iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** V **Month of publication:** May 2021

DOI: https://doi.org/10.22214/ijraset.2021.34681

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue V May 2021- Available at www.ijraset.com

Control of Three Phase BLDC Motor for Electric Vehicles by using Four Quadrant Operation

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Abstract: ***In this paper the four quadrant operation implemented for the recovery of electric vehicles. BLDC motor is used in EV, and bi-directional DC-DC converter is connected to the VSI (voltage source inverter). Bi-directional DC-DC converter performed to modes that is, buck mode and boost mode, energy is recovered through this mode. In buck mode utilized the energy for drive the motor and in the boost mode regeneration of energy and charged the battery. This proposal operated in MATLAB\Simulink software. By using this method we can improve the energy management of electric vehicles when vehicles in motoring mode bi-directional converter did buck operation and utilized energy for driving vehicles. During electric vehicles often start and stop, this operation proposes recovery of kinetic energy of motor and stored it in battery through the regenerative braking. Through electric vehicles going on downhill, drive speed develops more than reference speed, controlled speed offer energy and this energy return to battery.***

Keywords: BLDC Motor, Electric Vehicle (EV), PID Controller, Voltage Source Inverter (VSI), Back Electromotive Force (EMF), MOSFET, MATLAB.

I. INTRODUCTION

In our country pollution is increases in day by and as a person, control the pollution is our main responsibility. In India 27% pollution is created by conventional vehicles. Polluted gases are form by this vehicle like carbon dioxide, sulphur dioxide, carbon monoxide etc. therefore eco-friendly vehicles are demanded in world. By using electric vehicle, we can control the pollution. For future electric vehicles most demanded for transportation needs. BLDC motor is more popular in electric vehicle. The application of BLDC motor is aerospace, EVs, household, infrastructure, military etc.

BLDC motor has a low maintenance, high efficiency, long lifespan, compact size, no noise, no spark found. Four quadrant operations is proposed in this paper, In four quadrant operation forward/ reverse motoring and braking occurs. In forward motoring energy is consumed for drive the motor and in braking the energy is a regenerated. Only one battery is used to utilize the energy as well as storing the energy, also reduce the cost of extra rectifier. During deceleration the wheel of the drive is provided kinetic energy and this energy store in a battery. When an electric vehicle goes downhill, the speed of the motor is increases than reference speed and regenerated energy. Brushless DC motor is one of the top electrical drives that growing popularity, outstanding high efficiency, reliability, good dynamic response. The continuous attempt to decrease environmental pollution and growing cost of fuels had led to the importance of using alternate sources for transport since internal combustion (IC) engine vehicles brings more than 40% of the pollution. As the fuel resources are reducing, the energy efficiency electric drives are possible to replace vehicles running with fossil fuels. EVs are the minimum problem to the environment. A plug-in electric vehicle is several road vehicles that can be recharged from an outdoor source of energy.

Regenerative braking is just one of the methods to improve the efficiency of the drive. Throughout regenerative mode, drive energy which is in the procedure of kinetic energy. It can be used to the recharge the battery during deceleration. DC-DC converter and VSI are used to efficient consumption of power. VSI works as a rectifier during the braking mode and the rectified voltage is boosted to charge the battery.

II. METHODOLOGY

BLDC Motor is used in this paper, BLDC Motor more popular in industrial area and for electric drive BLDC motor play an important role for improving the EV efficiency. The three phases BLDC Motor is connected to the voltage source inverter. IGBT Switch which have antiparallel diodes connected across it. Switch like MOSFET can also be used but problem with MOSFET is ON-State voltage drop, MOSFET is used in low voltage application. BLDC motor has trapezoidal back EMF waveform, hall sensors are used to sense the rotor position.

A. Bi-Directional DC-DC Converter is fed to BLDC motor, Bi-directional DC-DC converter contains of two switches and two diode when T1 and D2 are worked. It works as a buck converter and energy utilized for motoring. When T2 and D1 are operated regenerative braking happens and converter work as boost operation and charged the battery.

B. Four quadrant operation of BLDC Motor are proposed in this paper. In 1st and 3rd quadrant, forward and reverse acceleration occurs; both speed and torque have same sign either positive or negative.

In 2nd and 4th quadrant, reverse braking and forward braking occurs, 2nd quadrant speed is negative and torque is positive and 4th quadrant speed is positive and torque is negative.

