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IJIEMR Transactions, online available on 25th May 2021. Link :http://www.ijiemr.org/downloads.php?vol=Volume-10&issue=Issue05

10.48047/IJIEMR/V10/ISSUE 05/64

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Volume 10, ISSUE 05, Pages: 305-311

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DESIGN AND ANALYSIS OF BI-DIRECTIONAL DC-DC DRIVER FOR ELECTRIC VEHICLE

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ABSTRACT

The level of exhaust gases is rising with increasing usage of internal combustion engine vehicles. In order to reduce carbon emission, researchers and industry head up for improving electric vehicle technologies in all over the word. This paper deals with design and simulation of a bi-directional power converter of electric vehicle. The power electronics block is comprised by batteries, bi-directional dc-dc converter and dc machine. The initial state of battery charge is set around 90% where the discharge current is 44.5 A during motor mode. The nominal voltage of battery stack is 350 V and maximum capacity is 100 Ah. The rated power of dc machine is set to 250 HP with 500 V armature voltage and 300 V field voltage. The operating mode of power converter is determined according to the torque values of dc machine which is operated in motor and generator modes. The charge and discharge conditions of batteries have been controlled regarding to operating modes of dc machine. The bi-directional dc-dc converter is controlled with fuzzy logic controller in both modes. The proposed converter and controller are designed to meet charge control and motor drive requirements of an all-electric vehicle.

Keywords: Electric vehicle, DC-DC driver.

INTRODUCTION

Transportation sector occupies a fundamental place in the world. Fossil fuels used in conventional vehicles technology emit greenhouse gases such as carbon dioxide, carbon monoxide and methane. The excessive consumption of these gases causes air pollution, climate change and global warming. In order to reduce these effects, there is a tendency to electric vehicle (EV) technology. The EV has much lower fuel cost according to fossil fueled car since they are mainly composed of battery system, power electronic circuits and electric machine. The battery system in an EV is the most crucial component in charge control time and determining distance [1,2]. The electric machines of an EV are operated in both motor and generator modes due to regenerative breaking feature that enables electric machine to be operated in generator mode which is impossible in conventional internal combustion engine (ICE) vehicles. Therefore, electric machine charges the battery by operating in generator mode during the regenerative braking and it ensures recharging the batteries [3,4]. EV are classified into two types as hybrid EVs (HEVs) and all-electric vehicles. The HEV technology is used in conjunction conventional vehicle technology. The main system in HEV technology includes fuel tank and ICE such as diesel or gasoline engine, and auxiliary system which is comprised by electric machine, power electronic circuits and battery. HEVs are classified as parallel and series hybrid vehicles [5] that the parallel HEV consists ICE and electrical machine together as shown in Fig.1. As the parallel electric vehicles operates at

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electric mode during the acceleration of electric machine, the motor operation is supplied from battery

The designed EV motor driver is comprised by four sections such as battery, bi-directional dc-dc converter, FLC and dc machine as shown In this study, the starting voltage of battery is set to 378 V while the operating voltage of dc machine used in traction system is 500 V dc. The battery voltage is increased up to 500 V with bi-directional dc-dc converter in generator mode. The battery is discharged when dc machine is started acceleration. The motor mode simulation with various torque values are performed to observe battery parameters such as state of charge (SoC), current, voltage and voltage of the dc machine. The voltage of the dc machine is decreased to 500 V with bidirectional dc-dc converter which is controlled with FLC. The battery is charged during the generator mode operation of dc machine. The FLC determines duty cycle of S1 and S2 to ensure charge and discharge of battery. The dc machine is comprised by brushes, armature core and windings, commutator, field core and windings. Armature circuit is comprised by series structure with inductor, resistance and counter-electromotive source. Similarly, battery parameters such as SoC, current, voltage and voltage of the dc machine are observed in the generator mode simulation regarding to various torque values applied to dc machine.

