed. The motor brake electromotive force E_b is bigger than the availability voltage V, than motor coil current flows to reverse direction. The motor begins to work as an electrical generator. The electrical bike will have either dc or ac motors. For Associate in nursing ac motor, inverters area unit accustomed changing battery dc to ac then giving to the motor. The gear structure of the electrical bike is a few because the standard vehicles each give variable speed and torques to the vehicle. During this vehicle, battery is that the main power sources. An I.C.E vehicle also can born-again into E.V., it involves charging the I.C. engine from motor to run the vehicles during this ways in which at the start price could also be raised however it's useful and value effective for users and it higher for surroundings.
In electrical bike offer energy to motor run. Whereas braking offer K.E. at motor is reborn into energy because of friction and this energy lost it. The regenerative braking is recapturing the energy to the system that tries to receive it before it reborn into heat. This energy may be kept in super-capacitor and when used once the vehicle is to run.
The super-capacitor is that the new technology that enables vehicle to storage twenty times additional energy than standard capacitance. It's vital energy memory device. During this paper, the super-capacitor encompasses a capability of fifty eight farads, and nominal's voltage as sixteen. 2volts dc and it compare two 5F and voltage of sixteen volts dc. And additionally compare the traditional capacitance of various ratings. The super-capacitor has only if high power density and high capacitance. It can't solely properties charge or discharge quicker however additionally no limit operational current and provides long life. The energy keep in super-capacitor will be calculated as $Ec=1/2CV^2$ Joules.
In electrical bike, braking system square measure differing types. In some bike typical friction brake have used. During this braking if continuous brakes square measure applied then it turn out friction and stopped the wheel the vehicle. However during this braking system disadvantage is that the braking is heat up and lost the energy within the sort of heat. Another form of brake is anti-lock brake, during this braking system continuous brake isn't applied to the bike. During this bike none continuous brake is applied so stop the bike as required and alternative form of braking is regenerative braking. During this braking system controller circuit or motor itself applies the brake by or limit the motor current.

2. Features of Electric Bike
Advantages of electric vehicle are listed below
1. Produces zero emission and environment friendly.
2. Less noise compare to I.C.E.
3. Fast acceleration.
4. Increase in driving range of vehicle.

5. Saving in fuel consumption leads to recovery of cost price of vehicle.

Disadvantage of electric vehicle are listed below

1. The electric bike maximum range as 150 to 200 kilometer sec while the I.C.E range is more up to 300 KM/S.
2. The cost of electric bike is large as compare to I.C.E.
3. Charging time of battery is more.

The super-capacitor is charged during acceleration period. In regenerative braking K.E. from wheels, used to charge the ultra capacitors. The loss of kinetic energy during braking of electric bike can be regained by controlling power electronics circuit.

Super-capacitors (SCs) storage system in electrical bike is one among the most recent enhancements within the field of power storage. The super-capacitors prohibit quick battery discharge throughout acceleration time. Motor acting as a generator transferring the energy keep within the battery. During regenerative breaking the excessive energy, are going to be drops in super capacitor, so it avoided the excessive amount of current flow through it.

Captured energy is delivered to the buck-boost converter which is used to maintain the efficiency and driving range of bike.

As the power density according to peak demand increases, size as well as price of battery also increases. Also, thermal management is required for battery to operate safely in peak load time.

To solve the problem analyzed above; the paper proposed the model which is a combination of battery and super-capacitor in electric bike to achieve a better overall performance.

Hybrid combination of bike can be classified into two types: passive or active. In the active methods are used one or multiple full size dc to dc converters to interface the energy storage device to the dc link. In other type refer, full size converter the fact that the dc to dc converter create the sole path for the energy flow in the storage device.

3. Regenerative Braking System

Working Principle

In this braking mechanism, kinetic energy from wheel is converted into electrical energy by means of generator. Application of brake slows down the speed of vehicle and motor works in opposite direction. When vehicle running in opposite direction the motor works like a generator and thus charge the battery as shown in figure 2. In figure 1 vehicle running in normal condition where motor goes forward direction and absorbs energy from the battery.

