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DC/DC CONVERTER BASED ON-BOARD CHARGER FOR ELECTRIC VEHICLE

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ABSTRACT

This paper describes the operation of a separately excited dc motor for EV application. Battery fed electric vehicles (BFEVs) are required to function in two different modes namely: acceleration mode and braking (regenerative) mode. During acceleration and normal modes the power flow is from battery to motor whereas during braking or regenerative mode the kinetic energy of the motor is converted into electrical energy and fed back to battery. Four quadrant and two quadrant operation of electric vehicles are implemented in this paper.

Keywords*: Battery, Bidirectional DC-DC Converter, Cuk Converter , PI Controller, Separately Excited DC Motor*

1.INTRODUCTION

Petroleum resources across the world is depleting at a high rate due to the large dependency of the transportation sector on petroleum as the primary fuel. Also due to this, there is a vast greenhouse gas emission that is degrading the quality of air and causing harm to life and environment. This has aroused a tremendous interest for the design of the vehicles with lesser or no dependency on the petroleum resources. And therefore the alternate propulsion technologies have been increasingly pursued by the automobile industries and this has led to the increased development rate of the of the Hybrid Electric Vehicle (HEV) or Battery Fed Electric Vehicle (BFEV) technology in the past two decades. Battery-powered electric vehicles (BEVs) seem like an ideal solution to deal with the energy crisis and global warming since they have zero oil consumption and zero emissions. However, factors such as high initial cost, short driving range, and long charging time have highlighted their limitations. But since then due to the better development in the ICE technologies and the cheaper petroleum prices made the ICE run vehicle a better option than a HEV. An HEV unlike conventional vehicle, which depends solely on the ICE engine for the traction power, utilizes electrical energy storage in combination with the ICE to provide the required traction power. Thus it facilitates the improvement in the energy conversion of the vehicle thereby increasing the efficiency and drivability and at the same time reducing the emissions. Furthermore the integration of the electrical storage system also makes the provision for the regeneration during braking which can further boost up the efficiency of the overall system. In future, a number of instantaneous changes in ICE technology, in energy storage device and energy conversion system, the efficiency of BFEVs will be increased that will attract more consumer.

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2.BIDIRECTIONAL DC-DC CONVERTERS

Bidirectional DC-DC converters serves the purpose of stepping up or stepping down the voltage level between its input and output along with the capability of power flow in both the directions. Bidirectional DC-DC converters have attracted a great deal of applications in the area of the energy storage systems for Hybrid vehicles, Renewable energy storage systems, Uninterruptable power supplies and Fuel cell storage systems. Traditionally they were used for the motor drives for the speed control and regenerative braking. Bidirectional DC-DC converters are employed when the DC bus voltage regulation has to be achieved along with the power flow capability in both the direction. These systems cannot serve as a standalone system for power supply because of the large fluctuations and therefore these systems are always backed up and supported by the auxiliary sources which are rechargeable such as battery units or super capacitors. This sources supplement the main system at the time of energy deficit to provide the power at regulated level and gets recharged through main system at the time of surplus power generation or at their lower threshold level of discharge. Therefore a bidirectional DC-DC converter is needed to be able to allow power flow in both the directions at the regulated level. Likewise in HEVs, bidirectional DC-DC converters are employed to link up the high voltage DC bus to the hybrid electrical storage system (usually a combination of the battery or a fuel cell with the super capacitor). Here they are needed to regulate the power supply to the motor drive to assist the ICE according to the traction power demanded.

3.STEP UP CONVERTER

3.1.Boost converter

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supplyside filter).

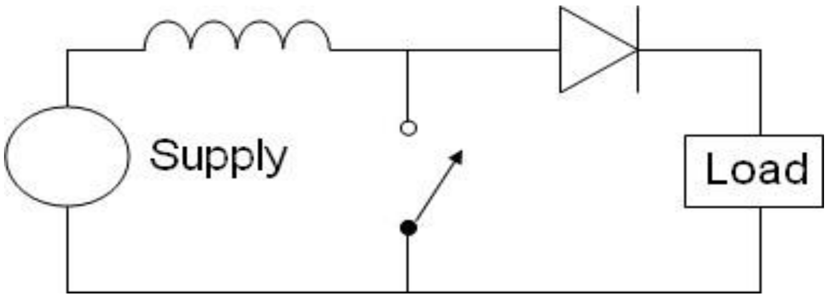

Fig 1: basic structure of boost converter

Figure 1 shows the basic schematic of a boost converter. The switch is typically a MOSFET, IGBT or BJT. Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power must be conserved, the output current is lower than the source current.

