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A New Topology for Buck-Boost Converter Using Fuzzy Logic Control

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Abstract: Two switch Buck-boost converter is a dc-dc converter provides an output voltage that may be less than or greater than the input voltage. The output voltage polarity is same as that of the input voltage polarity. Hence it can also be known as non-inverting regulator. This output voltage is controlled by tuning the gate pulses given to the switches. The basic conventional Two switch buck boost converter is modified by connecting the sources of two switches to common ground. This paper deals with the open loop analysis and the closed loop analysis using Fuzzy Logic control of the modified Two switch Buck boost converter and the results are compared.

Keywords: Conventional Two switch Buck boost converter, Modified Two switch Buck boost converter, open loop, Fuzzy Logic control

I. INTRODUCTION

In many industrial applications, renewable power generation, it is required to convert a fixed DC voltage to variable DC voltage. A DC-DC converter converts directly from dc to dc. Like a transformer, it can be used to step down or step up the DC voltage source. DC converters widely used in automobiles for traction motor control, trolley cars, marine hoists, regenerative braking of DC motors. The Two switch Buck boost converter takes the voltage from a DC source and converts into another DC voltage level. The converter is used to buck or boost the voltage level. In this paper, the input dc voltage 36V or 72V is converted to 48V i.e., the input voltage 36V is converted to 48V in boost and buck boost(step up) modes; the input voltage 72V is converted to 48V in buck and buck boost(step down) modes. The basic conventional buck-boost converter circuit is shown in Fig.1.The values of L and C are 250uH and 820uF taken respectively [1]

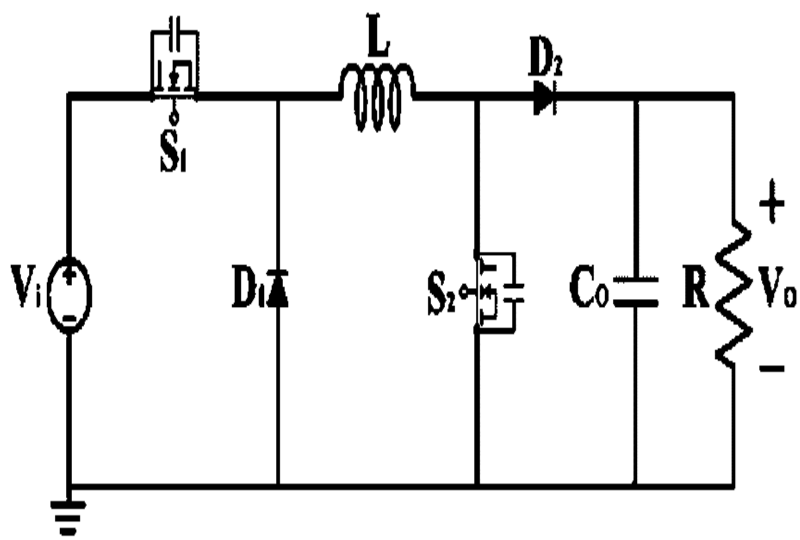

Fig.1. Conventional Two Switch Buck Boost Converter

Conventional two switch buck boost converter operates in 3 modes namely: buck mode, boost mode, buck boost mode. In buck mode, S1 switch is on and S2 switch is off. In boost mode, S1 switch is always on and S2 is switching i.e., during first interval, S1 and S2 are on; next interval the load is supplied with S1 and D2. In buck boost mode, both switches are simultaneously switching [4]. This modes are tabulated in Table1 [1]

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Table1. Modes of operation of Conventional Two Switch Buck Boost Converter

Operating Mode	Sub-interval I	Sub-interval II	Switching components	Control Scheme
Buck	S1,D1	D1,D2	S1,D1	S1: switching S2:off
Boost	S1,S2	S1,D2	S2,D2	S1:on S2:switching
Buck-Boost	S1,S2	D1,D2	S1,S2,D1,D2	S1:switching(simultaneously with S2) S2:switching(simultaneously with S1)

A. Buck mode

As shown in Table.1. Control scheme referred to buck mode, S1 is switching and S2 is off. The same is done in the below Fig.2 buck mode. The switch S1 is given pulse and S2 is kept off by giving 0 value to it. The input DC voltage 72V is converted to dc output voltage 48V using buck mode and is shown in Fig.3