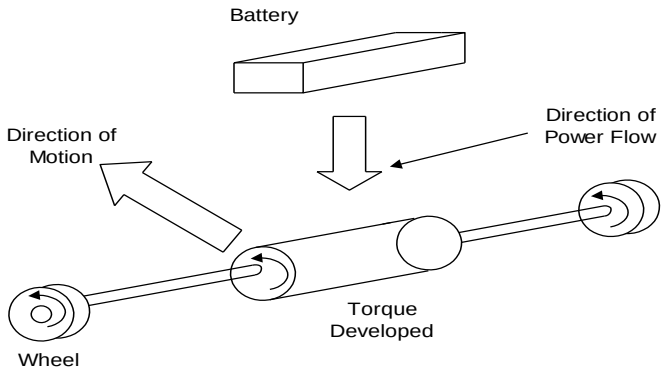

Fig 1: Normal driving condition

When regenerative braking applies in electrical bike, it reduces the price of fuel, increasing the efficiency of the bike and emissions are down. The regenerative braking provides the braking force through the speed of the vehicle is low and therefore the traffic stops and goes thus deceleration required is less in electrical vehicle. If we apply the break in vehicles then power generated goes to the battery and remaining power goes to super-capacitor. Thus, during this method the life span of battery conjointly will increase and this braking mode of vehicle is shown in figure 2.

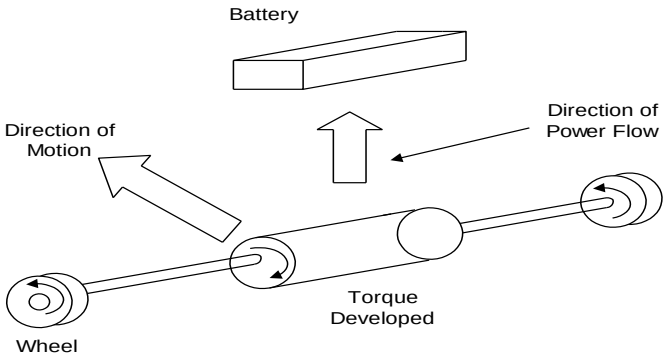

Fig 2: Regenerative action during braking

The braking system and controller is the main part of vehicles because it controls the whole part of the vehicle. The brake controllers are the function as monitor the speed of the wheel and calculate the torque of vehicle.

4. Switching mode of regenerative braking

The block diagram of hardware implementation is shown below in figure3. In this model battery and super capacitor are connected in parallel in between them one power diode is connected.

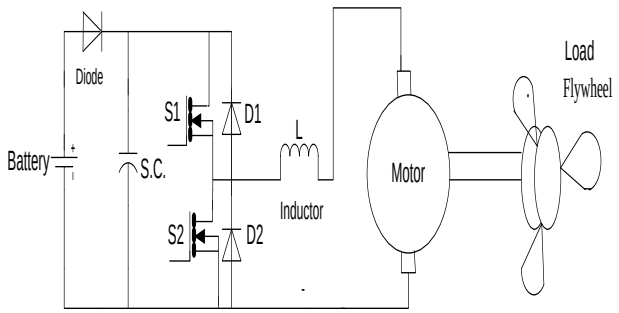

Fig 3: Block Diagram of Hardware Implementation

Two Power MOSFETs (IRF 460) are connected in two quadrant configuration mode. The diode is connected in between Battery (12V) and Ultra Capacitor (16V). An External Inductor is connected between armatures of DC motor and joining point of series connected MOSFETs as shown above figure.

5. Proposed Hardware Work

The hardware implementation of regenerative braking is shown below figure4. In this hardware, the battery (12V) and super-capacitor (16V) are connected in parallel and in between them two power diode is connected so that the super-capacitor current cannot flow in reverse direction.

Fig 4: Hardware Model

In this diagram the DC Motor (12V) is connected between the battery and power circuit and in between them one boost inductor is connected. In this model battery and super-capacitor are connected in parallel so that the twelve volts battery charged the super-capacitor up to twelve volts which is shown in multimeter.