3.2.Cuk converter

The Cuk converter is a type of DC/DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is essentially a boost converter followed by a buck converter with a capacitor to couple the energy. Similar to the buck–boost converter with inverting topology, the output voltage of non-isolated cuk is typically also inverting, and can be lower or higher than the input. It uses a capacitor as its main energystorage component, unlike most other types of converters which use an inductor. It is named after Slobodan cuk of the California Institute of Technology, who first presented the design. There are variations on the basic cuk converter. For example, the coils may share single magnetic core, which drops the output ripple, and adds efficiency. Because the power transfer flows continuously via the capacitor, this type of switcher has minimized EMI radiation. The cuk converter allows energy to flow bi-directionally by using a diode and a switch. Figure 2 shows the basic structure of cuk converter.

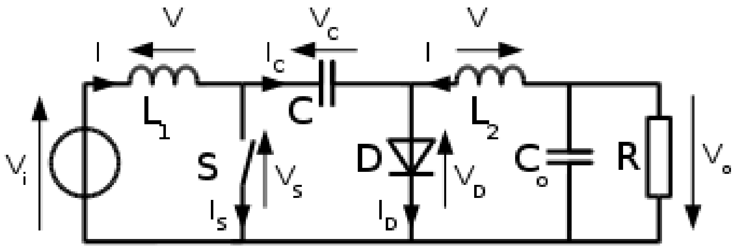

Fig 2: cuk converter

III. Bi-Directional Dc-Dc Converter

THE NEED FOR A BI-DIRECTIONAL DC-DC CONVERTER IN THE BFEV IS DUE TO THE FOLLOWING REASONS

High efficiency

Light weight and compact size

Lower electromagnetic interference

Controlled power flow in spite of wide input voltage variation

4.CONTROL STRATEGY

The control circuit of the bidirectional converter is shown in Fig.3 to control the speed of the dc drive; one possible control option is to control the output voltage of the bidirectional converter. To control the output voltage of the bidirectional converter for driving the vehicle at desired speed and to provide fast response without oscillations to rapid speed changes a PI controller is used and it shows satisfactory result[2]. In this control technique the motor speed ω_m is sensed and compared with a reference speed $\boldsymbol{\omega_{ref}}$. The error signal is processed through the PI controller. The signal thus obtained is compared with a high frequency saw tooth signal equal to switching frequency to generate pulse width modulated (PWM) control signals.

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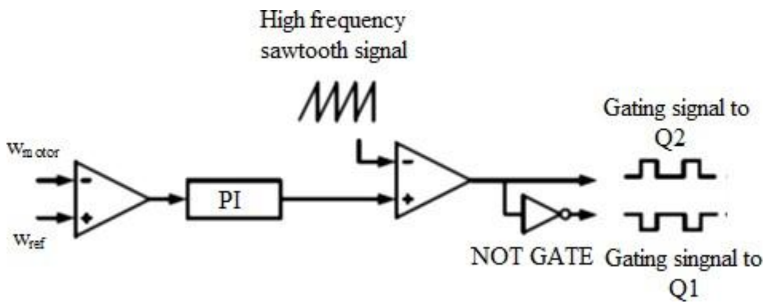

Fig. 3: Control strategy of the bidirectional dc-dc converter.