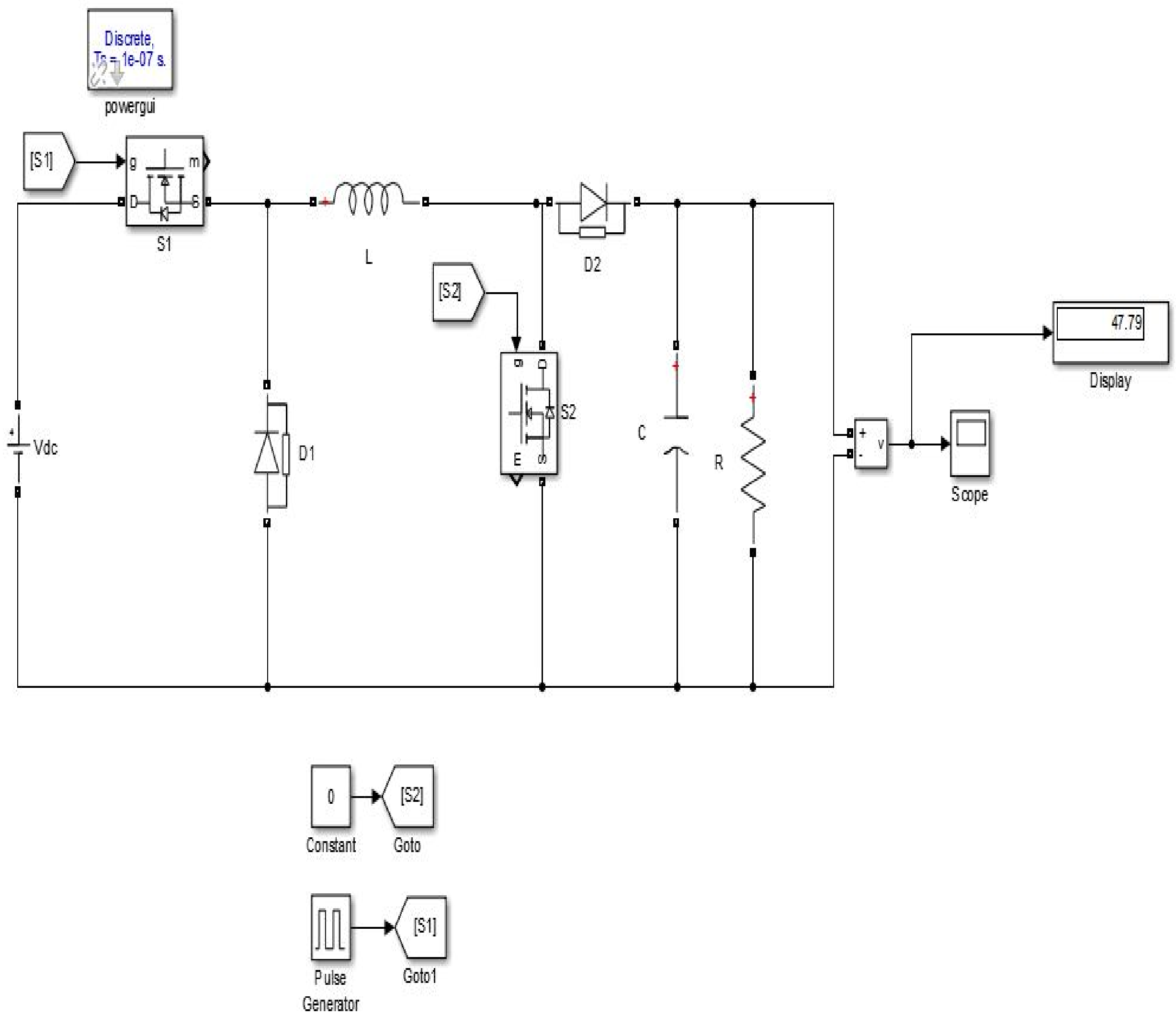

Fig.2. Conventional Two switch buck boost converter operating in Buck mode

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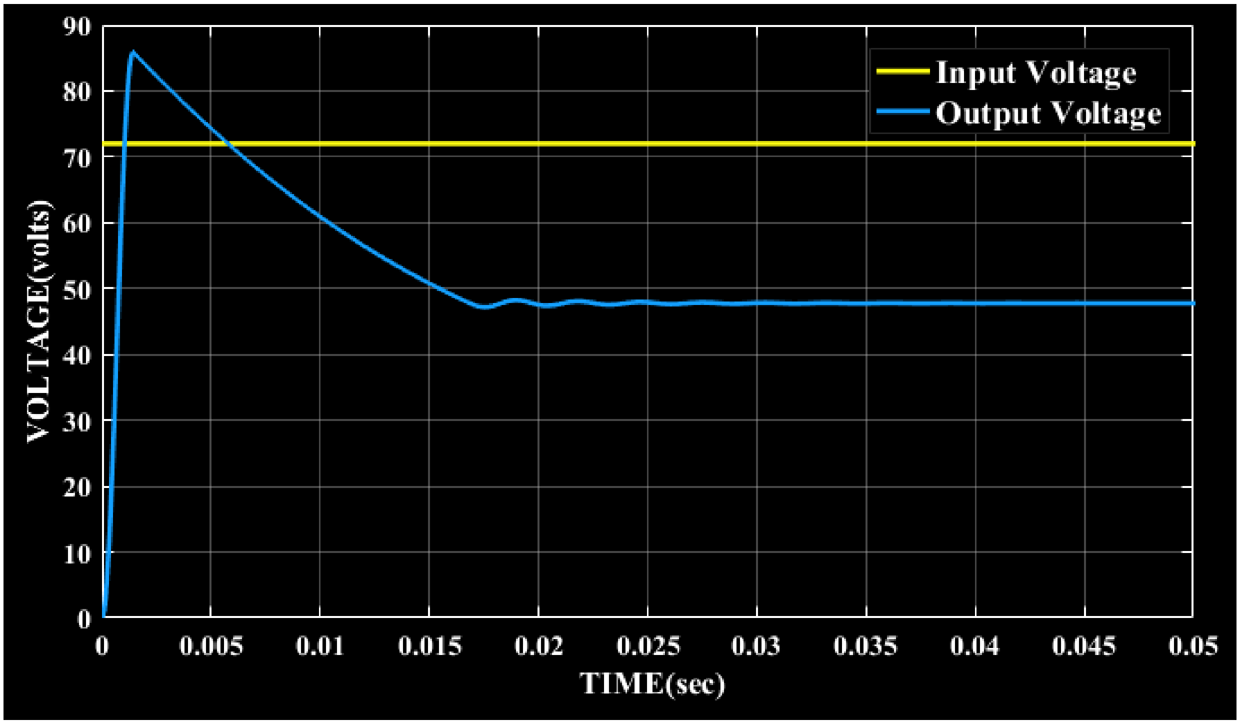

