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Fuzzy logic controlled Bi-directional DC-DC Converter for Electric Vehicle Applications

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Abstract: *Even though fossil fuels are limited, the demand for oil is increasing day by day which cause environmental problems such as Greenhouse effect. Battery powered electric vehicle found to be a solution to avoid dependency on fossil fuels. This paper presents an efficient circuit for battery fed electric vehicle. Where circuit consists of Fuzzy logic controlled Bi-directional DC-DC Converter. Comparison has been made between PI and Fuzzy logic control strategies. Performance of circuit is verified through a MATLAB/SIMULINK.*
Keywords: *Battery, DC machine, Bi-directional DC-DC Converter.*

I. Introduction

In recent years, oil consumption by vehicles powered by internal combustion engine has significantly increased which is affecting an environment. To overcome this, battery powered electric vehicles are introduced as they have zero emissions, zero oil consumption, Low maintenance. Battery Fed Electric Vehicle's (BFEV) architecture is not much complex than hybrid electric vehicles, as it is propelled by electric machine running by an electric energy stored in battery [1]. It consists of Bi-directional DC-DC Converter, DC machine, Battery. Bi-directional DC-DC Converter is the main part of BFEV which controls the power flow in both the directions and provides an appropriate voltage to DC machine. Battery powered electric vehicles required to operate in two modes namely Acceleration mode and Regenerative braking. Power stream is from Battery to DC motor during acceleration mode, and kinetic energy of electric motor is renewed to electric energy and fed back to Battery during regenerative braking. BFEV is widely researched by researchers where their main concentration is on charging of battery i.e. fast charging to attract more consumers even though slow charging is inexpensive. Bi-directional with PWM controller is implemented to get high efficiency [2]. Bi-directional with coupled inductors are implemented to reduce stress on low and high side of switches [4]. Soft switching techniques, ZCS, ZVS are implemented to achieve minimum switching losses. But in conventional DC-DC Converter output gets affected if there is any variation at the input side. During regenerative mode Boost converter with bi-directional dc-dc converter is implemented but drawback is high ripple output current. To overcome this CUK converter is used instead of boost converter.

This paper presents Acceleration mode of BFEV with fuzzy logic controlled Bi-directional DC-DC Converter and below section gives the comparison between PI and Fuzzy logic controller.

II. Battery fed electric vehicle

Battery fed electric vehicle consists of Battery, Bi-directional dc-dc converter, DC machine. The below fig. shows the block diagram of BFEV in both operating modes.

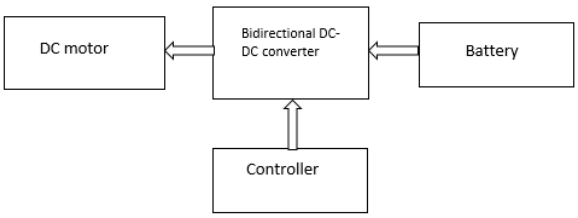


Fig1. Block diagram of BFEV during acceleration mode

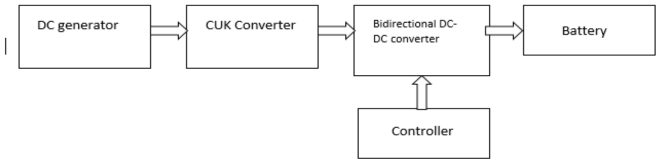


Fig2. Block diagram of BFEV during regenerative braking mode

During acceleration mode, the power flows from battery to DC motor, battery provides an appropriate voltage to DC motor to run. During regenerative mode that is when driver step on brake puts the vehicle's electric motor in reverse mode causing it to run backwards which causes the motor to act as generator. So the power flows from generator to battery. CUK converter is designed to provide an appropriate voltage for battery to charge.

1. BI-DIRECTIONAL DC-DC CONVERTER

Bi-directional DC-DC Converter is the main part of the BFEV. The main function of this converter is to control the flow of power in both the directions and to provide DC voltage to DC motor.

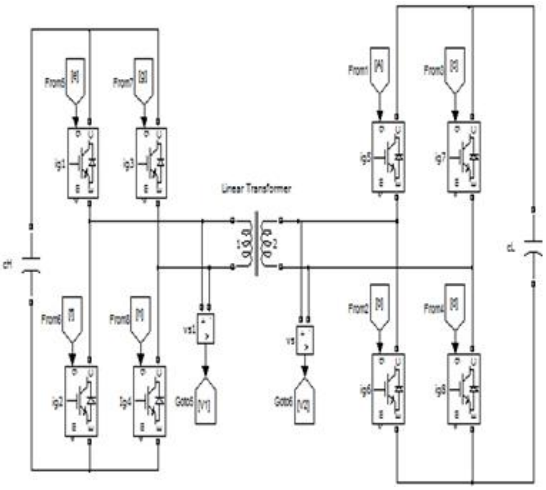


Fig3. Bi-directional DC-DC Converter

The fig3 shows the circuit diagram of bidirectional dc-dc converter. During motoring mode the low voltage side is controlled, high voltage side acts as rectifier and vice-versa for regenerative mode. Linear transformer provides isolation and to step up and step down the voltage during operating modes.

