Regenerative Braking of Electric Vehicle Driven by BLDC Motor

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***Abstract*— Recently the usage of fossil fuels must be reduced because they are likely to become extinct in the future and because fossil fuel vehicles contribute to global warming. Electric vehicles could take the place of these ones. Compared to internal combustion engines, EVs are more efficient and have lower fuel expenses. These vehicles can only be utilized within a particular range due to inadequate batteries and a lack of charging outlets.**

The BLDCM uses regenerative braking, which allows it to be reused when the car is braking, to extend the distance. This paper enlightens the operation of BLDCM with regenerative braking scheme. Performance for intended scheme has simulated at MATLAB, providing regeneration and motor characteristics.

Keywords- IC, EV, BLDCM

I. INTRODUCTION

Although automobiles playsa prime impact in society, having ICE is a noteworthy development of contemporary technology that has won plaudits in their sector. However, the environment and fossil fuel resources are seriously threatened by the enormous growth of the vehicle industry around the world [1].

In order to meet the energy requirements of transportation, fossil fuels are used. But mostly because they emit greenhouse gases, hence fossil fuels are harmful to the environment and They can be exhausted as well.[2]The utilization of EVs has recently been emphasized in terms of meeting its need for transportation, and attempt to build more effective vehicles in this field are rapidly advancing [3].

Regenerative braking, which is used to recover lost energy when the vehicle brakes, is one of these studies. Researchers referred it as energy regeneration. [4]Regenerating energy means making it ready for reuse. It strives to minimise energy loss as much as possible and so increases energy efficiency. Regenerative systems are often used to accomplish this. [5]

As EVs are more efficient than ICE, fuel expenses for EVs are lower than for conventional vehicles. However, due to the inadequacy of the batteries used in EVs, the received distances are constrained. [6]Especially compared to fuel stations, the number of charging stations for EV is incredibly low. A technology that can extend this distance is regenerative braking, which doesn't require these vehicles' energy source batteries to grow in size [7].

Deceleration and halting are provided by the cars' regular disc braking system. The brake pads gets worn out and emit heat during braking. The heat emitted dissipates into the environment. The regenerative braking produces energy by employing an idle motor during the braking phase. energy is recycled After applying the brakes and coming to a complete stop. [8]

The motor must be initially driven throughout the simulations since the regeneration is imparted to the moving vehicle. BLDCM is one of the most prevalent motor types in electric vehicles .Both sensor less and Hall Effect versions are available for such motors. The orientation of the rotor is logically ascertained by sensors in motors integrated with hall sensors. BLDCM begins to rotate after the transistor devices that used for position information to regulate the phases in the switching circuit are switched in the proper sequence.[9]

Regenerative braking has been found to extend an electric vehicle's range up to 15% more than an equivalent vehicle without RBS. Regenerative braking, however, is not always effective; oftentimes, braking must be accomplished by dissipating the energy in a resistive load. As a consequence, EV still retains its mechanical brake. Furthermore crucial for the safety as well as other operations of EVs is a mechanical braking system. [10]

In this paper, to illustrate regenerative braking study for BLDCM as motor and even a generator is provided thorough simulation study leading better utilization of wastage power through braking scheme.

II. CONVERTER ANALYSIS

Fig.1 shows block diagram for proposed circuitry. It comprises a battery source feeding inverter and with control circuitry.

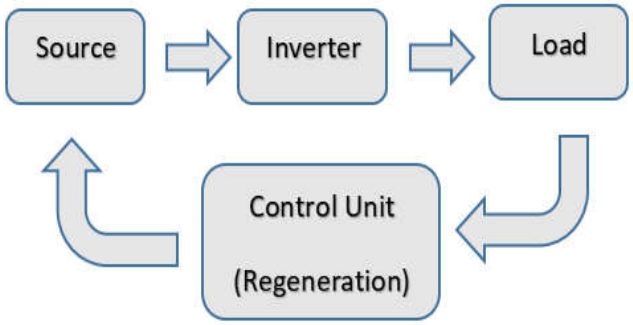

Fig.1. Block Diagram for Typical Regenerating Scheme

In this circuitry DC source is supplied to inverter that converts DC into AC. This AC voltage is fed to respective BLDCM. By employing necessary control scheme PWM pulses are provided for triggering the switch of inverter. Inverter can be any converters that are H bridge, 3-level etc. Then it is to be fed to AC load. Regeneration of power is accomplished through regenerative braking so as to feed the battery.

