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A Fuzzy Controlled Dual Boost DC-DC Converter for BMPS Fabrication

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ABSTRACT: A discharging (Boost) mode of the bidirectional dc-dc converter with fuzzy logic controller is present in this paper .To achieve high voltage step-up conversion two boost conversion stages are obtained by controlling one power switch. High efficiency is achieved since the energy stored in the leakage inductor is recycled. For understanding the advantages of fuzzy logic control conventional PI control has applied and compared under the same circumstances of the converter. Simulation results show that fuzzy controlled converter has an improved steady state and transient performance than PI controlled converter. This converter can be used for Board Mounted Power supply (BMPS).

KEYWORDS: Bidirectional dc-dc converter, BMPS, Fuzzy logic control, Leakage Inductor, PI control, Step-up conversion

I.INTRODUCTION

An uninterrupted power supply is needed for every activity in the world .For this reliable power has to be stored in batteries. Under this situation there could be the need for dc-dc converter. DC-DC converter is an electronic device which can change the dc voltage from one level to another level .Also high conversion ratio is required where the voltage level of source and load is large. DC-DC converter can be broadly classified into isolated and non-isolated bidirectional DC-DC converters based on the isolation material between input and load. Since the isolated bidirectional DC- DC are having more complex structure, are more bulky, costlier and heavier than the non-isolated bidirectional DC- DC converters due to the presence of the transformer. Non-isolated dc-dc converter can be either buck boost converter, buck boost cascade converter, cuk converter or half bridge dc-dc converter; these converters require many active components and can be used only for low power applications. High conversion ratio can be achieved through the use of coupled inductor .Leakage inductance of coupled inductor results in leakage current which can be used for the soft switching operation in a power converter but on the other hand this leakage current if not properly dealt can cause serious problems such EMI or resonance phenomenon across different operating switches.

In this paper, it proposes a double boost dc-dc converter with a high step-up conversion. Coupled inductor technique is used for the high step-up conversion. The leakage inductance energy of the coupled inductor is recycled thus reducing the voltage stress on the switching devices. Fuzzy control and PI control has applied to the same converter and compared. It is found that the fuzzy controlled converter has fast response and improved steady state and transient response. This converter can be used for on board switch mode dc-dc power module.

II.LITERATURE SURVEY

In 2006 L. A. Flores, O. Garcia et al[1] this paper, a bidirectional dc-dc converter is proposed to satisfy the hybrid vehicles requirements and can be used to work permanently with any output voltage from 0 to 420V without any difficult. This converter is integrated by a full bridge, a high frequency transformer and two inductor rectifiers. This topology is suitable to be implemented in applications of hybrid vehicles since the fullbridge plus two inductor rectifier allow to handle high currents that are divided to half and conduction losses are reduced when is working in down mode. When this topology operates in up mode, converter can deliver output voltage from 0V to high output voltage in capacitors without over current in the inductors.

In 2008 B. R. Lin, J. J. Chen et al [2] a bidirectional dc converter with high conversion ratio is presented in this paper to achieve bidirectional power flow capability. In the proposed converter, two boost conversion stages are used to achieve high conversion ratio. The power flow is transferred from low voltage side to high voltage side if the converter is operated in the boost mode. On the other hand, the power flow is transferred from high voltage side to low voltage side if the converter is operated in the buck mode. To further reduce the switching losses on the power switches, the active snubber circuit is adopted in the converter to achieve zero voltage switching (ZVS) of power switches.

In 2009 L. S. Yang, T. J. Liang et al [3] proposes transformer less dc–dc converters to achieve high step-up voltage gain without an extremely high duty ratio. In the proposed converters, two inductors with the same level of inductance are charged in parallel during the switch-on period and are discharged in series during the switch-off period. The structures of the proposed converters are very simple. Only one power stage is used.