Fig.3. Input voltage and Output voltage waveform

B. Boost mode

As shown in Table.1. Control scheme referred to boost mode, S1 is on and S2 is switching. The same is done in the below Fig.4 boost mode. The switch S1 is 1 value to make S1 always on and S2 is given pulse to make S2 in switching. The input DC voltage 36V is converted to dc output voltage 48V using boost mode. The input and output voltage waveforms are shown in Fig.5.

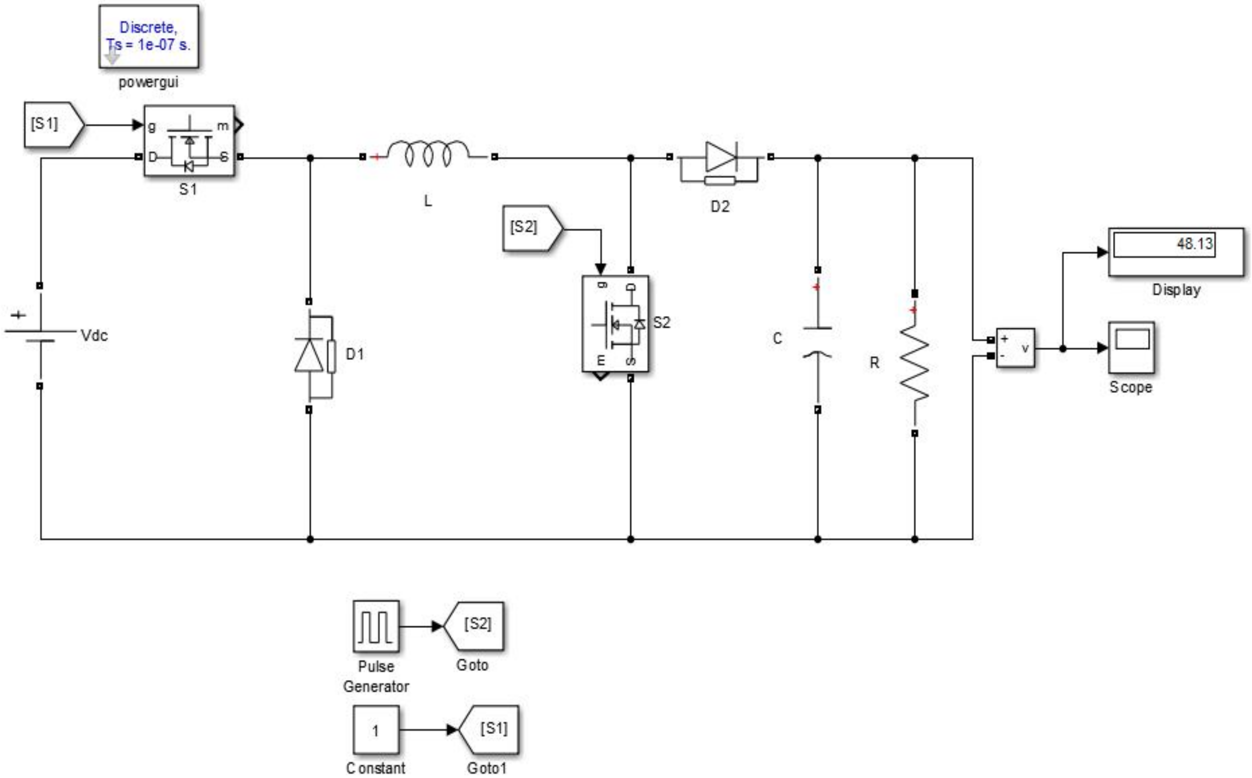

Fig.4. Conventional Two switch buck boost converter operating in Boost mode

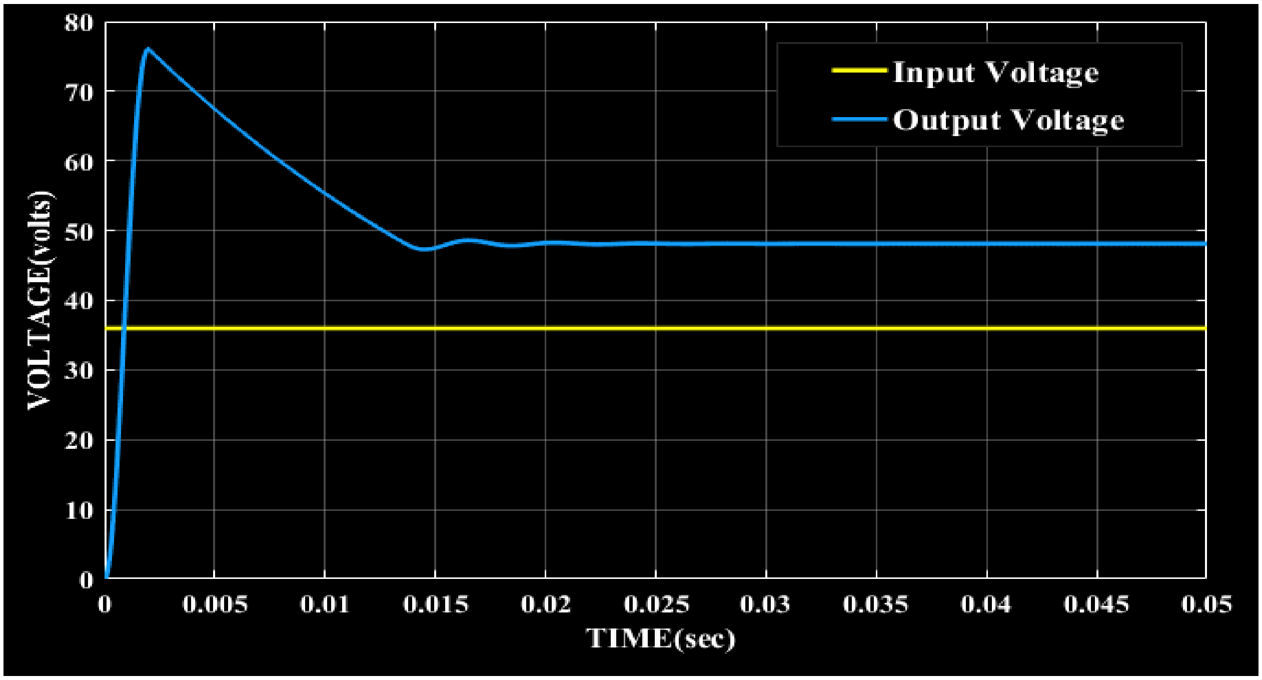

Fig.5. Input voltage and Output voltage waveform

C. Buck Boost Mode

As shown in Table.1. Control scheme referred to buck boost mode, S1 and S2 are switching. The same is done in the below Fig.6 buck boost mode. The switches S1 and S2 switching simultaneously in this mode. The input DC voltage is converted to dc output voltage 48V in this mode. The input and output voltage waveforms are shown in Fig.7.