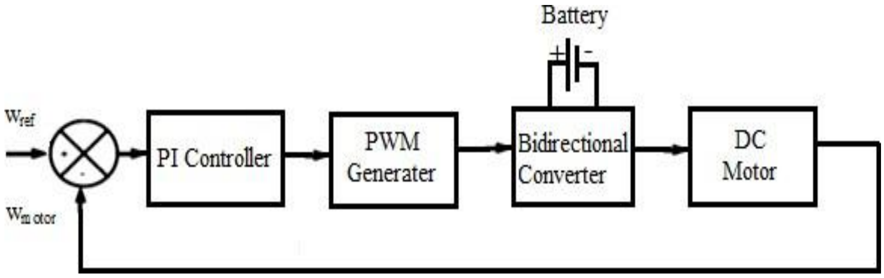

Fig. 4: Closed loop operation of the drive.

The block diagram of feedback speed control system for DC motor drive is shown in Figure 4. the control objective is to make the motor speed follow the reference input speed change by designing an appropriate controller. The proportional-integral(PI) controller is used to reduce or eliminate the steady state error between the measured motor speed (ω_{motor}) and the reference speed (ω_{ref}) to be tracked.

5.PROBLEMS WITH BIDIRECTIONAL DC TO DC CONVERTER

- Makes circuit more complex
- Introduces more amount of ripples
- Reduce the magnitude of quantities
- Make control complex

6.BOOST CONVERTER

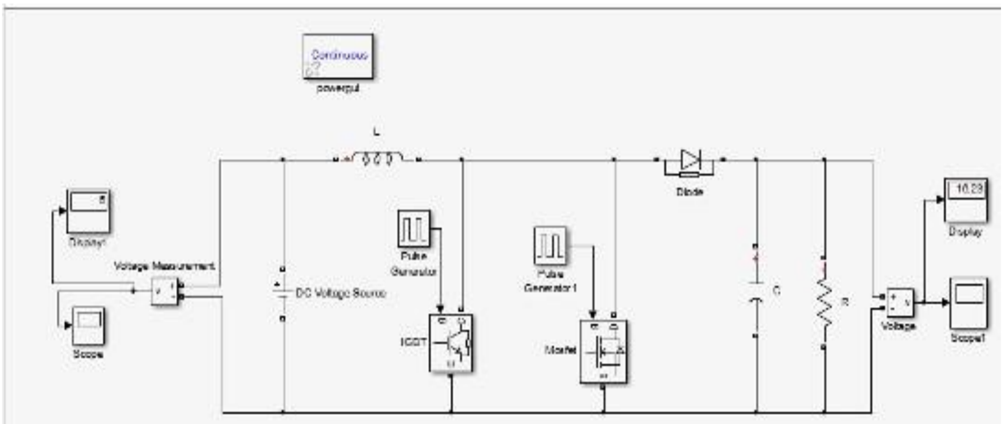

Fig 5: Boost converter simulink model

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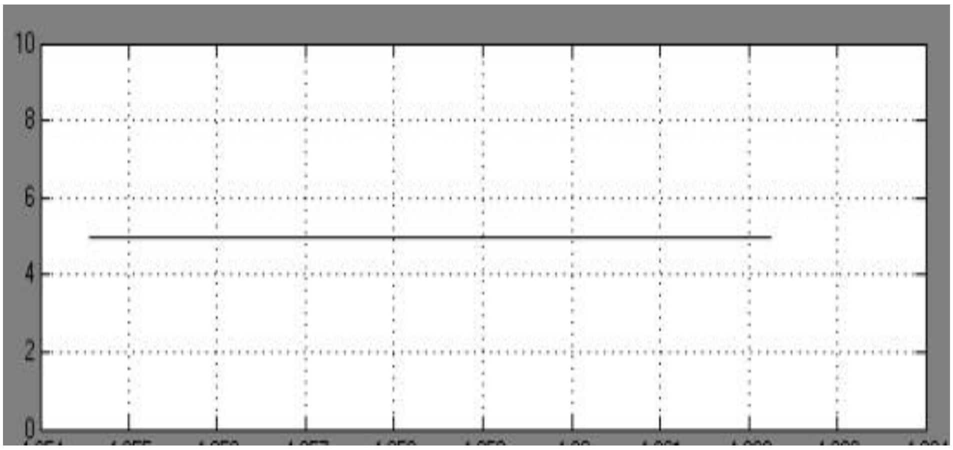