In 2010 Z. Amjadi and S. S. Williamson[4] proposes a hybrid SC bidirectional dc/dc converter that can offer features of voltage step-down, voltage step-up, and bidirectional power flow. It has the following advantages lower source current ripple, simpler dynamics, control simplicity; and continuous input current waveform in both modes of operation.

In 2010 G. Y. Jeong [5] presents a high efficiency asymmetrical half-bridge flyback converter using a new voltage-driven synchronous rectifier that operates over a universal input voltage range (75–265 V) with a fixed 5 V DC output voltage. Both power semiconductor switches of the proposed converter primary operate asymmetrically under zero voltage switching to achieve high efficiency and low switch voltage stress. Because the proposed converter uses the transformer leakage inductance as its resonant inductance, its structure is simplified. The proposed synchronous rectifier can cover a universal input voltage range and can maintain control in a narrow switching period, features that are essential in converters with universal input voltage. The synchronous rectifier switch of the proposed converter conducts under zero voltage/zero current switching conditions with a discontinuous conduction mode.

In 2011 S. M. Chen, T. J. Liang [6] presents a cascaded high step-up dc–dc converter to increase the output voltage of the micro source to a proper voltage level for the dc interface through dc–ac inverter to the main electricity grid. The proposed converter is a quadratic boost converter with the coupled inductor in the second boost converter. It has high step-up voltage gain; the voltage gain is up to 20 times more than the input. The leakage energy of coupled-inductor can be recycled, which is effectively constrained the voltage stress of the main switch $S1$ and benefits the low ON-state resistance can be selected.

In 2011 L. S. Yang, T. J. Liang [7] presented a novel high step-up dc–dc converter. The coupled-inductor and voltage-doubler circuits are integrated in the proposed converter to achieve high step up voltage gain. The energy stored in the leakage inductor of the coupled inductor can be recycled. The voltages across the switches are half the level of the output voltage during the steady-state period. Compared to above circuit the efficiency is improved. However, since more circuit components are used in the proposed converter, it results in higher cost. and the equivalent series resistance of inductors and capacitors.

III.PROPOSED CONVERTER

In the proposed double boost converter high voltage conversion ratio is achieved by using coupled inductor technique. The leakage inductance energy of the coupled inductor is recycled thus reducing the voltage stress on the switching devices. In this paper fuzzy controller is applied at the discharging mode (Boost mode) of the converter. Controllers are used to adjust the output voltage with the help of a feedback loop. This feedback loop feedbacks the output voltage to calculate the difference between reference voltage and the output voltage and hence controlling is done to obtain the required output voltage.

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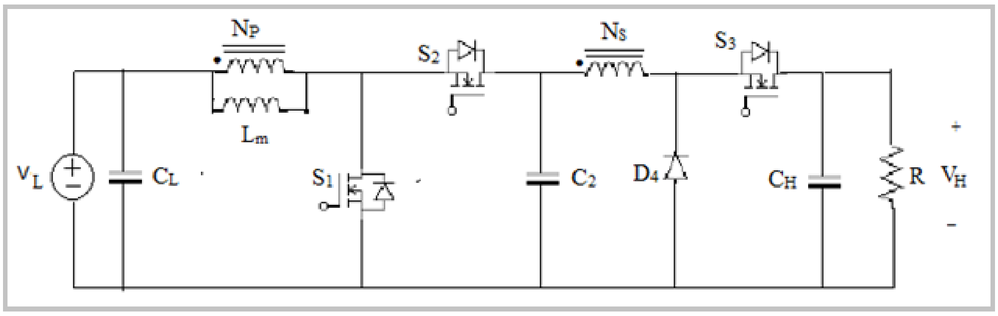

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Fig 1 Proposed bidirectional dc-dc converter

Fig 1 shows the proposed converter scheme. There are six modes of operation for the boosting mode of the converter.

Mode1: In this mode S1 and Ds_3 are turned ON. The energy stored in the secondary leakage inductor is is released to capacitor C_2 .The battery voltage V_L releases energy into primary leakage inductor. When current through the switch S_3 reduced to zero, this mode ends also switch Ds_3 is turned off.