III. CIRCUIT DESCRIPTION

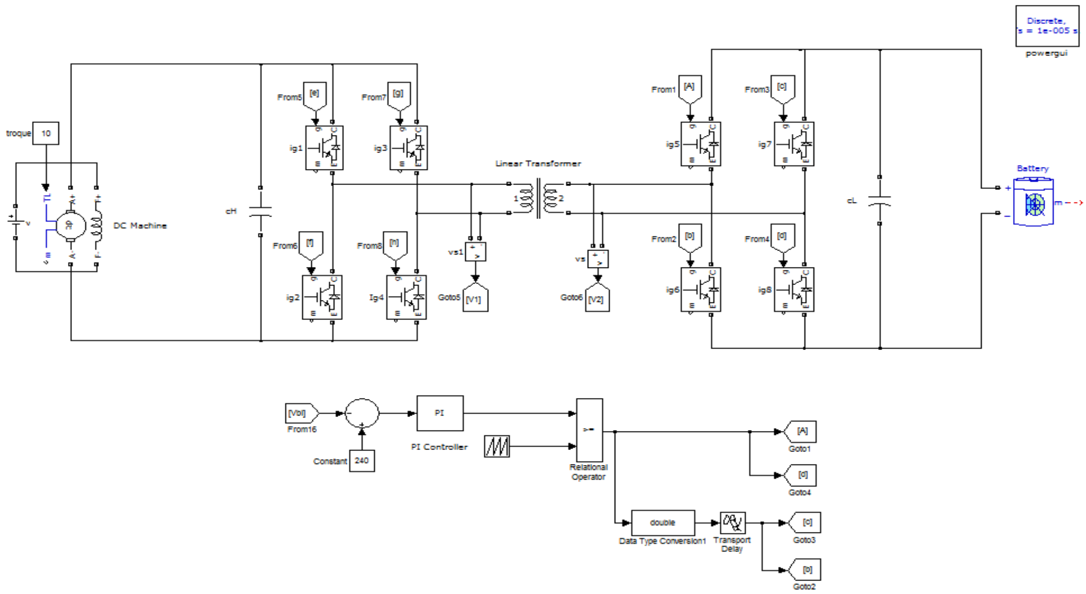
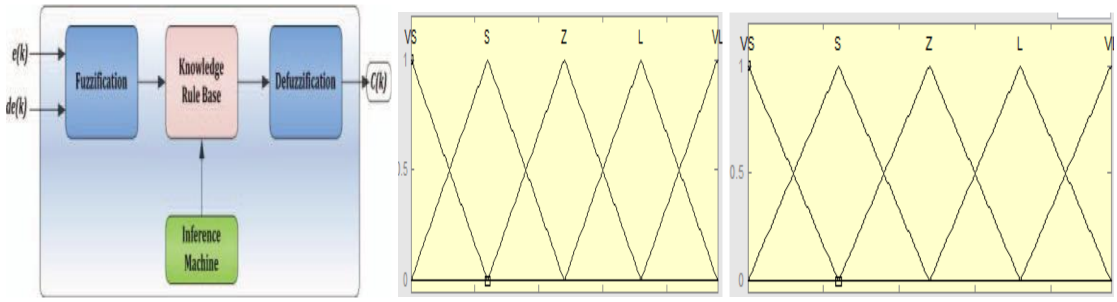


Fig4. Simulink model of BFEV with PI controller during acceleration mode

The fig 4. Shows Simulink model of BFEV during acceleration mode, switches at battery side of Bi-directional DC-DC Converter are controlled by PI controller, battery of 48V is inverted to 48Vac and fed to transformer. It is boosted to 240Vac after that it is rectified to 240Vdc and it is given to a DC motor. Motor runs at 1750rpm. PI controller is designed such that the output of Bi-directional is compared with constant, the error signal is given to PI to reduce steady state losses and then it is compared with high frequency sawtooth signal to generate pulses. Pulses are given switches A and D. pulses with some delay are given to switches C and B such that when switches A and D are ON C and B should be OFF and vice-versa. Parameters- battery-48V, battery capacity-6.5Ah, SOC-88%, switching frequency-5KHz, DC machine-1750rpm, Armature voltage 240V.