Fig 6: Input to the boost converter

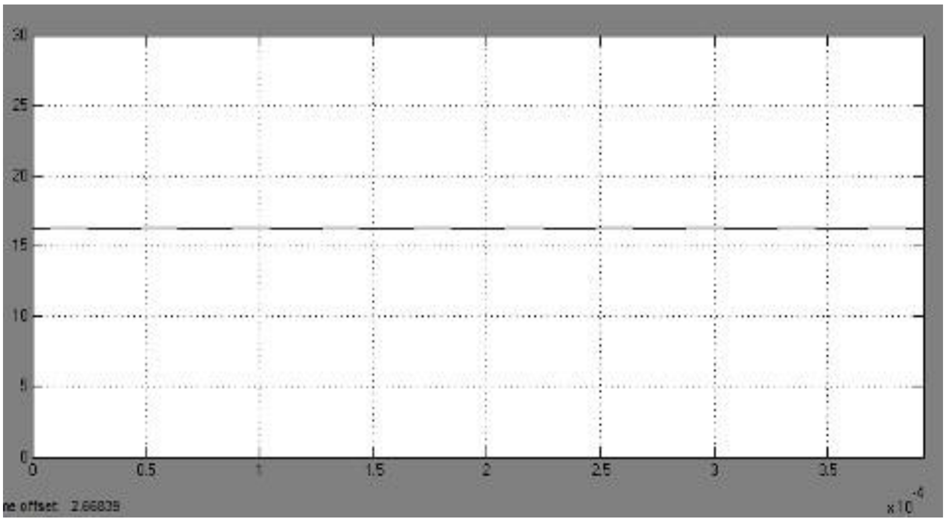

Fig 7: Output of boost converter

7.CUK CONVERTER

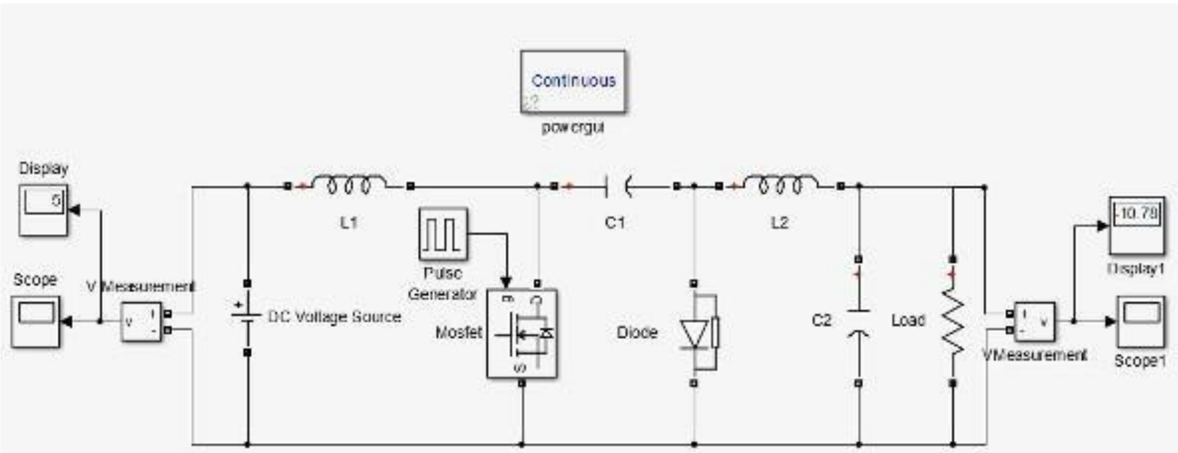

Fig 8: Cuk converter Simulink model

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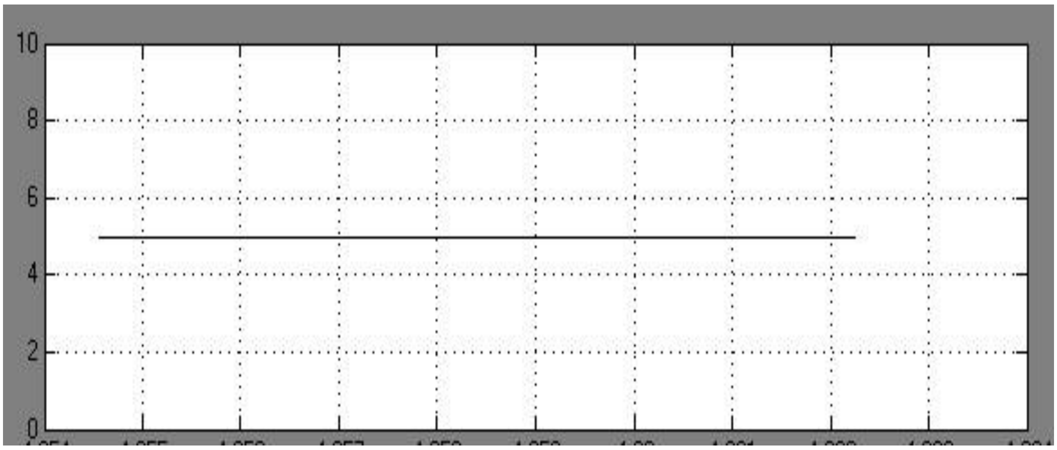

Fig 9: Input to cuk converter

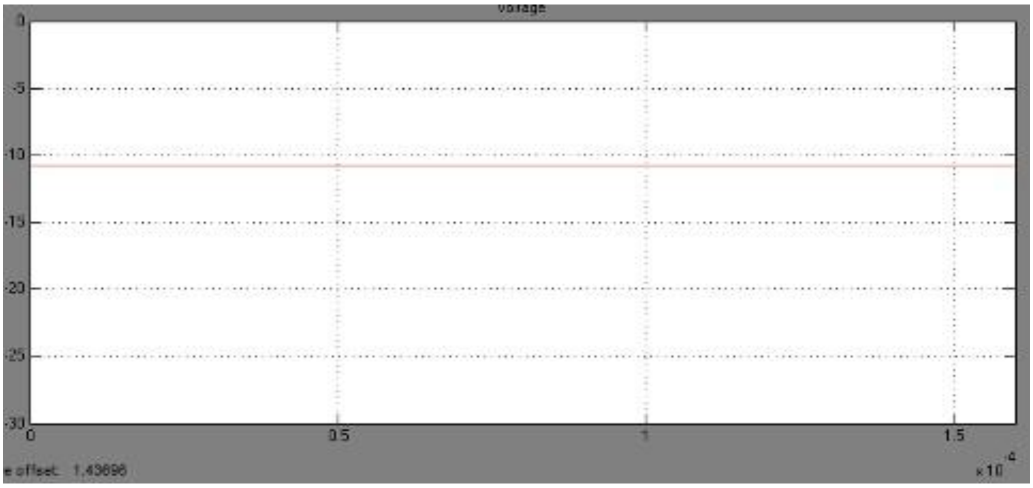