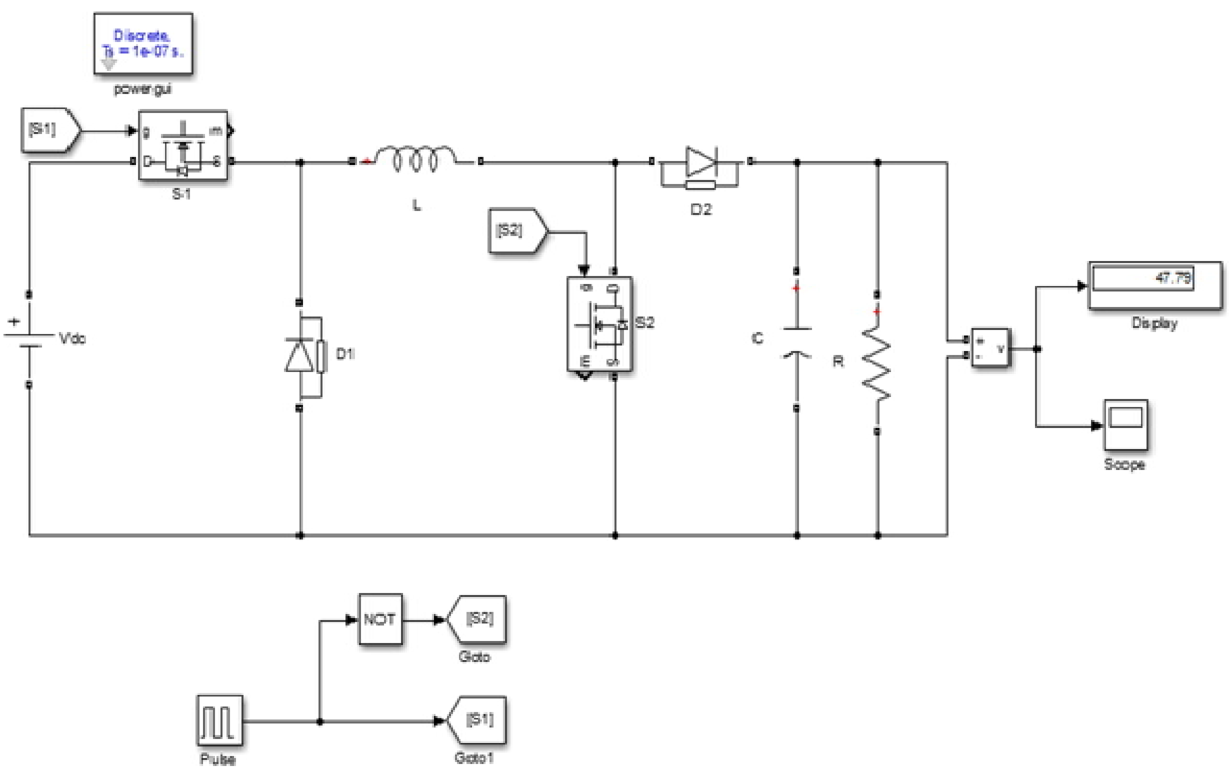

Fig.6. Conventional Two switch buck boost converter operating in Buck-Boost mode

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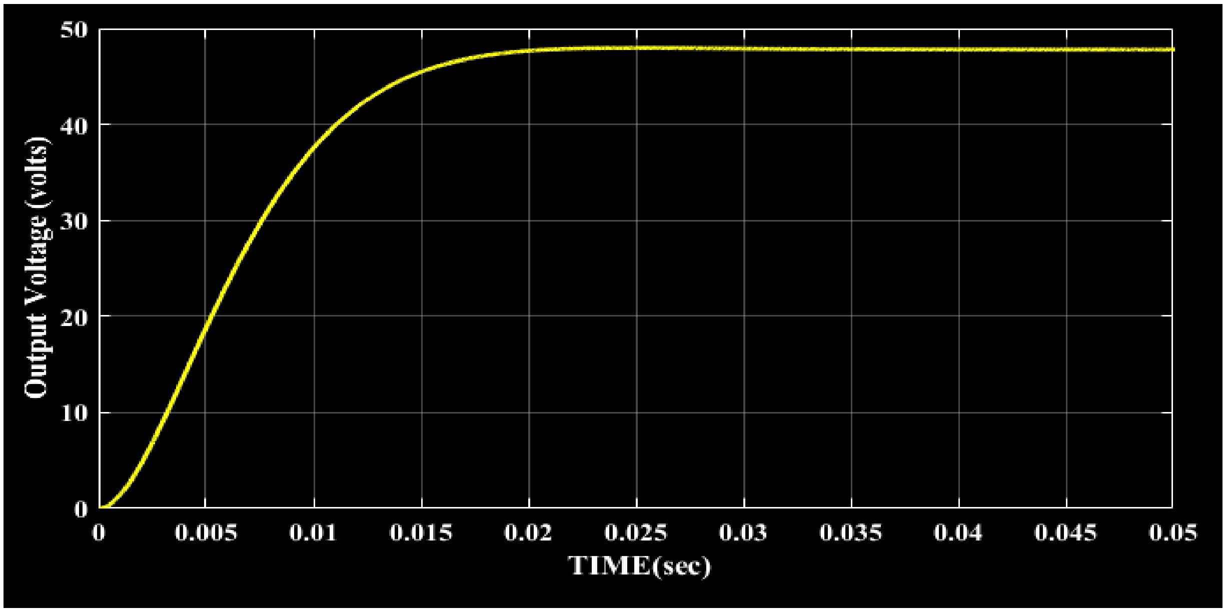

Fig.7. Input voltage and Output voltage waveform

II. FUZZY LOGIC CONTROLLER

Fuzzy logic controller with two inputs and one output has chosen in this paper. The output voltage Vo obtained from the two switch buck boost converter is compared with the reference voltage Vref. The difference between these two values i.e., error is taken as input1 and the change in error (derivative of error) is taken as input2 as shown in fig 8. The matlab equivalent Fuzzy logic designer is shown in fig.9.