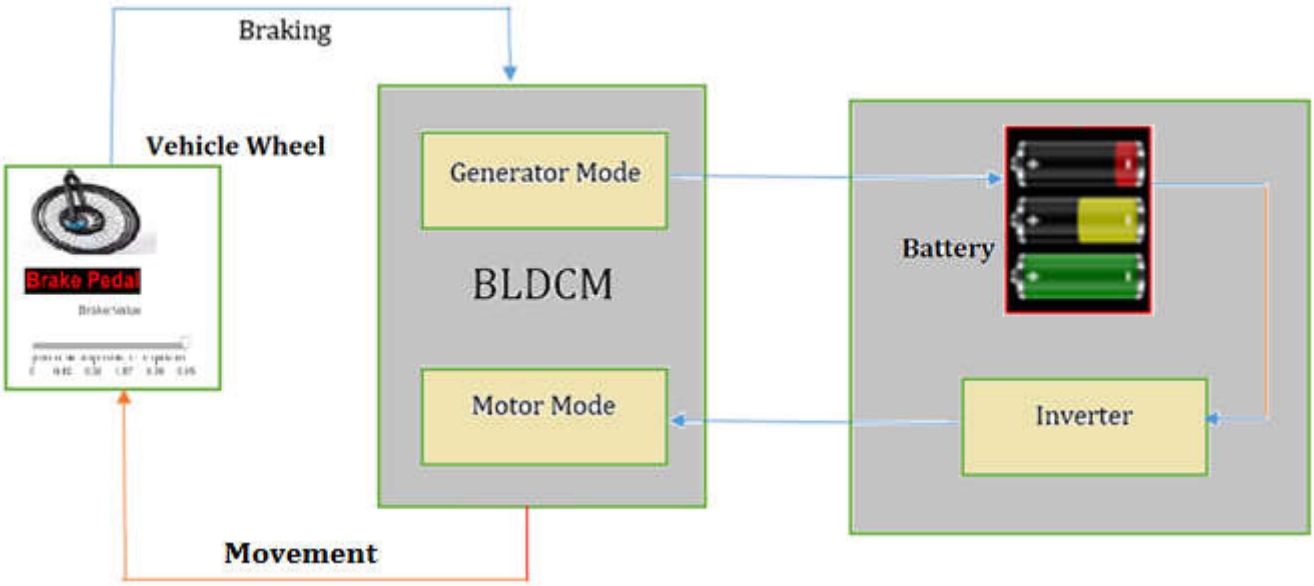

Fig. (2). Proposed Scheme for Isolated SEPIC Converter Feeding Induction Motor

III. PROPOSED SCHEME

The proposed system used for BLDCM drive with regeneration approach depicted in Fig. 2.

Inverter switch is functioned at higher switching frequency provided effective control with reduced component rating such as inductors. However MOSFET are employed in inverter for lower frequency operation.

Motor speed N_s is equated by means of N_s* to produce error signals i.e. deviation of N_s* along withN_s, speed error is fed to PI block so as to get output in regulated manner. At last, the controlled output is to be equated with higher frequency triangular wave which yields pulses (PWM) for switching of respected inverter.

Brake pedal is used for regulating the speed of motor more ever the characteristics reveals the power regeneration through braking