Fig 10: Output of cuk converter

8.HARDWARE IMPLEMENTATION OF CUK CONVERTER

8.1.Cuk converter analysis

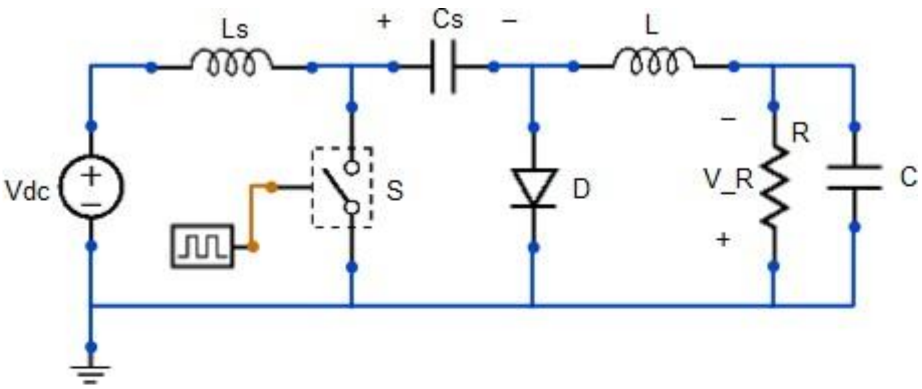

Fig 11: cuk converter

Switch OFF state:

- The inductor currents flow through the diode.
- Capacitor Cs is charged through the diode by energy from both the input and L1.
- The current IL1 decreases, because Vc1 is larger than Vd .

