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Control of BLDC motor and Regenerative Braking in Electric Vehicle

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Abstract: With the rising economy, fuel demand also increases. In today's world, fossil fuels are the major contribution to meeting these demands. However, it is not going to be the same scenario in the next decades as the fossil fuels levels are depleting there is a need for an alternative fuel that will satisfy energy requirements and will be a sustainable source in coming years. In the automotive industry petrol and diesel have been major fuels in driving vehicles. Although electric vehicles are going to be replaced by IC engines. Electric vehicles have lower fuel costs as compared to internal combustion engines but because of limited charging stations vehicles are bound to drive within certain distances. With the implementation of regenerative braking in electric vehicles, it is possible to charge batteries when the vehicle is breaking and thus increasing driving distance. This paper presents a simulation of control of BLDC motor with regenerative braking.

Keywords: Regenerative Braking, BLDC Motor, Bi-Directional DC-DC Converter, VSI, Electric Drives.

I. INTRODUCTION

For the past several years fossil fuels have been extensively used for meeting energy demands however these fuels levels are depleting each year and are projected to vanish by 2050. Moreover, after utilizing fossil fuels it generates toxic gases (Co2) which severely harms the environment. To meet future automobile energy demands industries and nations are focusing on introducing efficient electric vehicles. Electric vehicles were in a practice from the past several decades but because of major limitations it was not scaled up like IC engine vehicles. These limitation includes low power, unreliability of components and fewer charging stations. An introduction of regenerative breaking in EV has taken a leap forward on becoming efficient, reliable and commercial scalable vehicles. In breaking operations energy is wasted in friction and to recover this energy loss regenerative breaking system can be implemented. Regenerative breaking increases the distance driving of the vehicle as it charges battery when braking takes place. In normal breaking operation disc brakes are utilized to decelerate and stop the vehicle thus producing heat which then released in the environment. where as regenerative breaking utilizes rotation of wheel in which motor connections are changed such that it acts as generator and inertia of wheel is used to rotate generator thus charging the battery. Ultimately, it is stored in battery cells and utilised further. Regenerative breaking enables an extended range in electric vehicles as well as lowering fuel consumption and improving CO_2 balance in hybrid vehicle.This paper provides basic introduction, details of used components, their characteristics and simulation is explained and results are given.

II. LITERATURE SURVEY

A. BLDC Motor with Hall Effect Sensors

BLDC refers to Brushless DC Motor. A Brushless DC motor is an electric motor powered by DC Voltage Supply and commuted electronically instead of by brushes like conventional DC Motors. It has high efficiency, high power saving capability, longer lifespan and is compact in size making it most sought for electric drive. Hall effect sensors are used to determine the position of motor rotor. The rotor position must be known for switching operation of BLDC motors. In BLDC motors, the rotor position can be determined with or without sensor. In case of sensor-less position determination, the transition of the back EMF formed in the phases through the zero point is determined. The switching sequence is determined accordingly. Hall effect sensors are positioned to the stator in order to find the rotor position. Three hall effect sensors are sufficient for a three-phase BLDC motor. These sensors are placed in the stator with angles of 60° or 120. In this paper, the position of the rotor in the BLDC motor is obtained with the help of 120° hall sensors. The inverter is the part that enables the BLDC motor to be driven. It consists of IGBT switches or MOSFET. In case of MOSFET the On-state voltage drop is greater. Two switches of IGBT are used for each stator phase. The inverter circuit used in a three-phase BLDC motor. To store energy into the battery, it is necessary to apply a higher voltage than its nominal voltage, For that Bi-directional DC-DC converters are used to achieve the required voltage level for storing energy. Boost converter is used to amplify DC voltage of the BLDC motor during regenerative braking.