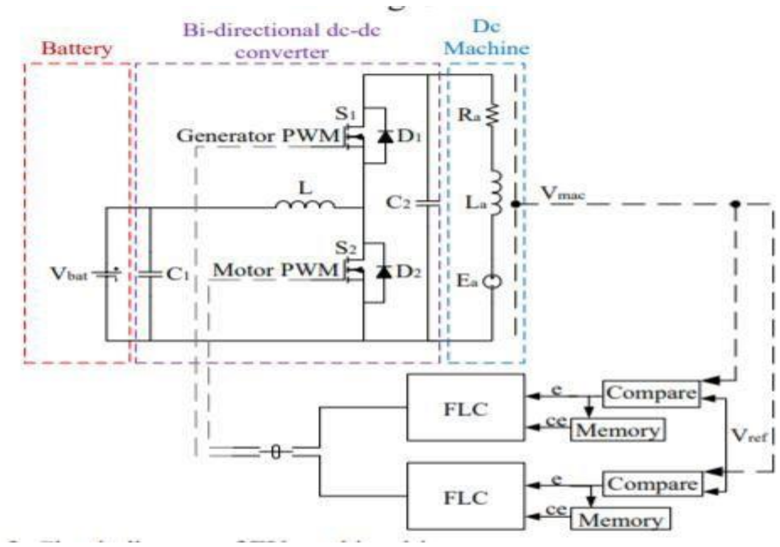

Fig 1 Proposed circuit configuration

The electrical energy is converted to mechanical energy or vice versa by dc machine that operates regarding to electromechanical energy conversion theory [7]. If a conductor is moved within the magnetic field, the voltage is induced on it which is known as generator operating mode. If alternating current passes through the conductor, magnetic field is created around it which explains the motor mode operation. When the dc machine is started acceleration, the resultant positive torque is achieved. On the other hand, negative torque is generated at the dc machine when it is operated in generator mode

FLC is comprised by fuzzification, rule base, interface mechanism, defuzzification. Fuzzification is used to convert digital signals received through the system into linguistic variable. Rule base is comprised by the conditions to set for controlling the system at desired

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location. Interface mechanism makes inferences according to the rules of system by establishing a relationship between inputs. Defuzzification is used to convert linguistic variable received through the system into digital signals.

PROPOSED SYSTEM

The design and analysis of a bi-directional DC-DC drive for an electric vehicle involves developing a power converter that can convert the DC voltage from the vehicle's battery to the appropriate voltage level for the electric motor, and also convert the regenerative braking energy back to the battery during deceleration.

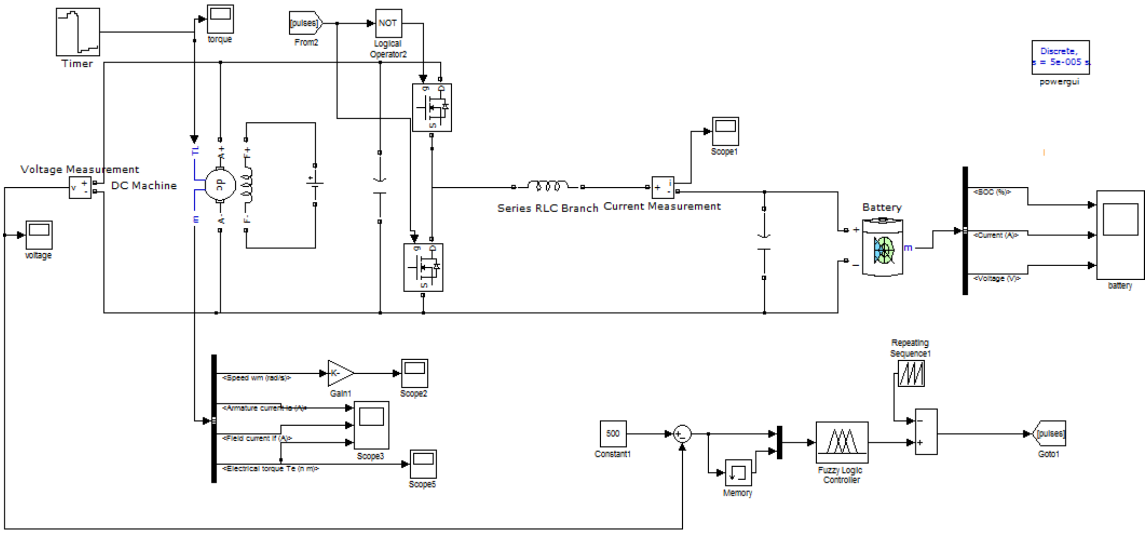

Fig 2 Proposed circuit configuration

The bi-directional DC-DC drive typically consists of a power converter, a filter, and a control system. The power converter is responsible for converting the voltage level of the DC power from the battery to the voltage level required by the electric motor and vice versa. The filter is used to smooth out the DC voltage and current to reduce the ripple and noise in the system. The control system regulates the power flow in the system, ensuring that the energy is transferred efficiently and safely between the battery and motor.

Some of the key considerations in the design and analysis of a bi-directional DC-DC drive for an electric vehicle include:

Voltage and current ratings: The drive must be designed to handle the voltage and current levels required by the motor and battery, and the power converter must be capable of handling the bi-directional power flow between the motor and battery during acceleration and regenerative braking.

Efficiency: The drive must be designed to minimize energy losses during the power conversion process, to maximize the efficiency of the electric vehicle.