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- Energy stored in L2 feeds output and therefore IL2 decreases

Switch ON state:

- VC1 reverse biases the diode.
- IL1 and IL2 flows through the switch.
- As VC1 > V0, C1 discharges through the switch, transferring energy to the output and L2 and therefore IL2 increases.
- The input feeds energy to L1 causing iL1 to increase.

9.TWO WHEELER VEHICLES

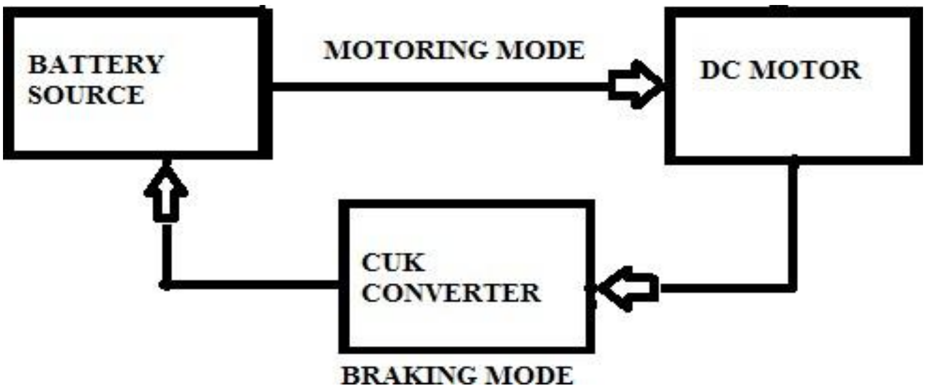

Fig 12: Block diagram of Two wheeler system

In two wheeler vehicle system the bidirectional DC-DC converter is not necessary since there is no bidirectional power flow. During motoring mode, power flow from battery to motor and during braking mode power flow reverses through cuk converter.