Mode2: In this mode S1 and D4 are turned on.V_L charges Lm and primary leakage inductor .V_L transfers energy into C2 through the secondary winding of the coupled inductor. This mode ends when S1 turned off.

Mode 3: In this mode S1 and Ds_3 are turned off and Ds_2 turned on. The energy of the primary and secondary leakage inductors are released into C_2 through Ds_2 and D_4 respectively. At end D_4 is turned off.

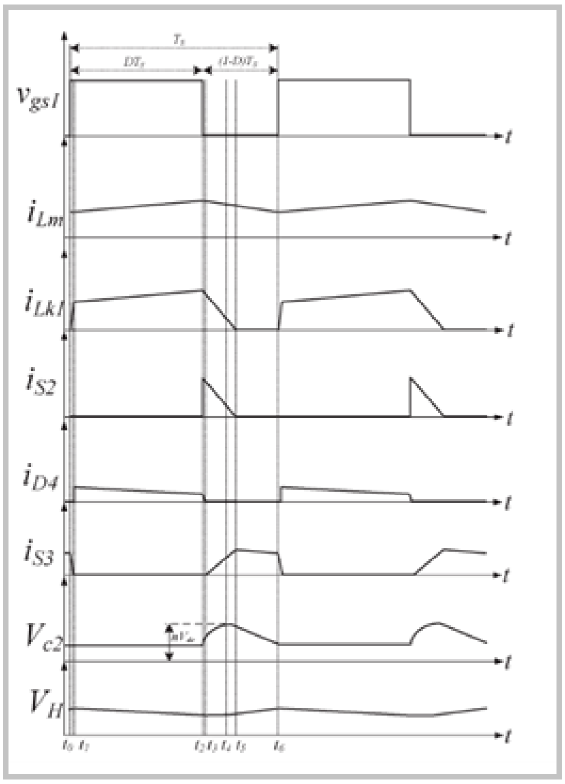

Fig 2 Typical waveforms during Boost mode

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Mode4: In this mode Ds_2 and Ds_3 are turned on. The energies of V_L, Lm and primary leakage inductor are released into C_2 through Ds_2.Small portion of this energy is transferred to C_H and R_H via secondary side of the coupled inductor.

Mode5: In this mode S_1 is turned off and Ds_2 and Ds_3 are turned on. The Lm energy is released to C_H via the coupled inductor Ds_3.The energy stored in C_2 is transferred to C_H and R_H.

Mode6: In this mode S_1 and Ds_2 are turned off and Ds_3 is turned on . The Lm energy is released to C_H and R_H via the secondary side of the coupled inductor Ds_3.The energy stored in C_2 is also transferred to C_H and R_H. This mode ends when S_1 is turned on.

Fig 2 shows the typical waveforms during discharging mode. The power switch S_1 is the main power switch. The switches S_2 and S_3 are off during the entire period. The energy-stores in Lm is during Mode II, and thus, the voltage across L_m equals V_L. During Modes IV and VI, L_m releases energy to the load with the voltage across L_m is $(nV_L - V_H)/n$. According to the volt–second balance principle in L_m, we have $\upsilon_L \cdot D + [\frac{1}{n}((n\upsilon_L - \upsilon_H)].D = 0$

Thus, the voltage gain of discharging mode can be derived as follows: $\frac{V_H}{V_L} = \frac{n}{1-D}$