IV. BLDCM OPERATION

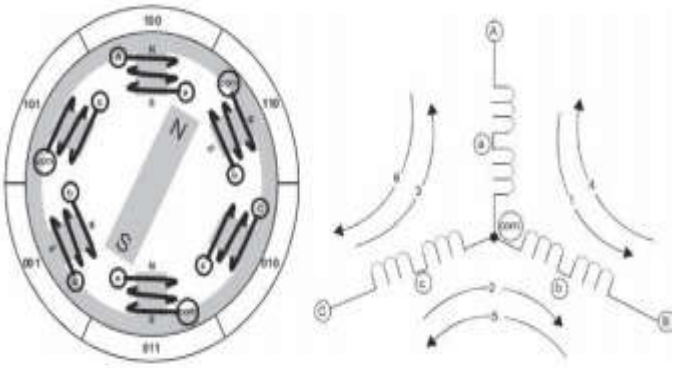

Fig.3: Inverter Circuitry for BLDCM

Due to its high power densities, favorable speed-torque characteristics, great efficiency, broad speed ranges, and lower maintenance requirements, BLDCM are perfectly suited for EVs. BLDCMs are a special subset of synchronous motor. It indicates that the magnetic fields generated by the rotor's spinning and the stator's magnetic field have the same frequency. Induction motors typically exhibit "slip," that is not evident in BLDCM. But rather to regulate it require quite complex circuitry. In BLDCM, armature windings are fixed to stator with laminated steel core, while permanent magnets are installed at rotor. Energy-opposing pole winding pairs that are referred to as form phases sequentially start and retain rotation. To keep the windings moving, determining the rotor orientation is crucial.

Inverter enables BLDCM to drive. The switches are of semiconductors. This type of switch allows rapid switching. , Two switches are used as per each stator phase. The most crucial component of electric vehicles is the battery. By doing this, the electrical energy is stored and the system's overall energy supply is maintained. It also stores the energy generated during regenerative braking. By applying a higher voltage than the battery's voltage is necessary to store energy in the battery. In low-voltage systems like these, boost converters are employed to reach the necessary voltage level for energy storage.

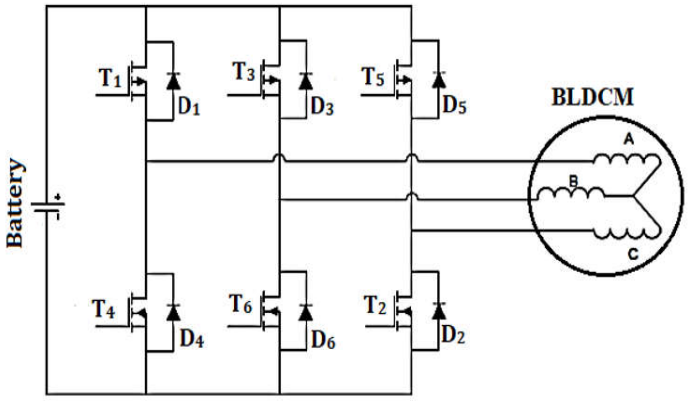

Fig.4: Inverter Circuitry for BLDCM

Electronic switching is used in conjunction with inverter. The diagram below shows how the threephase inverter circuit's current flows during regular driving and regenerative braking.

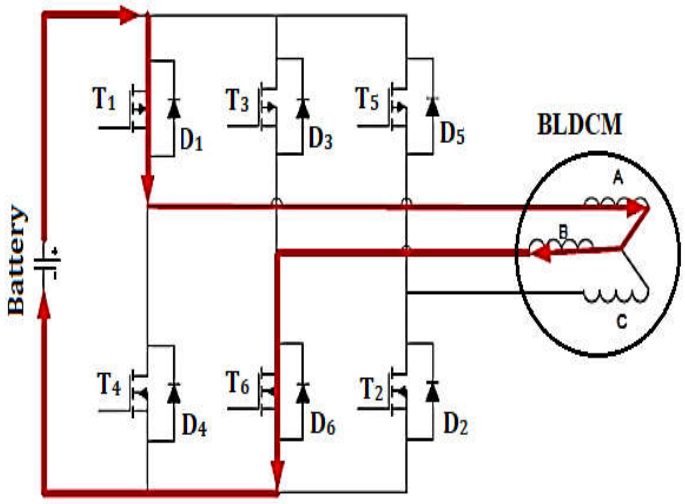

Fig. 5. Current Flow during Motoring

Current in the winding switches to flow in the opposite direction and is delivered back into the battery during the regenerative braking mode. Current can return through the freewheeling diode of T1, the battery, and T6 when all switches are off.

PWM, however, allows for adjustment of the level of braking. When all of the low-side switches are off, the most regeneration can be achieved.