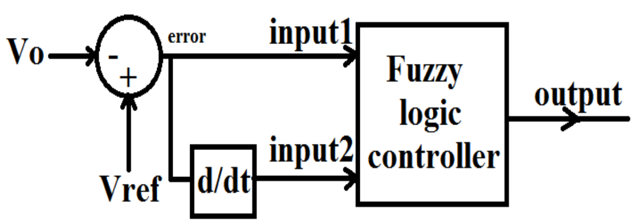

Fig.8.Concept of Fuzzy logic controller

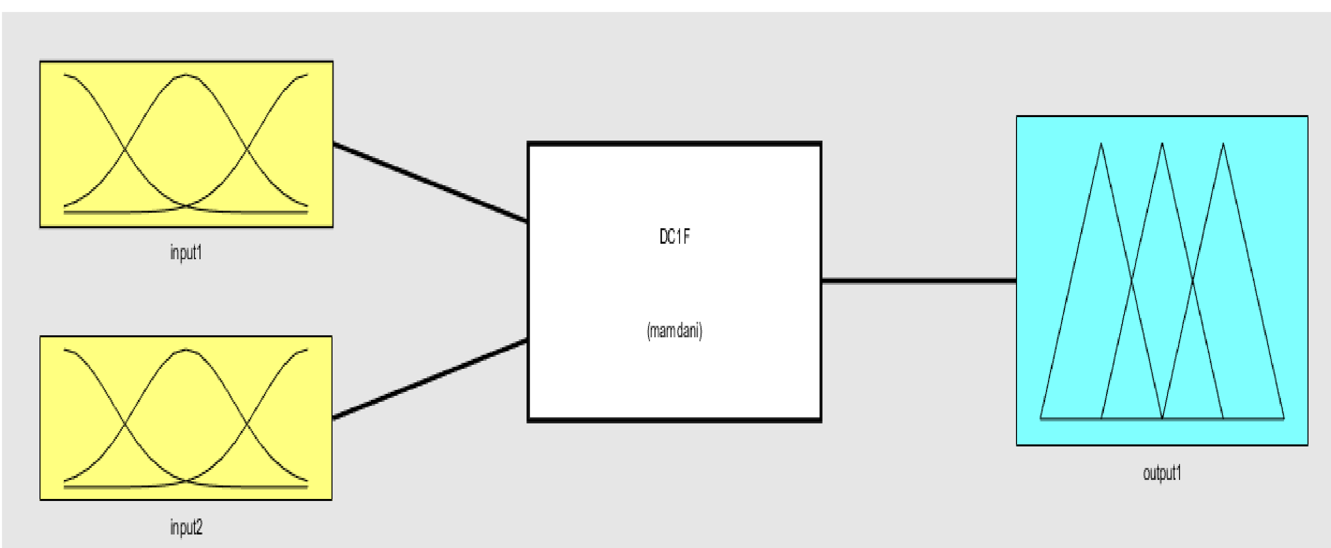

Fig 9 Fuzzy Logic designer

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Here, the fuzzy logic controller performs 3 functions: Fuzzification, mamdani fuzzy inference system, De-fuzzification [2]. Fuzzification is process of changing a precise value to a fuzzy value. This is achieved with the different types of fuzzifiers or membership functions. The membership functions used in this are: Negative Big (NB), Negative Small(NS), Zero (ZE), Positive Small (PS), Positive Big (PB).The input1(error) has 5 membership functions i.e., NB, NS, ZE, PS, PB as shown in fig.10. The input2 (derivative of error) has 5 membership functions i.e., NB, NS, ZE, PS, PB by fuzzification as shown in fig.11. These two inputs are given to Fuzzy logic controller. The output block also taken 5 membership functions NB, NS, ZE, PS, and PB as shown in Fig.12.