IV.DESIGN CONSIDERATIONS

1.Output Capacitor (C_H) : According to the mode analyses, when *S*1 is turned on, energy is provided by capacitor C_H, i.e.,

$$\Delta Q = \Delta V_o . C_H \tag{1}$$

$$\Delta Q = I_o . (DT_s) = \frac{V_o}{R} ..(DT_s) \tag{2}$$

$$C_H = \frac{I_H DT_S}{\Delta V_o} = \frac{V_H DT_S}{R\, \Delta V_H} \tag{3}$$

2.Input Capacitor (C_L) : When S1 is turned off ,energy is provided by capacitor C_L i.e

$$C_L = \frac{I_L(1-D)T_S}{nV_L} = \frac{V_L DT_S}{R\, \Delta V_L} \tag{4}$$

3.Coupled Inductor: The Inductor value has to be calculated. This is done based on the circuit topology. The inductance at the Boundary conduction mode is

$$L_1 = \frac{(1-D)^2 D R_H T_S}{2n^2} \tag{5}$$

No. of turns $N_1 = \sqrt{\frac{L}{A_L}}$ Where A_L is permeance (6)

Let turns ratio $n = 3$

No. of windings on secondary $= 3^x N_1$ (7)

$$\frac{L_1}{N_1^2} = \frac{L_2}{N_2^2} \tag{8}$$

Inductance of secondary winding $L_2 = L_1 (\frac{N_1}{N_2})^2$ (9)

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V. FUZZY LOGIC CONTROLLER

Fig 3 shows the block diagram of the fuzzy logic controller.

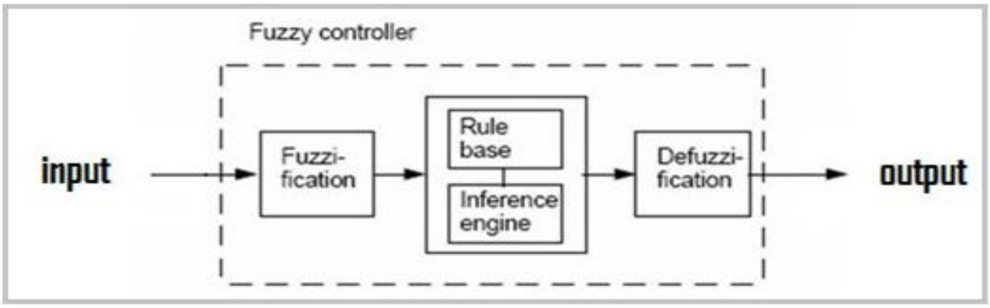

Fig 3 Block diagram of FLC

Here Mamdani type fuzzy logic scheme is used. In the proposed system there are two inputs given to the fuzzy controller, error and delta error. The inputs are converted to fuzzy sets using fuzzification module. Here for the fuzzy inference, max-min method is used. The Fuzzified output is converted into crisp value using defuzzification module. The defuzzification method used is centroid method.

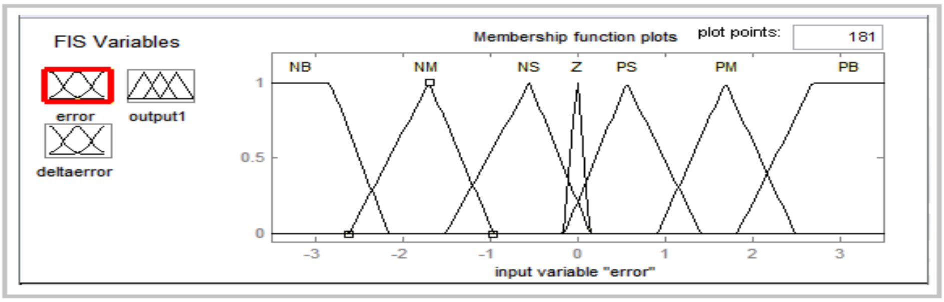

Fig 4 Plot of membership function for error

Fig 4 represents the membership function for the input variable error. Triangular type member ship function is selected. There are seven membership function for the input variable error.