Regenerative Braking is done through the Bi-directional DC-DC Converter. Converter work in two mode-Buck mode and Boost mode. Buck mode operated and energy utilizes for motor driving and when boost mode operate, Braking mode occurs and regenerated energy and stored in the same chargeable battery.

EV operated when regular start and stop period then regenerative form and recovery of energy for every stopping operation energy recovery and charged the battery.

PID Controller is used for speed controlling, four quadrant operations form a linear system and PID controller is finest for the linear system.

III.MODELLING AND ANALYSIS

The model of the Four Quadrant Operation of Three phase BLDC Motor is given in fig.1, In this circuit the battery is connected to the Bi-directional DC-DC converter, the output of the DC-DC converter is fed to voltage source inverter, BLDC motor is connect to drive the motor, BLDC motor can be drive in full load, during the acceleration speed of the motor is constant that is 1000 rpm and during deceleration the speed of the motor is decreases up to the 350 rpm.

Four quadrant operation is implemented in this paper, Regenerative braking is done through the four quadrant operation, all four quadrant can be controlled the operation. PID controller is used here, to control the speed of the motor, MOSFET are used here, for switching sequence and trigger the switches.

Table 1.
Parameter of BLDC Motor

voltage (V) of BLDC motor	200
Rated speed (rpm)	1000
flux-linkage (Wb)	0.1194
Pole pair	4
Phase resistance (Ω)	0.0485
Phase inductance (mH)	8.5

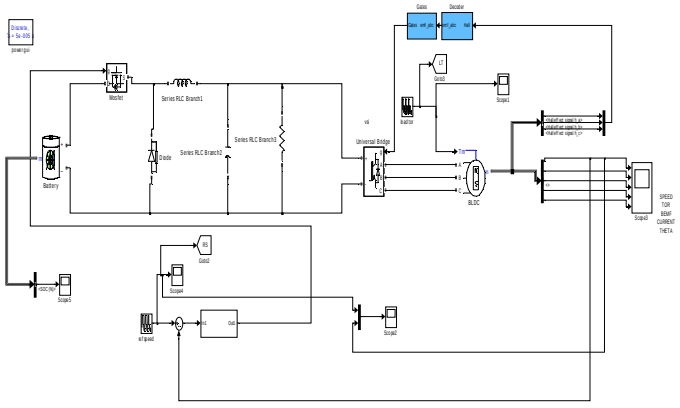

Fig. 1 Circuit Diagram

IV. RESULTS AND DISCUSSION

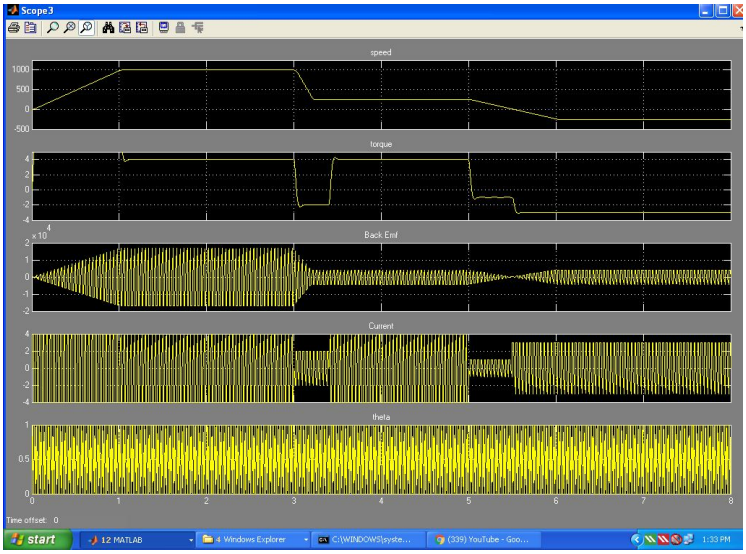

Fig.2 Simulation Results

The voltage of BLDC Motor is kept 200V through the Bi-directional converter, Lithium ion battery is used and its voltage is 250V. Ampere-hour rating is 50Ah and charging of battery at an early state is 60%. When braking is needed the torque command develops negative. But not every time required regenerative braking to decrease the speed, through the current control of BLDC motor speed can be control. The simulation results are shown for 8 second. The motor is worked in forward motoring mode up to 3 sec. and then braking is done for 0.5 sec. then reverse motoring is happens after 3.5 sec. In 0.5 sec. recovery of energy and charged the battery.