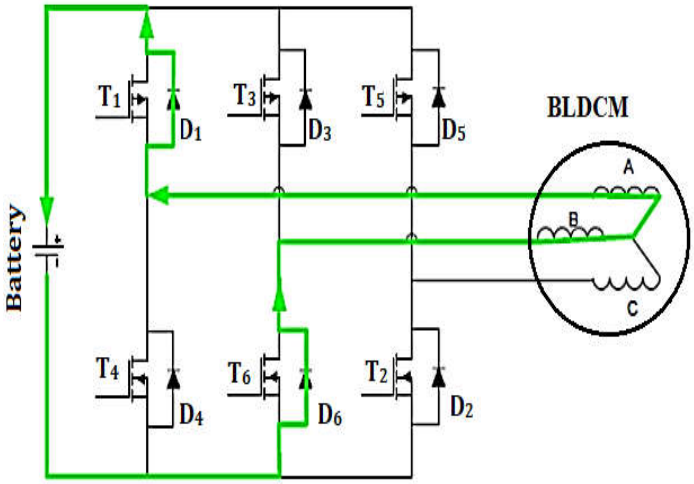

Fig. 6. Current flow during Regenerative Braking

V. CONTROL FOR PROPOSED SCHEME

A. PWM Generator

Output from PI is fed to PWM generator so that it yields stable frequency PWM signal and variable duty ratio. Output from PI controller is equated by saw-tooth waveform and PWM is generated.

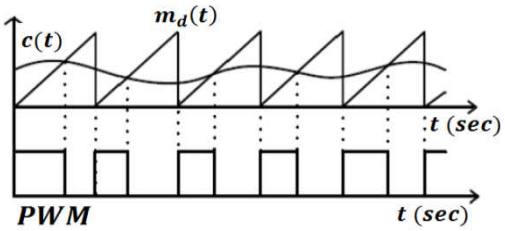

Fig.7. Pulse generation

B . Control for PI

In general, the schemes for control are employed for motor i.e. PI control. A single sensor is opted for controlling the motor. Initially, Motor speed is compared with reference speed N_s* is chosen as reference furthermore equated along withmotor speedN_s to get error speed.

The error from N_s* and $N_s$is fed toPI togenerateoutput as slip (error) with respect to error speed.

The slip error at all instant[11],

$$N_e(k) = N_s{}^*(k) - N_s(k)$$

Error speed is to be fed to PI to generate controlled speed. The controlled output from PI controlleris $N_c(k)$

$$N_c(k) = k_i N_e(k) + N_c(k-1) + k_p\{N_e(k) - N_e(k-1)\}$$

Where, $K_p$and K_i are constants of proportional as well as integral gain respectively.Higher frequency saw tooth signal is equated with output commencing the controller to produce PWM pulses for switching of inverter switch.

VI. SIMULATIONS AND RESULTS

A. Simulink Model for Proposed Scheme

The projected scheme is simulated in MATLAB. Fig.8.depicts a Simulink model intended for regenerativescheme with BLDCM employing PI Control and external Braking pedal for Speed variation.

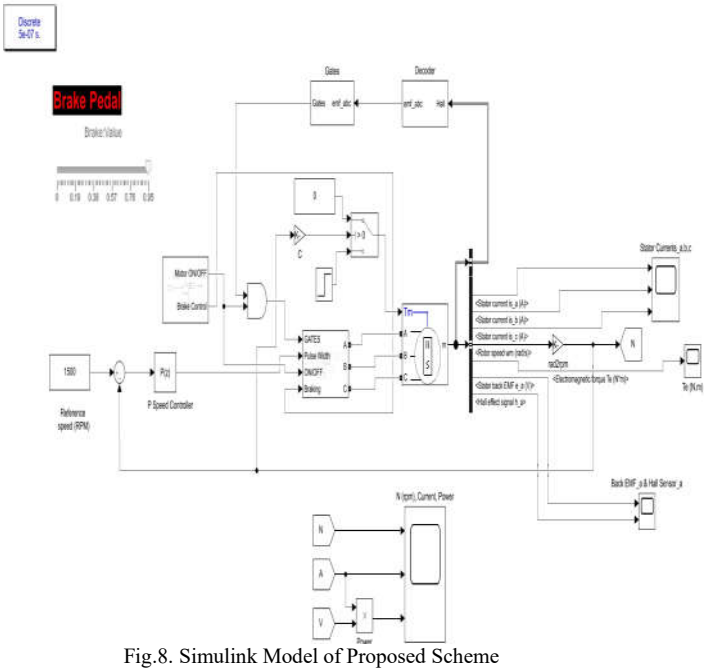

Fig.8. Simulink Model of Proposed Scheme

B. Results for Proposed System

In this section Waveforms and relative characteristics of their parameters such as power speed current are analyzed.