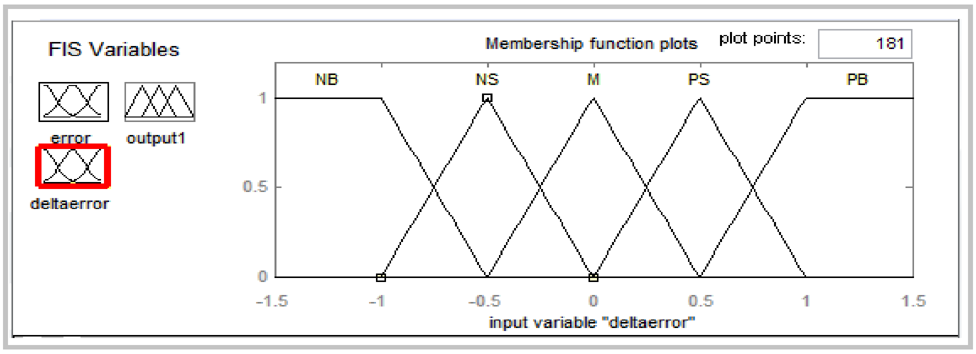

Fig 5 Plot of membership function for deltaerror

Fig 5 represents the membership function for the input variable deltaerror. Triangular type member ship function is selected. There are five membership functions for the input variable error.

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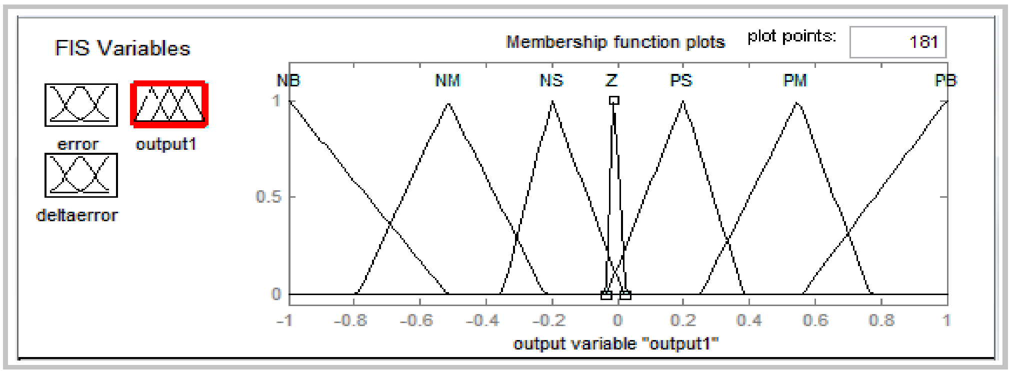

Fig 6 Plot of membership function for output

Fig 6 represents the membership function for the output variable. Triangular type member ship function is selected. There are seven membership functions for the output.

Eleven rules are used for obtaining fuzzy controlled output. They are:

Rule 1: If error is (Z) then output1 is (Z).
Rule 2: If error is (PS) then output1 is (PS).
Rule 3: If error is (PM) then output1 is (PM).
Rule 4: If error is (PB) then output1 is (PB).
Rule 5: If error is (NM) then output1 is (NM).
Rule 6: If error is (NB) then output1 is (NB).
Rule 7: If error is (NS) then output1 is (NS).
Rule 8: If error is (PS) and deltaerror is (PS) then output1 is (PS).
Rule 9: If error is (PS) and deltaerror is (PB) then output1 is (PM).
Rule 10: If error is (NS) and deltaerror is (NS) then output1 is (NS).
Rule 11: If error is (NS) and deltaerror is (NB) then output1 is (NM).

VI. RESULTS AND DISCUSSIONS

Closed loop Simulation of the Bidirectional Converter with the designed values was done in the Matlab Simulink. In order address the benefits of FLC controller, the classical proportional-Integral (PI) controller has implemented for same CI-BDC converter and compared. The simulation results were found satisfactory and as expected.