1. FUZZY LOGIC CONTROLLER



(a) (b)

Fig5. (a)Block diagram of Fuzzy logic controller, (b) membership function of error and change in error

"Fuzzy logic control system is based on Fuzzy logic which analyses the analog input values in terms of logical variables which take on continuous values between 0 and 1". The fig4(a). Shows basic block diagram of Fuzzy logic controller the first step is Fuzzification where crisp values are converted to fuzzy values using membership functions, then rules are to be applied which is given in Table1. Combining the results of the rules by using centroid method Defuzzification will be done where fuzzy values are converted to one crisp value.

Table1. Matrix formulation (5x5) for fuzzy logic rules

e(k) de(k)	VL	L	Z	S	VS
VL	VL	VL	VL	L	Z
L	VL	VL	L	Z	S
Z	VL	L	Z	Z	S
S	L	Z	Z	S	S
VS	Z	S	S	S	VS

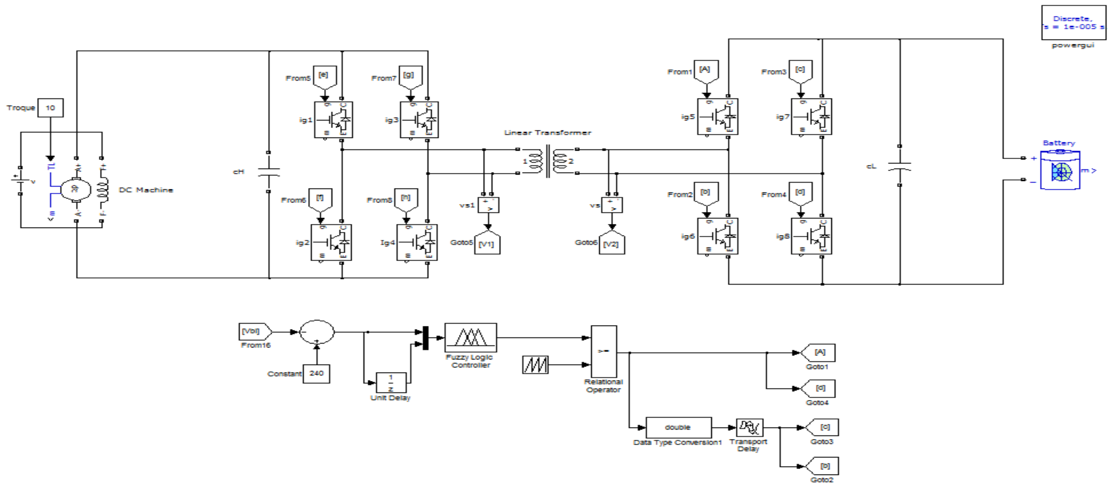


Fig6. Simulink model of BFEV with Fuzzy logic controller during acceleration mode

IV. simulation results

The performance of the circuit is simulated with two control strategies. The simulation is carried out through MATLAB/SIMULINK. The results for PI controller are shown in fig7(a)-(d).SOC of a battery is decreasing, speed of motor is 162rad/sec and bi-directional output is 213V.