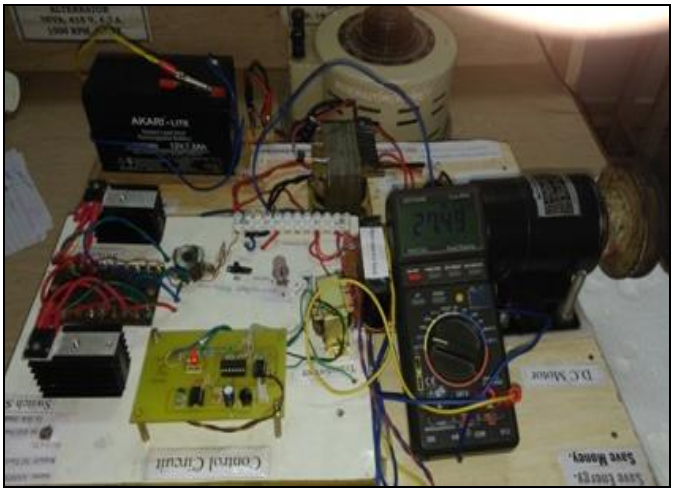

Fig 5: Hardware Model

In above diagram the multimeter show the super-capacitor voltage. When the motor operates in braking mode the kinetic energy of machines is converted into electrical energy and stored in super-capacitor shown in multimeter which is connected to super-capacitor terminal when applied the brake to motor, the super-capacitor voltage rises 12 volts up to 30 volts. This storing voltage depends on speed of Electric vehicle.

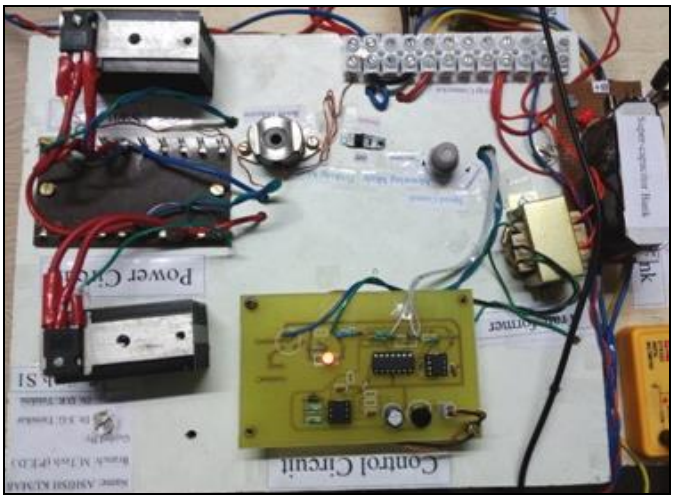

Fig 6: Control & Power circuit of hardware

In above fig.6 show the power circuit and control circuit of regenerative braking in electrical vehicles/industrial drives. In this model, motor speed is control by varying the duty ratio of pwm pulse.

6. PWM CIrcuit Waveforms

When the braking switch is pushed, the duty cycle of the pwm wave given to the motor goes on decreasing unceasingly that is braking pattern signal goes on increasing from lower duty cycle to a better duty cycle in sequential cycles.

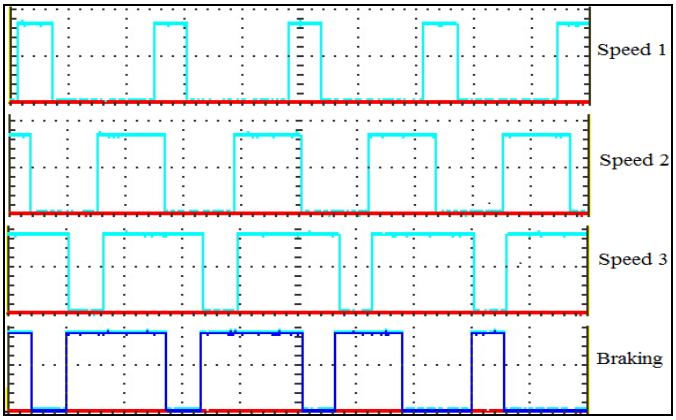

Fig 7: Buck Operation Waveforms

7. Hardware Results

The results of above hardware model of regenerative braking experimental results are shown below in table.