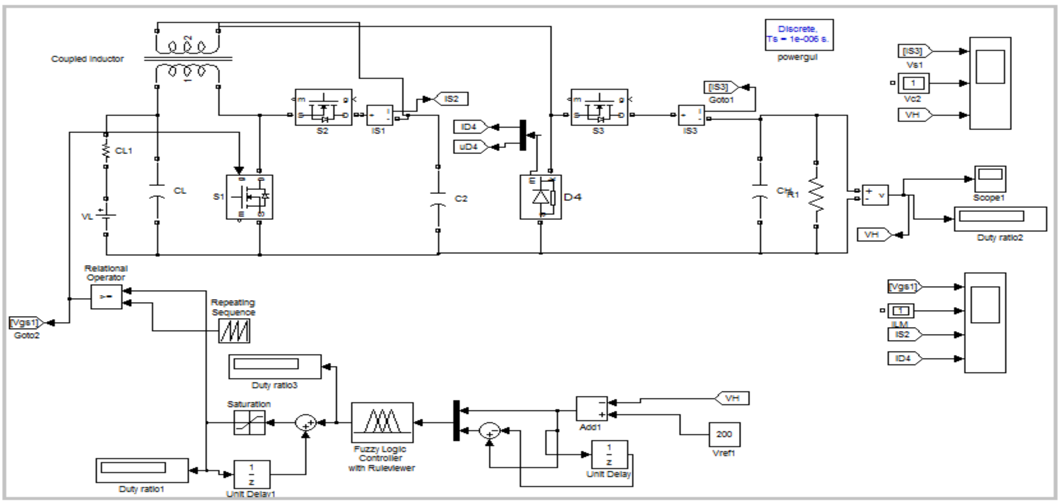

Fig 7 Simulink model of the Boost mode of DC-DC converter using fuzzy logic controller

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Fig 7 shows the Simulink model of the mode of DC-DC converter using fuzzy logic controller. The input given to the system is 24 V dc and gets a regulated output of 200V dc. The values of capacitors are C_L=220μF, C_2=C_H =300μF. Mosfet is selected as power switches. A coupled inductor of turns ratio 1:3 is used. The load is 500Ω resistance. The fuzzy logic controller with rule viewer is used for the implementation of fuzzy logic.