B. Regenerative Braking, Bi-Directional DC-DC Converter and Inverter

When the driver steps on the brake, electric motors switch to generator mode. The wheels transfer kinetic energy via the drive train to the generator. Through its rotation generator converts a portion of the kinetic energy into electrical energy. This energy is stored in a high voltage battery. The generative braking torque of an electric motor which is the result of energy generation decelerates the vehicle. At low speed for example shortly before the vehicle comes to a stop the electric motor can no longer supply sufficient generating braking torque and friction brake must be activated to maintain required deceleration. The braking torque from the friction brake is continuously adapted to the current generated braking torque, a process called torque blending. In case of full braking and unstable driving condition, the vehicle is usually decelerated solely by the friction brake as wheels specific interventions are required.

Recently, bidirectional DC-DC converters have been significantly researched and developed in various applications such as battery chargers, electric vehicles and UPS systems. Bidirectional DC-DC converters are a key component of traction systems for hybrid electric vehicles. With a DC motor drive driven by a bidirectional DC-DC converter for electric vehicles (EVs), both motor and regenerative braking operations can be properly controlled, significantly improving the overall efficiency of the drive system. Bi-Directional DC-DC converter provides bidirectional conversion of two different levels of DC voltage with the ability to reverse the direction of the power flow if needed.

The DC-DC converter needs to perform two main functions. One is to adapt the battery voltage to the nominal motor voltage, and the other is to control the flow of power in steady and transient states so that the drive power fulfils the requirements. Battery power in inverter-driven motor drives used to propel electric vehicles is typically at low voltage levels, and in many applications, the battery is used to power the input terminals of the inverter directly. However, such inverter feeders adversely affect the drive efficiency of the motor and do not allow control of the regenerative braking process. This is, in fact, the energy recovery of the vehicle's battery is performed by proper motor brake current control. To overcome the above problems, a bidirectional DC-DC converter can be used with the DC link of a battery-fed AC motor drive for EV applications. In the operation of the motor, a DC-DC converter is used to raise the battery voltage to a voltage level that allows for highly efficient operation over the entire speed range of the vehicle. In addition, the bidirectional arrangement of the DCDC converter allows for power flow reversal and motor brake current control.

C. PID Controller and Inverter

Batteries are the main energy storage device for ground vehicles. Today, battery-fed electric drives are used for various advantages, including nearly zero emissions, guaranteed load balancing, good transient operation, and energy recovery during braking. An inverter with bidirectional power flow capability is required to connect the accumulator (battery) to the intermediate circuit of the motor drive system. Battery-fed electric vehicles (BEVs) must function in three different modes: acceleration mode, normal (stationary) mode, and braking (regeneration) mode. In acceleration mode and normal mode, the flow of power flows from the battery to the motor, while in brake mode or regeneration mode, the kinetic energy of the motor is converted to electrical energy and fed back to the battery.

PID controller stands for Proportional-Integral-Derivative Controller. These three mathematical blocks assess error in speed and make appropriate changes. In proportional control difference in magnitude of set values and process variable (error) is calculated and appropriate changes are made according to reference speed. The integral equation monitors offset of set points (reference speed) and process variable and consequently corrects it over time. Derivative equation constantly tracks rate of change of process variable (error signal) and control changes are made

D. Simulation

First, a vehicle simulation model is created by MATLAB/ Simulink which is shown in Figure 1, to make clear the effect of the motor capacity and the battery current on the regenerating energy. In this paper, a simple model that the vehicle differential equation is connected with the motor differential equation by the slip is made to understand the basis of the phenomenon. Where, it assumes the ideal condition, that is, a bobbing motion, a pitching movement and a rolling movement are not taken into account and it is also assumed that the vehicle has one motor connected with the gear which ratio is selectable. The demand torque and power are calculated by giving speed reference to the speed controller and the torque reference is as output to the vehicle model in which the output torque is equal to the reference.