Motor action	Time duration (sec.)
Acceleration	0-1
Constant speed of 1000 Rpm	1-3
Braking	3-3.5
Reverse motoring	Beyond 5.5

V. CONCLUSION

The four quadrant operation is used in this paper. In electric vehicles, Maximum efficiency and fuel consuming of drive, this factor are keeping in the mind. Four quadrant operations are used here for fuel constraint of drive and maximum efficiency of drive. The battery is utilized during motoring mode and battery is charged during the regenerative braking. Speed is control using the closed loop control is achieved. During regenerative braking, the kinetic energy of drive is refunded to the bi-directional converter to charge the battery. When electric vehicles downhill run, the speed of drive more than reference speed and that time regeneration occurs. This practical execution is under improvement for future scope.

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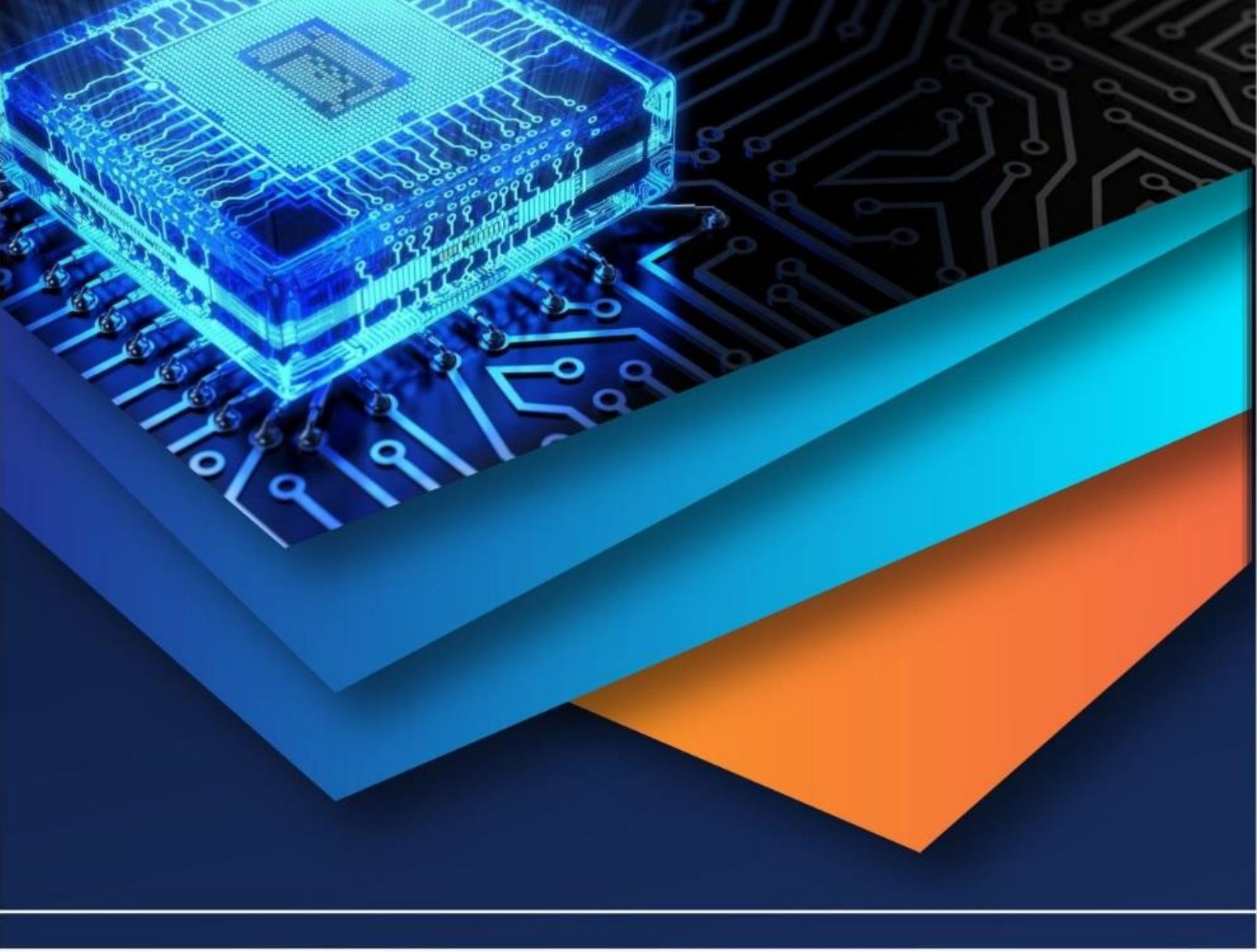

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