Table 1: Experimental Results of Hardware

Motor Speed (in rpm)	Time (in sec) (With Braking)	Time (in sec) (Without Braking)	Super-capacitor Voltage (in volt)	Energy Stored (in joule)
3100	3.79	4.32	30.12	2.012
2465	3.90	4.80	20.80	0.545
2015	3.54	3.71	17.83	0.239
1783	3.29	3.60	16.32	0.132
1627	2.83	3.14	15.06	0.066
1535	3.05	3.21	14.14	0.032
1413	2.77	2.91	13.65	0.019
1234	2.53	2.68	12.99	$6.909*10^{-3}$

8. Simulation of Regenerative Circuit

The Regenerative braking circuit is done in Simulink (Matlab).

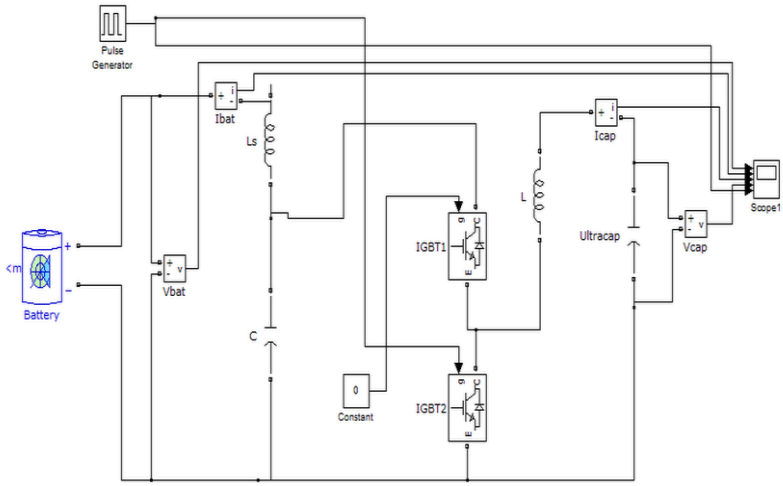

Fig 8: Braking Circuit Model

The current through the electric device will increases thought the on time of pwm wave and reduces a bit thought the off time.

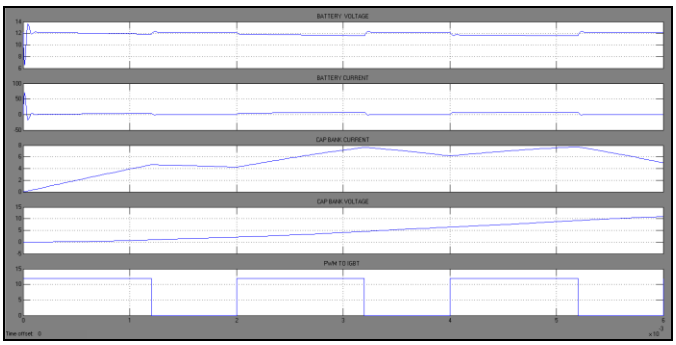

Fig 9: Buck Operation Waveforms

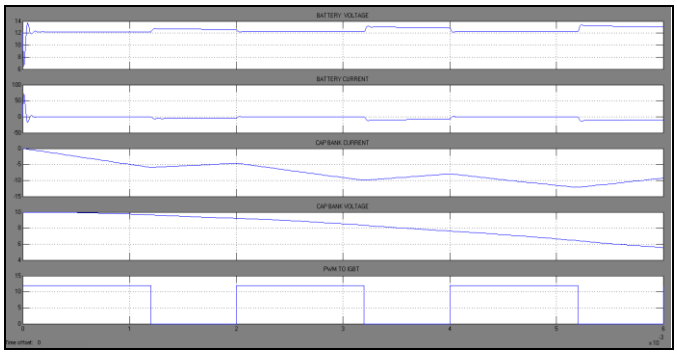

Fig 10: Boost Operation Waveforms

9. Proposed Work

The block diagram of regenerative braking of electric bike is shown below in figure 11. In this system the electrical machine operates as a generator.