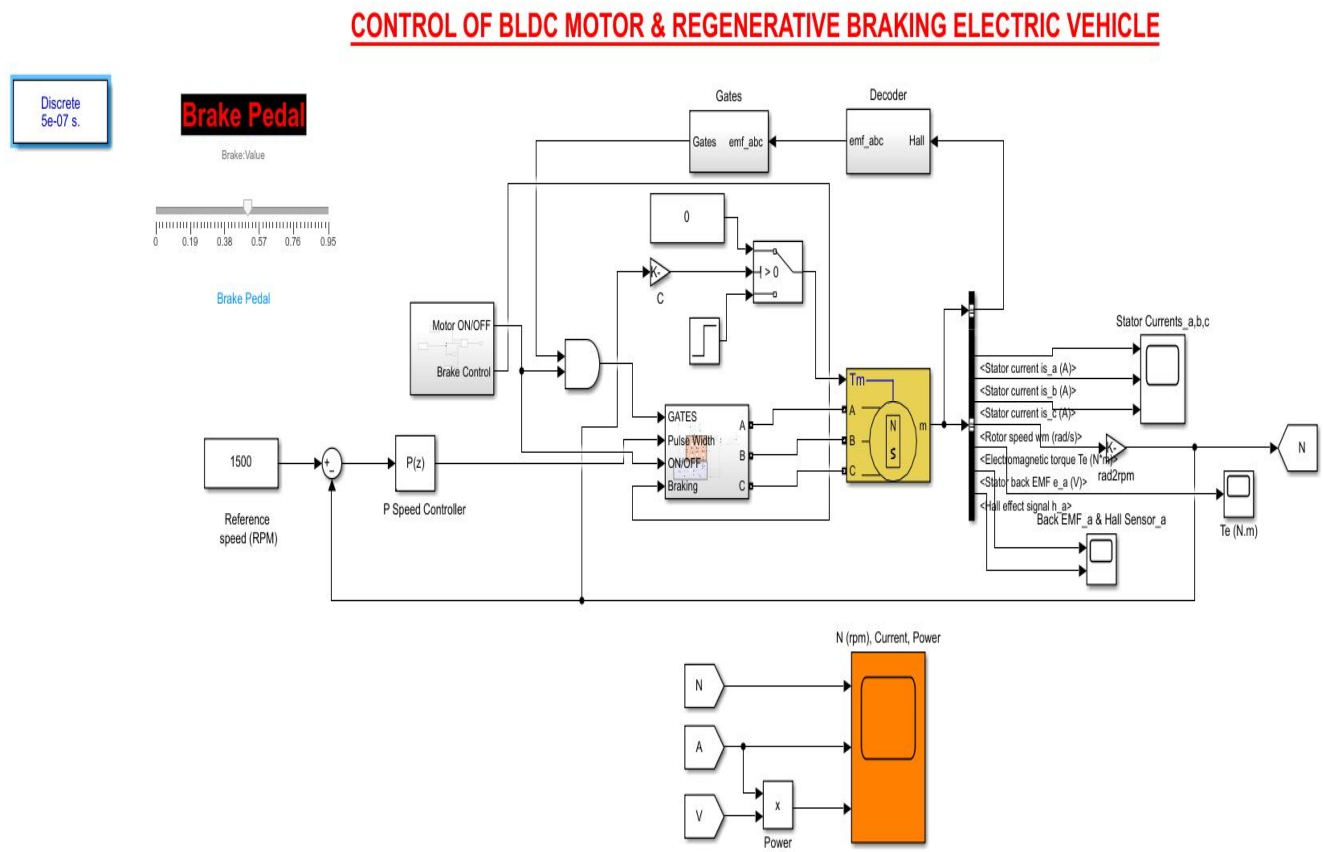

Fig. 1 Simulation model of BLDC Motor with Regenerative Braking

The regenerative braking system is an energy recovery mechanism used in EVs. When brakes are applied the vehicles slow down, the kinetic energy is simply get released in form of heat and becomes useless. RBS convert this energy into electric energy or mechanical energy and use it to drive the vehicle. It improves the performance and efficiency of the vehicle.
In this system, Kinetic energy is converted into electric energy with the help of the generator store in the battery. This electrical energy in Battery is used to drive the motor connected to the driveshaft.