The waveforms of speed are revealed in Fig.9.Speed variation is done through brake pedal and regeneration is accomplished.

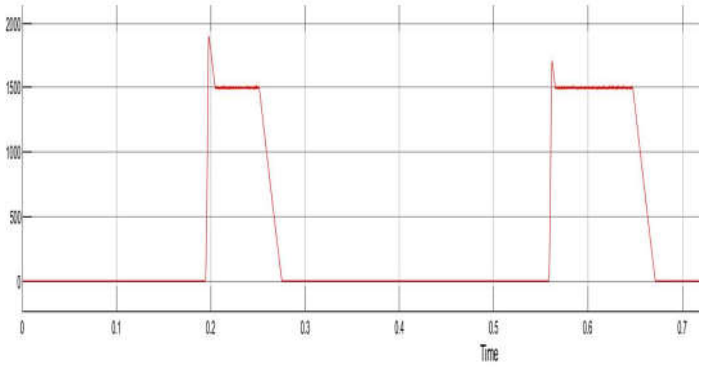

Fig.9.Speed

The speed variation shows the application of brake pedal at respective up and downs in speed. When mild brake is applied speed reduces slightly whereas full brake causes sudden drastic reduction in speed.

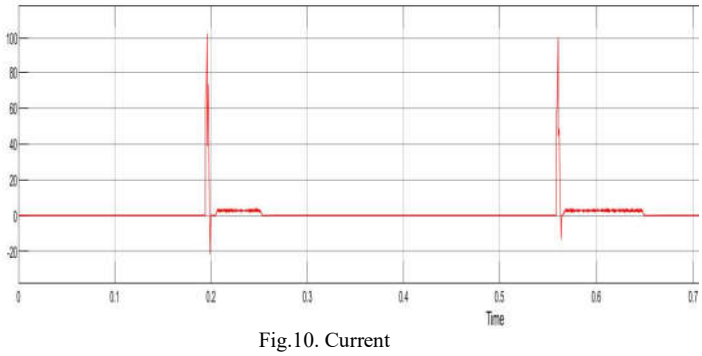

Fig.10. Current

The current waveform is expressed in Fig 10.As Speed varies current also varies according to it. When brake pedal is applied speed reduces while current start increases as battery gets starts to charge through regenerative operation.

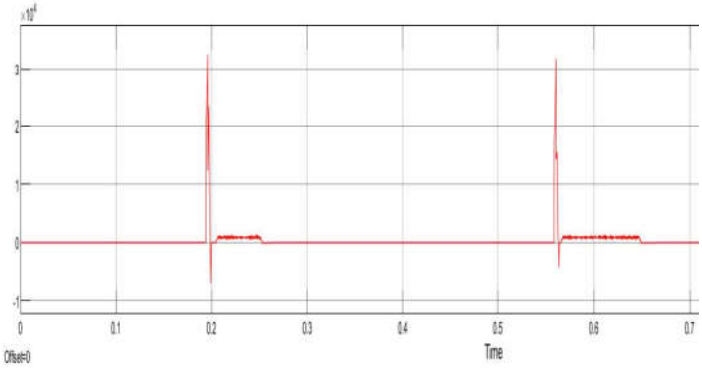

Fig.11.Power

The waveform of battery power is revealed in Fig.11. It is used to store the regenerated energy after braking and supply it to the load. As speed reduces battery power is start to increase

VII. CONCLUSION

In this study, a detailed MATLAB simulation of regenerative braking of a BLDC motor that can be used in electric vehicles is accomplished. BLDCM was let to rotate that has its own inertia while regenerative braking. The resulting back EMF level is elevated to the battery's maximal voltage level, and the battery is then charged. All (EVs) are capable of regenerative braking. With the increasing usage EV in transportation, a substantial amount of energy which was formerly squandered is recovered. Consequently, the motor's speed is influenced by the variances at load, thus regenerative braking is also accomplished.

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