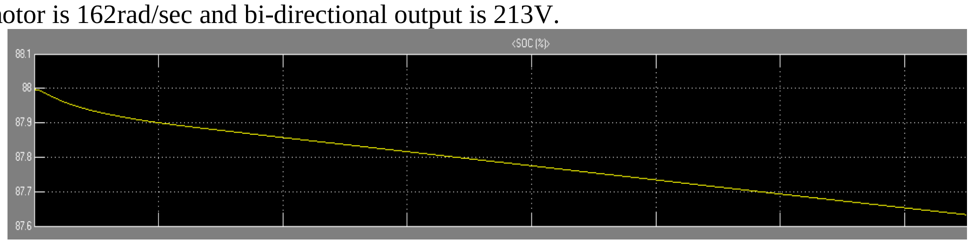


Fig7(a). SOC of Battery with PI controller

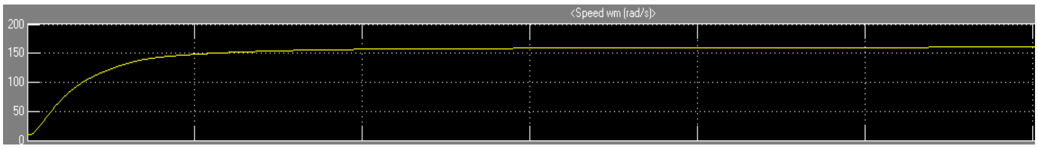


Fig7(b). Speed of DC motor with PI controller

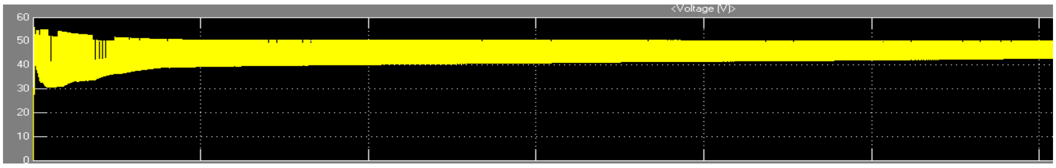


Fig7 (c). Battery voltage with PI controller

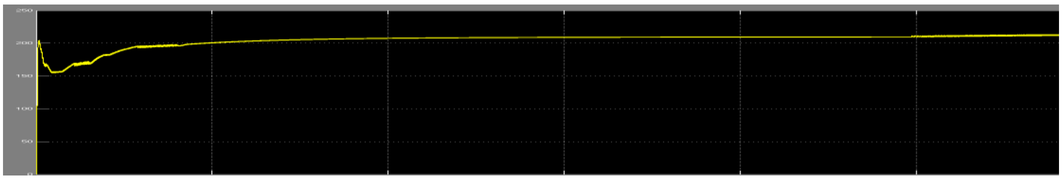


Fig7(d). Bi-directional dc-dc converter output with PI controller

Results with Fuzzy logic controller are shown in Fig8(a)-(d), where Speed of motor is 183rad/sec and bi-directional dc-dc converter output is 237.9V. Voltage at the battery having less ripple content than voltage at battery with PI controller.

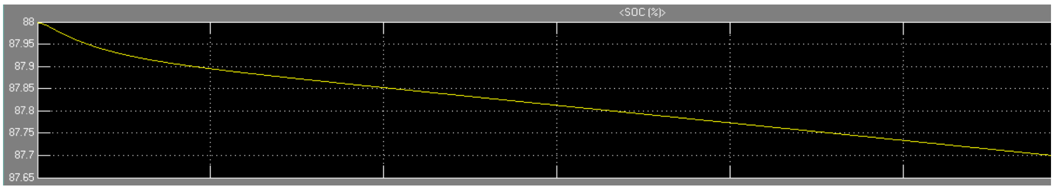


Fig8(a). SOC of battery with Fuzzy logic controller

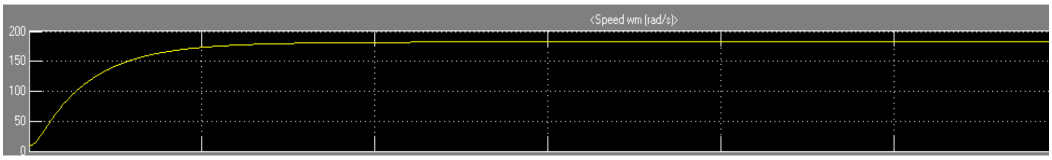


Fig8(b). Speed of DC motor with Fuzzy logic controller

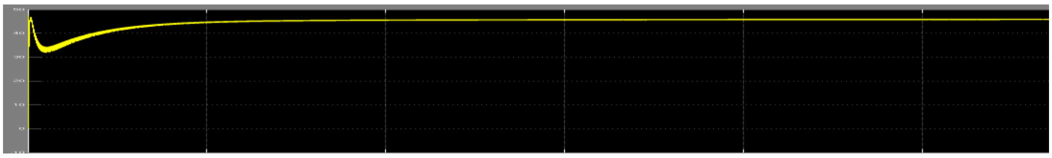


Fig8(c). Battery voltage with Fuzzy logic controller

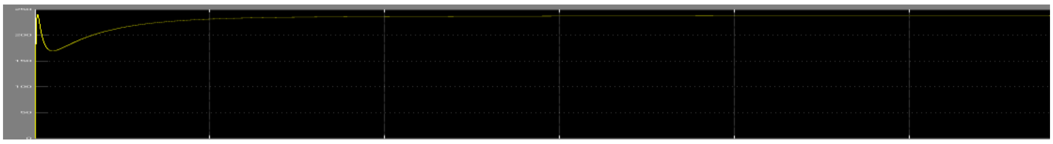


Fig7(d). Bi-directional dc-dc converter output with Fuzzy logic controller

From the results of PI and Fuzzy logic controller, it is concluded that fuzzy is efficient than PI. Ripples at the battery side is less with Fuzzy compare to PI.

V. Conclusion

This paper presents Acceleration mode of BFEV with fuzzy logic controlled Bi-directional DC-DC Converter has been proposed to maintain battery voltage. Comparison has been made with PI and Fuzzy logic control strategies. Performance of circuit is verified through MATLAB/SIMULINK. From the results is has been concluded that fuzzy is efficient than PI. Feasibility of this converter in Regenerative mode will be publishing in near future.

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