In this, there are three types of braking according to pressure applied on the brake pedal

1) During no brake condition, there will be no regenerative energy created
2) During mild braking condition, minimum current will be sent to the battery
3) During hard braking condition, maximum current will be sent back to the battery

E. Result

The current-time graph of the battery is demonstrated in the graph. In the initial condition, the current direction was from the battery to the BLDC motor. It meant that energy was consumed by the battery and the graph was in the positive region. When the brake is applied, the current-time graph passed to the negative zone with the beginning of the regenerative braking and the current direction was from the BLDC motor to the battery. It indicated that energy was generated from the BLDC motor and stored in the battery. Moreover, that region was a regenerative braking zone. The BLDC motor back EMF operated without and with regenerative braking. When the regenerative braking was applied to the BLDC motor, the battery was fed as a load. Therefore, the back EMF curve was narrowed in the time axis after the brake is applied. In the two graphs, it was seen that the measured back EMF had phase and phase-phase voltages of 20 V and 40 V, respectively when the brake is applied and deceleration begins and the voltages decreased with time.

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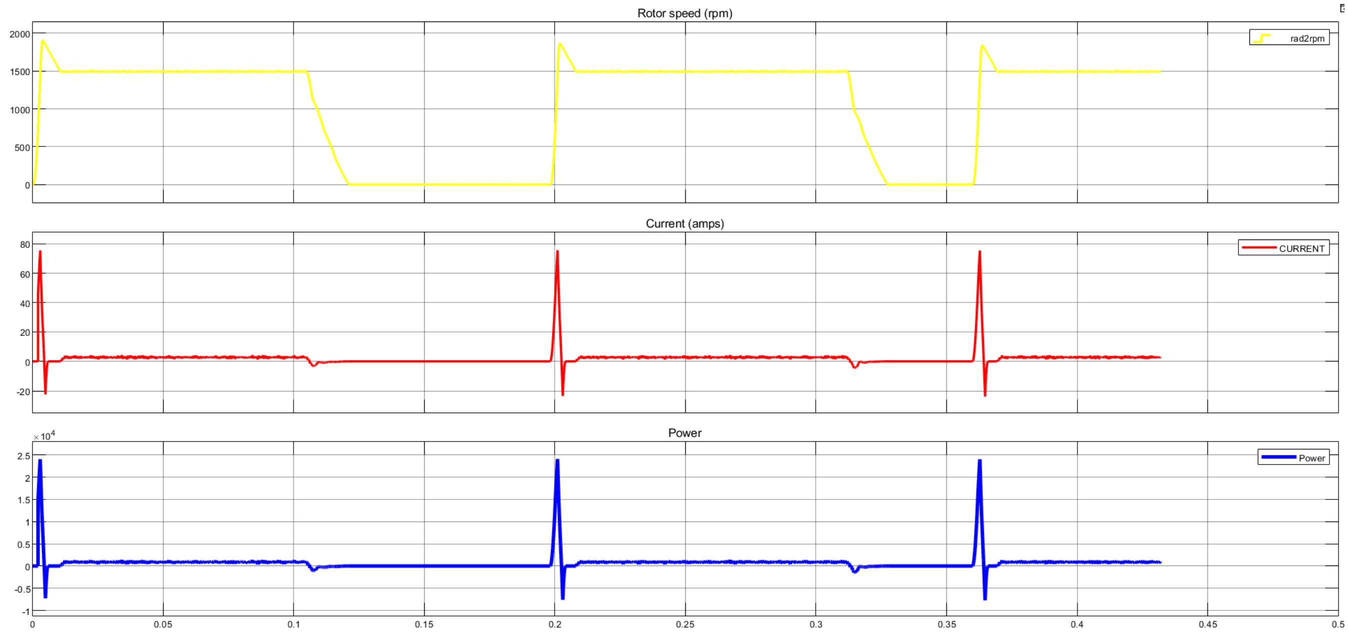

Fig. 2, Graph of Rotor speed, Current (Amps), Power after effect of regenerative braking

III.CONCLUSION

In this paper simulation of BLDC motor with regenerative braking was carried out, mainly focusing on electric vehicle application. In simulation BLDC is powered by battery and able to provide acceleration, deceleration/ braking motion using VSI control. When braking is applied motor changes to generator mode, wheel rotates with its own inertia and meanwhile DC-DC converter then reverses energy flow and charges battery.