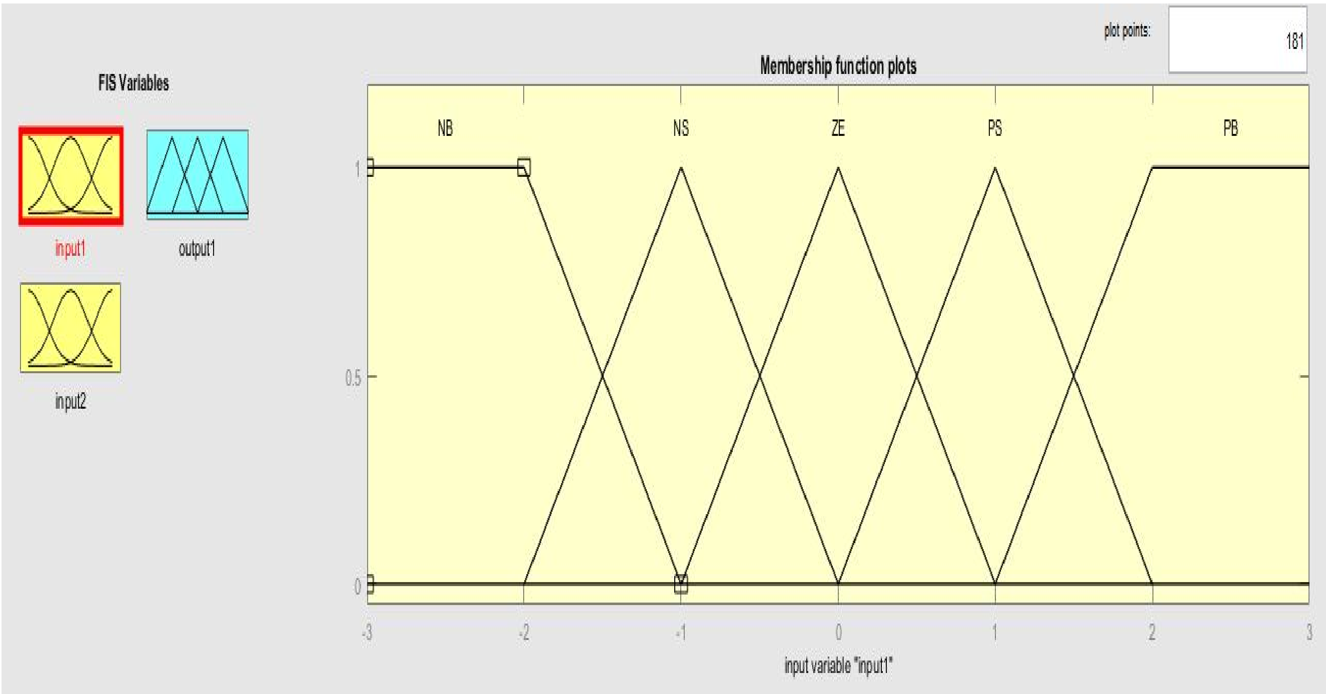

Fig.10. Input1 with 5 membership functions

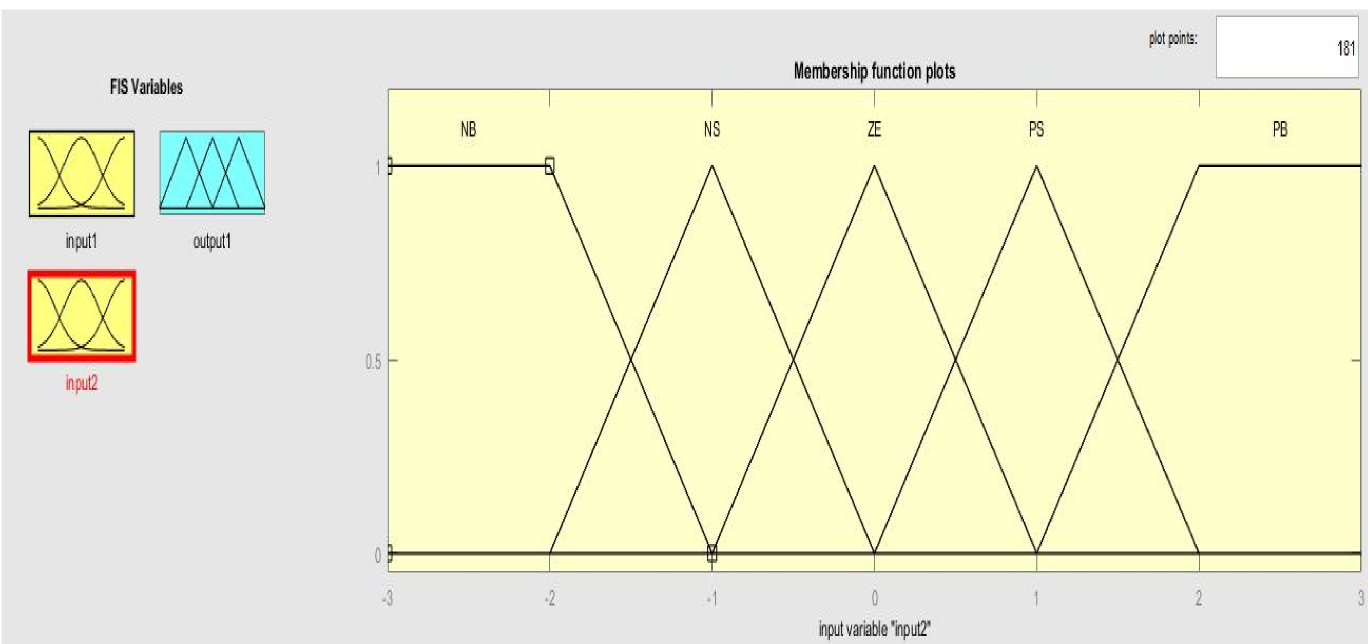

Fig.11. Input2 with 5 membership functions

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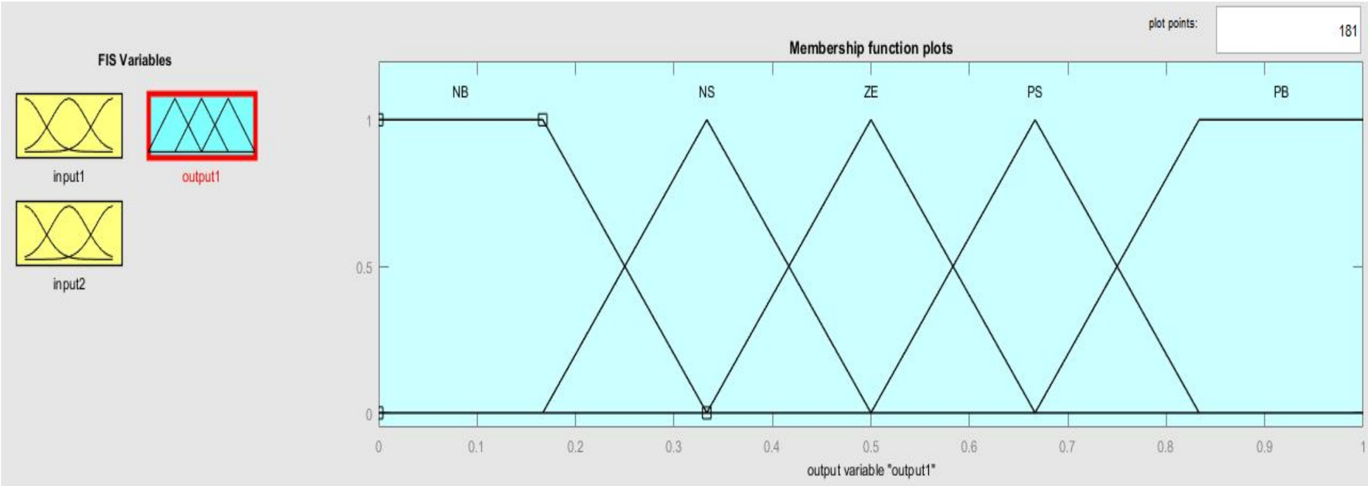

Fig.12. Output with 5 membership functions

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. Mamdani Fuzzy inference is a method that interprets the values in the input and based on some set of rules, assigns values to the output [3]. The process of fuzzy inference involves Membership Functions, Logical Operations, and If-Then Rules. Fuzzy logic maps inputs to an output with a list of if-then statements called fuzzy rules. The fuzzy rules used in this paper are shown in Table.2. All rules are evaluated in parallel and the order of the rules is not important. Thus fuzzified inputs based on the Fuzzy rules i.e., If-Then rules; assigns some output values. Then de-fuzzification is done by centroid method to assign a fine value at the output of Fuzzy logic controller.