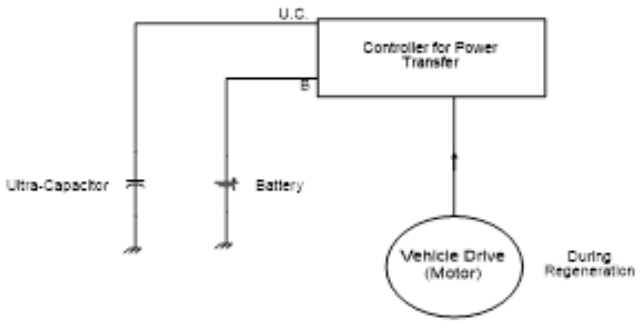

Fig 11: Model of hardware implementation

10. Conclusion

This paper has proposed the prototype hardware model of regenerative braking and software model in MAT-lab in electric bike are implemented and braking energy of electric vehicles or industrial drives is stored in super-capacitor. And the stored energy is re-use when the vehicles running in Motoring mode. The super-capacitor is too charge and discharge fast so that the energy flow can be fast and efficient way without much loss. This makes a battery life expectancy longer and allows an electric vehicles travel further on a single battery charge. That means the average mileage of vehicles increases.

11. References

1. Cao J, Emadi A. A New Battery/Ultra Capacitor Hybrid Energy Storage System for Electric, Hybrid, and Plug-In Hybrid Electric Vehicles, IEEE Transactions on Power Electronics. 2012; 27(1):122-132.
2. Hegazy O, van J, Mierlo, Lataire P. Analysis, modeling, and implementation of a multidevice interleaved DC/DC converter for fuel cell hybrid electric vehicles, IEEE Trans. Power Electron. 2012; 27(11):4445-4458.
3. Cheng-Hu Chen, Wen-Chun Chi, Ming-Yang Cheng. Regenerative Braking Control for Light Electric Vehicles IEEE Peds 2011, 5-8.
4. Miller JM, Smith R. Ultracapacitor Assisted Electric Drives for Transportation, IEEE international Electric Machines and Drives Conference, IEMDC'03, Monona Terrace Convention Center, Madison, WI, 2003; 1-4.
5. Miller JM. Propulsion Systems for Hybrid Vehicle (Renewable Energy Series), 2nd ed. Stevenage, U.K.: Institution of Engineering and Technology, 2010.
6. Antanaitis D. Effect of regenerative braking on foundation brake performance, Soc. Autom. Eng., Warrendale, PA, USA, SAE Tech. 2010.
7. Jingang Guo, Junping Wang, Binggang Cao. Regenerative Strategy for electrical vehicles IEEE, 2009.
8. Mutoh N, Hayano Y, Yahagi H, Takita K. Electric braking control methods for electric vehicles with independently driven front and rear wheels, IEEE Trans. Ind. Electron. 2007; 54(2):1168-1176.
9. Ortuzar M, Moreno J, Dixon J. Ultra capacitor-based auxiliary energy system for an electric vehicle: Implementation and evaluation, IEEE Trans. Ind. Electron, 2007; 54(4):2147-2156.
10. Dixon JW, Ortlizar ME. Ultracapacitors + DC–DC converters in regenerative braking system, IEEE Aerosp. Electron. Syst. Mag. 2003; 17(8):16-21.
11. Dixon J, Ortuzar M. Regenerative Braking for an Electric Vehicle using Ultracapacitors and Buck-Boost Converter, Aerospace and Electronic Systems Magazine, 2002; 17:16-21.
12. Caratti A, Catacchio G, Gambino C. Development of a predictive model for Regenerative Braking System, IEEE Transportation Electrification Conference and Expo 2013, 1:1-6.