10.SIMULATION AND RESULTS

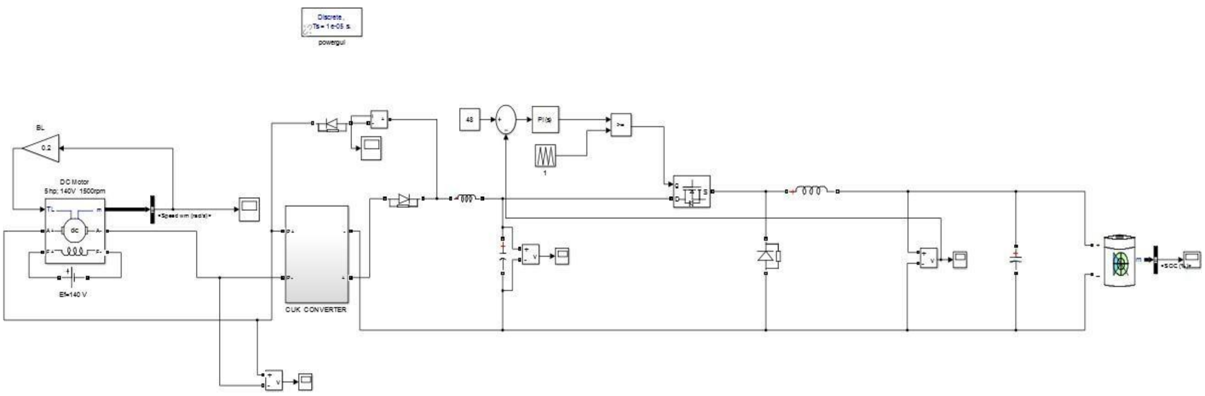

Fig 13: Simulink model of two wheeler system in motoring mode

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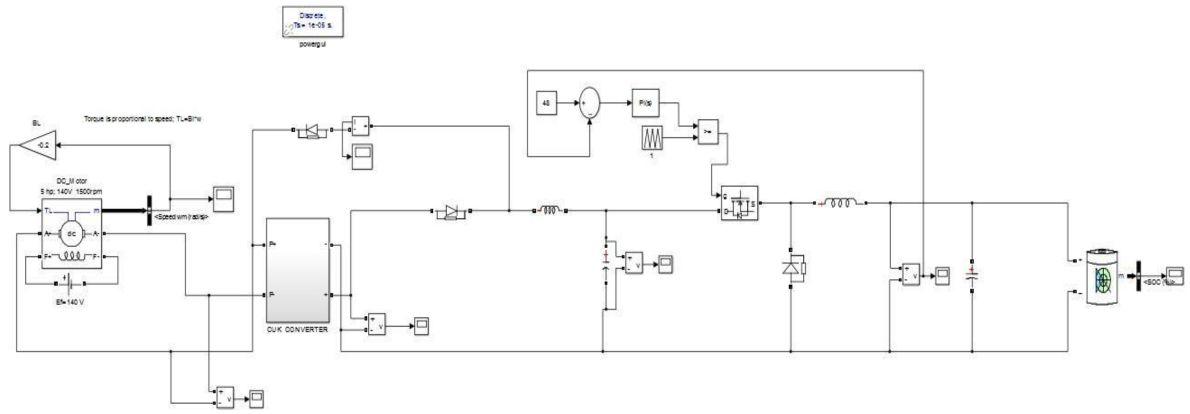