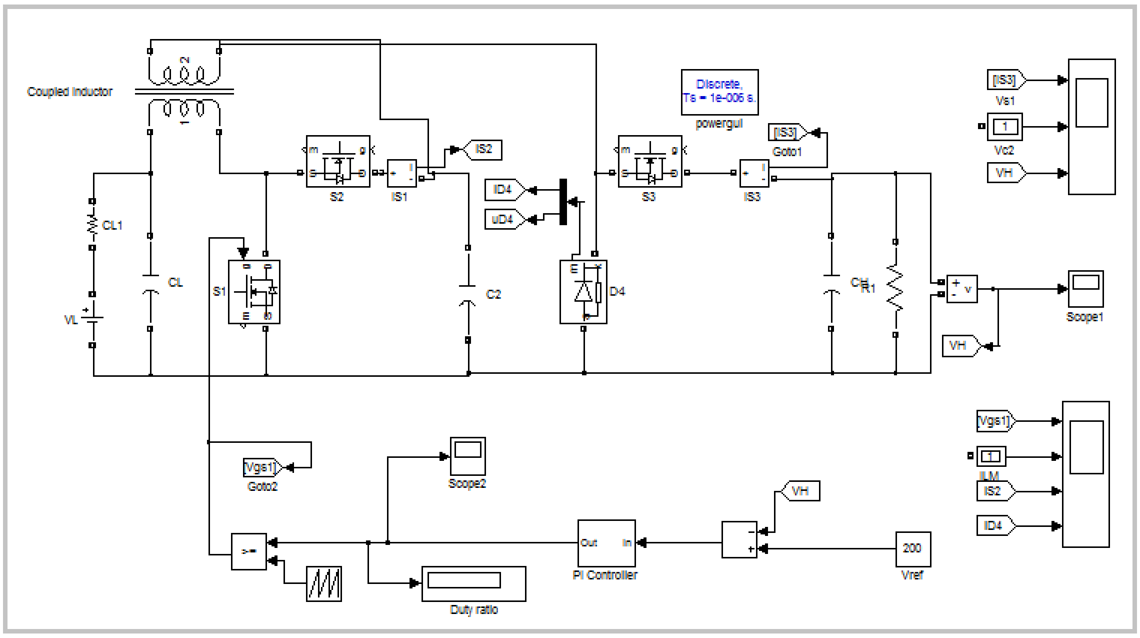

Fig 8 Simulink model of the Boost mode of DC-DC converter using PI controller

Fig 8 shows the simulink model of the proposed converter using PI controller under the same conditions of the fuzzy controlled converter. The input voltage given is 24V and obtain 200V as output with duty ratio of 0.6 and a switching frequency of 50kHz.

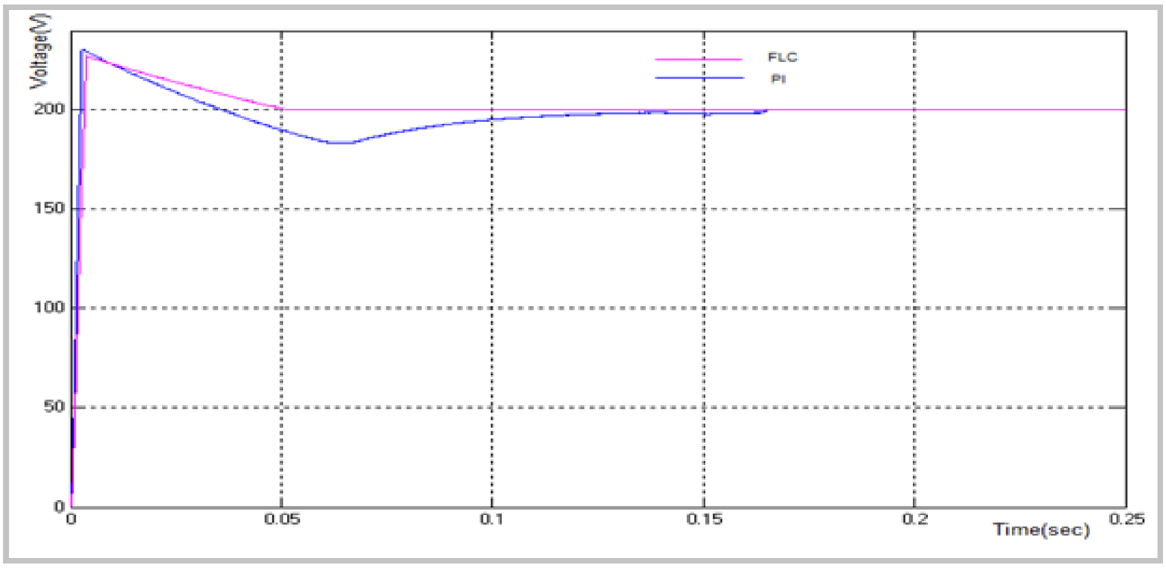

Fig 9 Output voltage waveform of the converter using FLC and PI Controller

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Fig 9 shows the comparison of the output voltage waveform of the converter using Fuzzy logic controller and conventional PI controller. From this waveform it can be seen that ripples are free in the case of FLC and there are large ripples in PI controller. The settling time of the output voltage is 0.05 sec for FLC and in the case of PI controller this is about 0.16 sec. The peak overshoot is greater in the case of PI than FLC.

VII. CONCLUSION

The discharging mode of the fuzzy controlled bidirectional converter with high voltage conversion ratio is presented in this paper .Using fuzzy logic control, an improved steady state and transient response is obtained. With the help of simulation result, a comparison of the output voltage using PI and FLC are done .Fuzzy logic is designed using Mamdani model. It is easy to design a FLC system with requisite knowledge and also it is a model free system .Due to the presence of coupled inductor a high voltage conversion ratio, about 8.33 is achieved.

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