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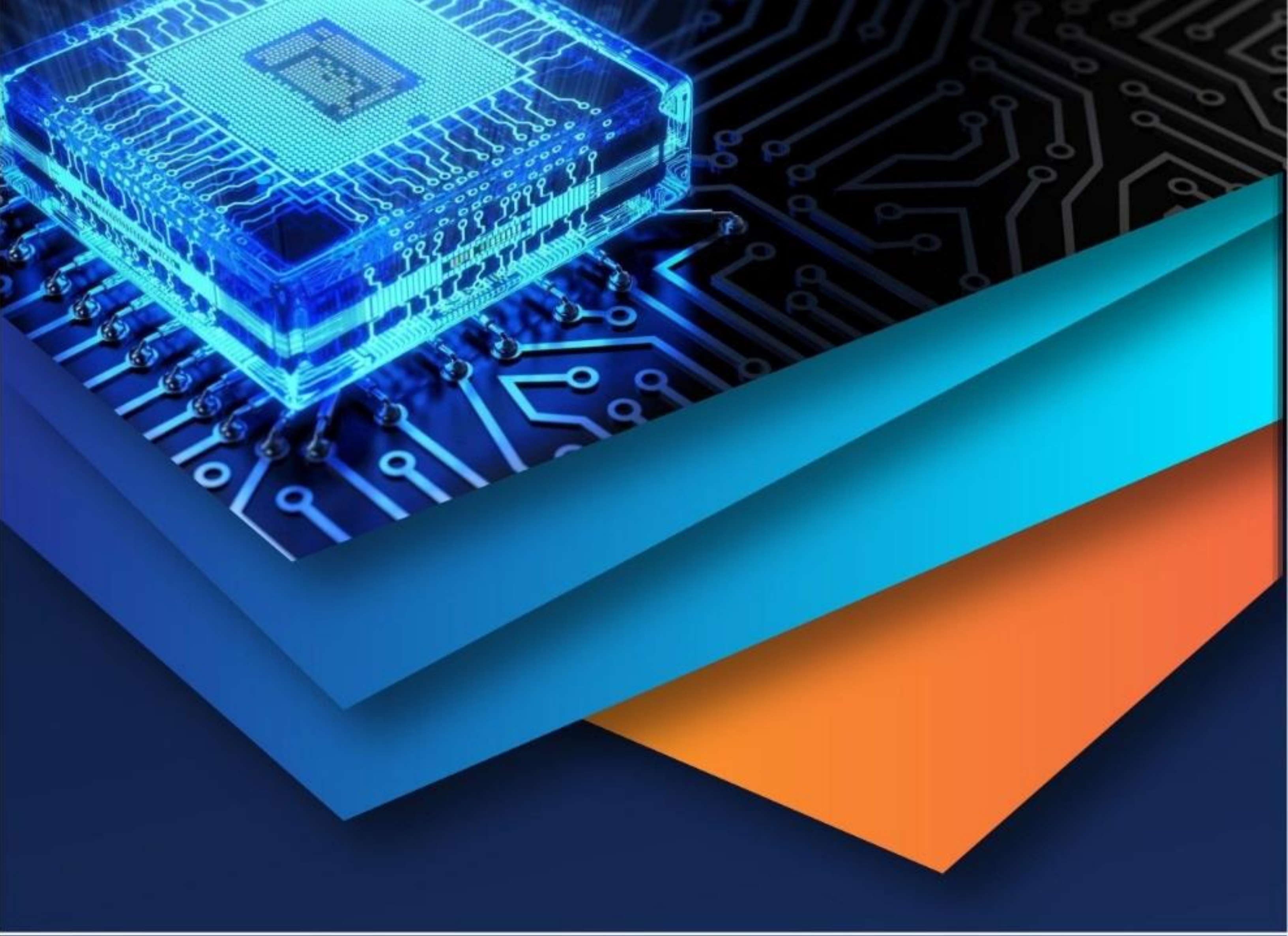

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