Fig 14: Simulink model of two wheeler system in regenerative braking mode

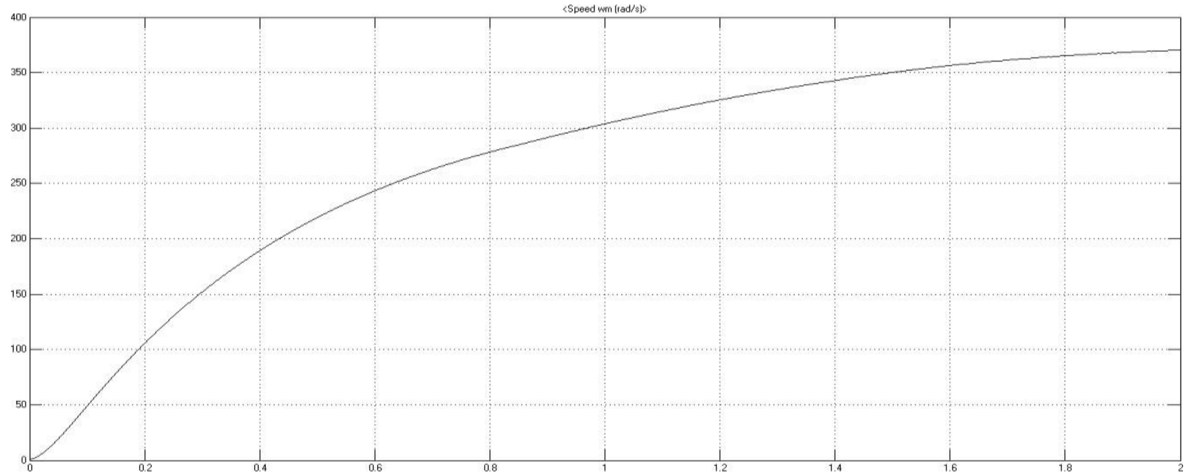

Fig 15: Speed waveform

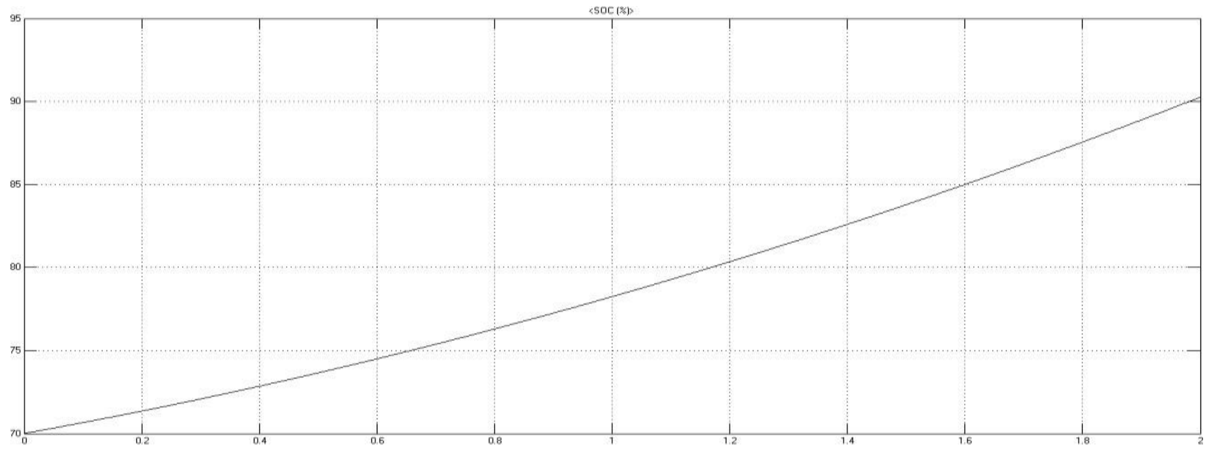

Fig 16: Battery charging waveform

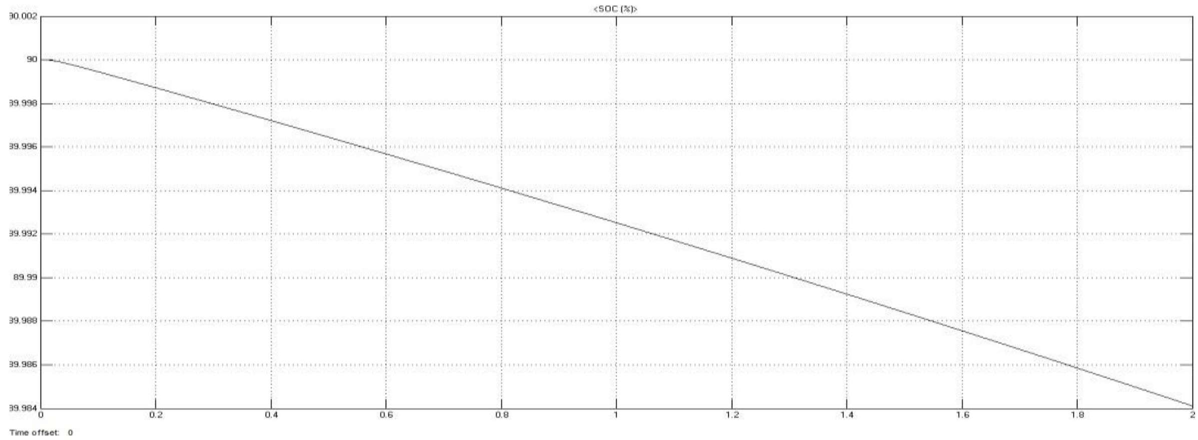

Fig 17: Battery discharging waveform

11.CONCLUSION

We have studied a battery operated electric vehicle system and it shows satisfactory performance at different driving condition. The proposed control technique with PI controller find suitable for this electric drive. .But as the circuit become more and more complex we have formulated a new idea of using a cuk converter without a bidirectional converter and it showed a better result. The performance of dc machine can be effectively increased by using the same. This circuit does not need large capacitive filters at both sides of the converter and thus, increases the efficiency of BFEVs. As a future work, a super capacitor bank for this system can be introduced and fuzzy technique can be used for converter control instead of a pi controller. The overall cost and volume of the battery operated electric vehicle is less with the least number of components used in the system. Acknowledgment We would like to express our gratitude towards our guide and mentor XYZ for her/his valuable advice, positive criticism, and consistent encouragement. I would also like to thank our all faculties for their blessings, moral and emotional support and valuable feedback, without which this work would not have been completed.

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