Reliability: The drive must be designed to operate reliably over the lifetime of the vehicle, to minimize maintenance and repair costs.

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Size and weight: The drive must be designed to be compact and lightweight, to minimize the impact on the vehicle's overall weight and size.

Overall, the design and analysis of a bi-directional DC-DC drive for an electric vehicle is a critical component in the development of a high-performance and efficient electric vehicle. By optimizing the power flow between the battery and motor, the bi-directional DC-DC drive can help to maximize the range and performance of the vehicle, while also minimizing its environmental impact.

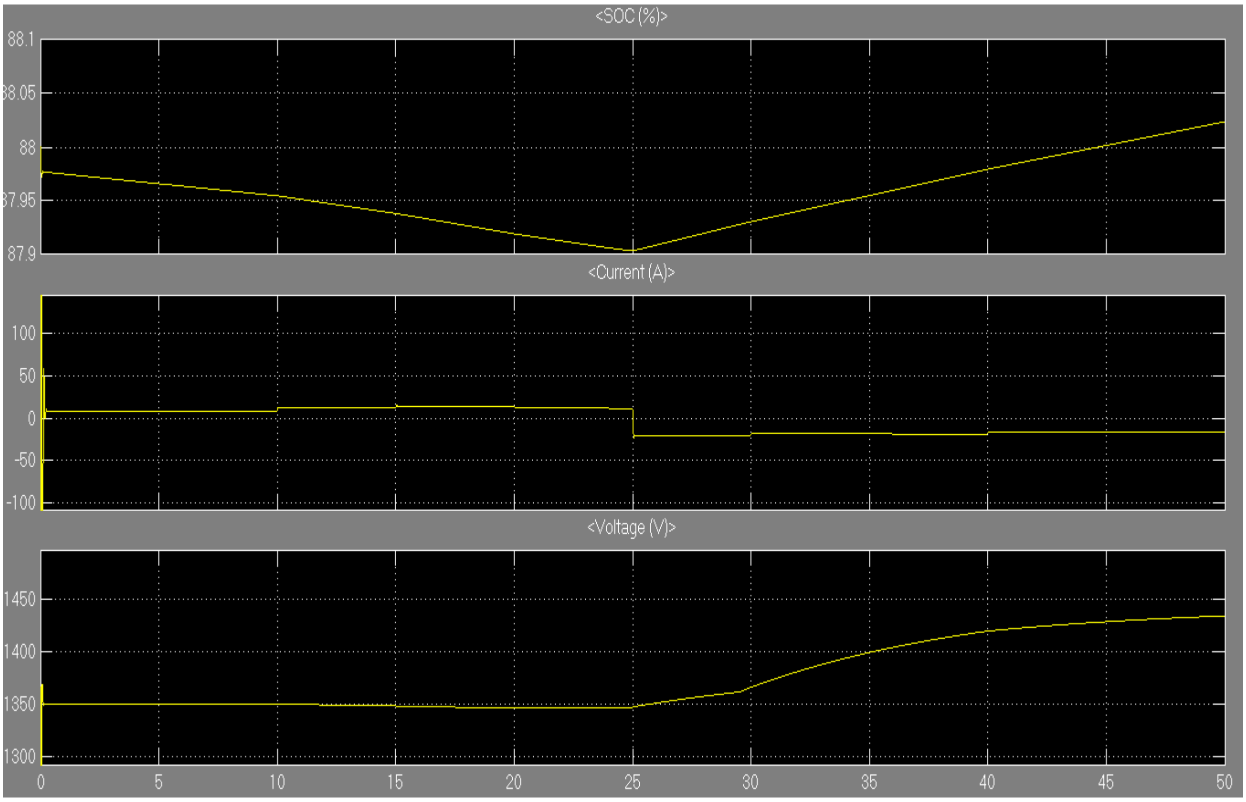

Fig 3 Proposed system Battery SOC, current, voltage

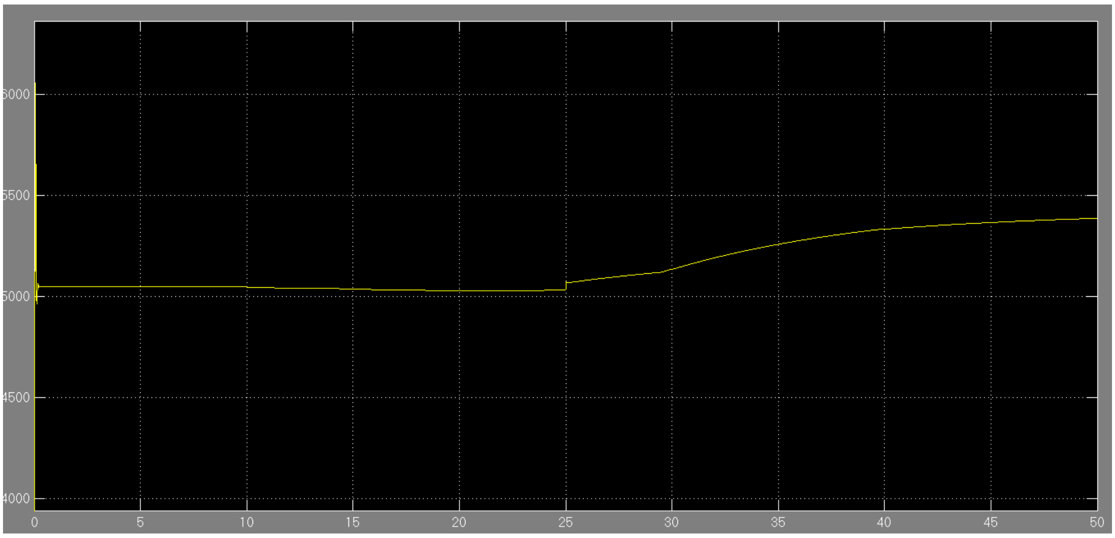

Fig 4 Proposed system Speed of the dc machine

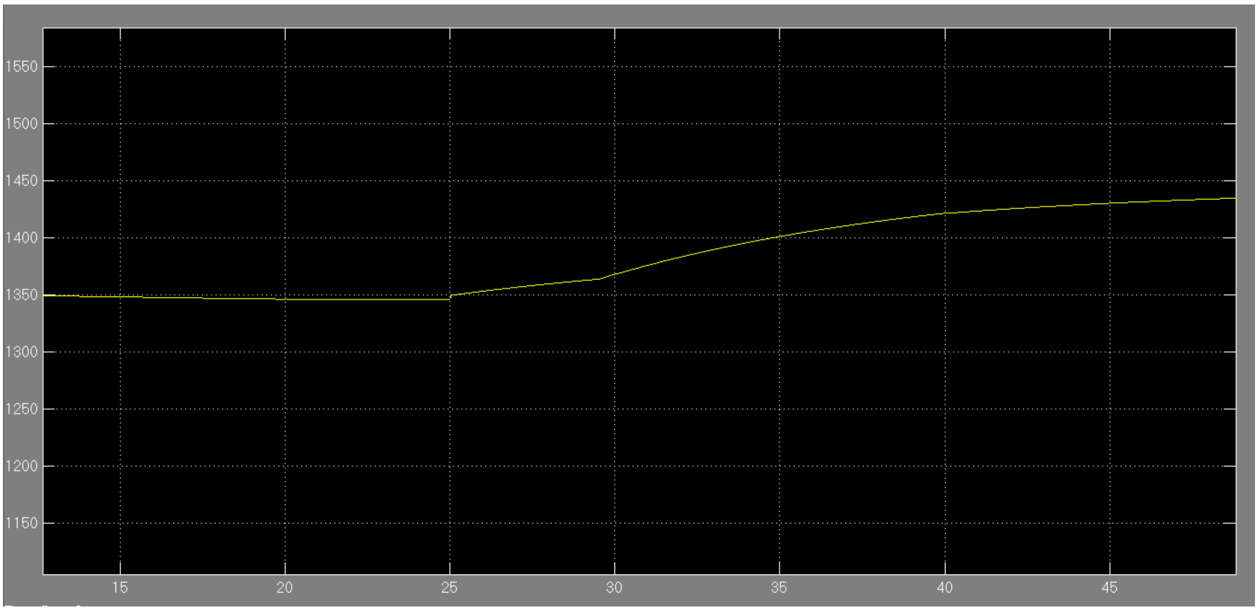

Fig 5 Proposed Dc machine across voltage

CONCLUSION

This project presents design and control bi-directional dcdc converter for all-electric vehicle. The bi-directional dc-dc converter is controlled with FLC according to rules. When the battery is discharged, the dc machine is operated in motor mode and bi-directional dc-dc converter is operated in boost mode. Variable positive torque values are applied to the dc machine and condition of the battery is observed. According to simulation result, the battery SoC is reduced from %88 to %87.337 and voltage of the dc machine is constant at 500 V. When the battery is charged, the dc machine is operated generator mode and bi-directional dc-dc converter is operated in buck mode. Variable negative torque values are applied to the dc machine and effect on the battery is observed. According to simulation result, the battery SoC is increased from %87.337 to %87.445. In all-electric vehicle, regenerative breaking is occurred in this state. Charge and discharge states of the battery are the most essential for distance to determining.

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