Table 2 Fuzzy rules

input2 \ input1	NB	NS	ZE	PS	PB
NB	NB	NB	NB	NS	ZE
NS	NB	NB	NS	ZE	PS
ZE	NB	NS	ZE	PS	PB
PS	NS	ZE	PS	PB	PB
PB	ZE	PS	PB	PB	PB

III.MODIFIED TWO SWITCH BUCK BOOST CONVERTER

The modified topology for the conventional two switch buck boost converter also consists of same number of components: two switches: S1, S2; one inductor L=250uH; one capacitor C=820uF. In this, the sources of two mosfet switches are grounded to the same ground as shown in Fig.13. This reduces conduction losses and switching losses. The modified topology has decreased power loss compared to the conventional [1]. The modified converter also operates in buck mode, boost mode, buck boost (step up) and buck boost (step down) modes. The converter is used to buck or boost the voltage level. In this paper, the input dc voltage 36V or 72V is converted to 48V i.e., the input voltage 36V is converted to 48V in boost and buck boost(step up) modes; the input voltage 72V is converted to 48V in buck and buck boost(step down) modes.

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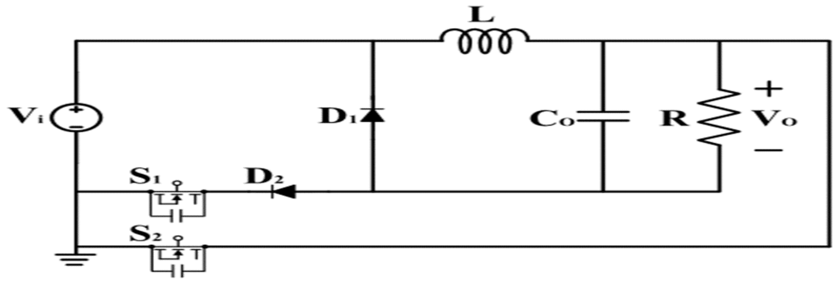

Fig.13.Modified Two Switch Buck Boost Converter

Modified two switch buck boost converter operates in 3 modes namely: buck mode, boost mode, buck boost mode. In buck mode, S1 switch is switching and S2 switch is off. In sub-interval I, when S1 is on, D2 is forward biased and L builds up current. In sub interval II, S1 and S2 are off, inductor current starts conducting through D1 (D1 is forward biased). In boost mode, S1 switch is always on and S2 is switching [1]. In buck boost mode, S1 switch is off and switch S2 is switching [1]. This modes are tabulated in Table 3.

Table.3. Modes of operation of Modified Two Switch Buck Boost Converter

Operating Mode	**Sub-interval I**	**Sub-interval II**	**Switching components**	**Control scheme**
Buck	S1,D2	D1	S1,D1,D2	S1: switching S2:off
Boost	S2	S1,D2	S2,D2	S1:on S2:switching
Buck-Boost	S2	D1	S2,D1	S1:off S2:switching

IV. OPEN LOOP ANALYSIS OF MODIFIED TWO SWITCH BUCK BOOST CONVERTER

A. Buck Mode

As shown in Table.3. Control scheme referred to buck mode, S1 is switching and S2 is off. The same is done in the below Fig.14 buck mode. The switch S1 is given pulse and S2 is kept off by giving ‘0’ value to it. The input DC voltage 72V is converted to dc output voltage 48V using buck mode and is shown in Fig.15.

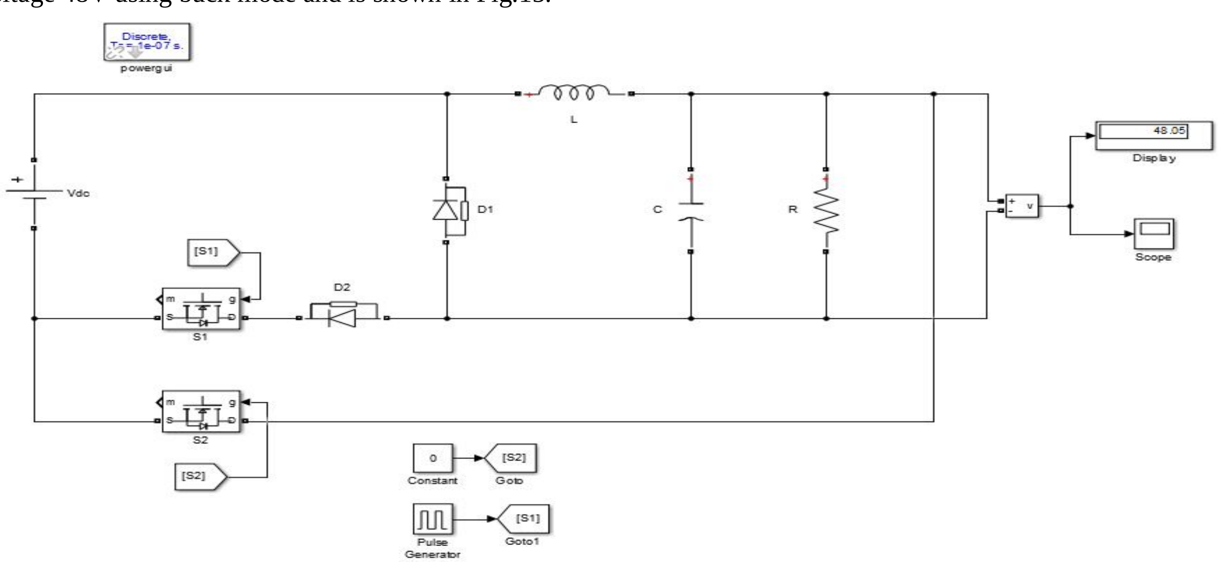

Fig 14 Modified Two switch buck boost converter operating in Buck mode

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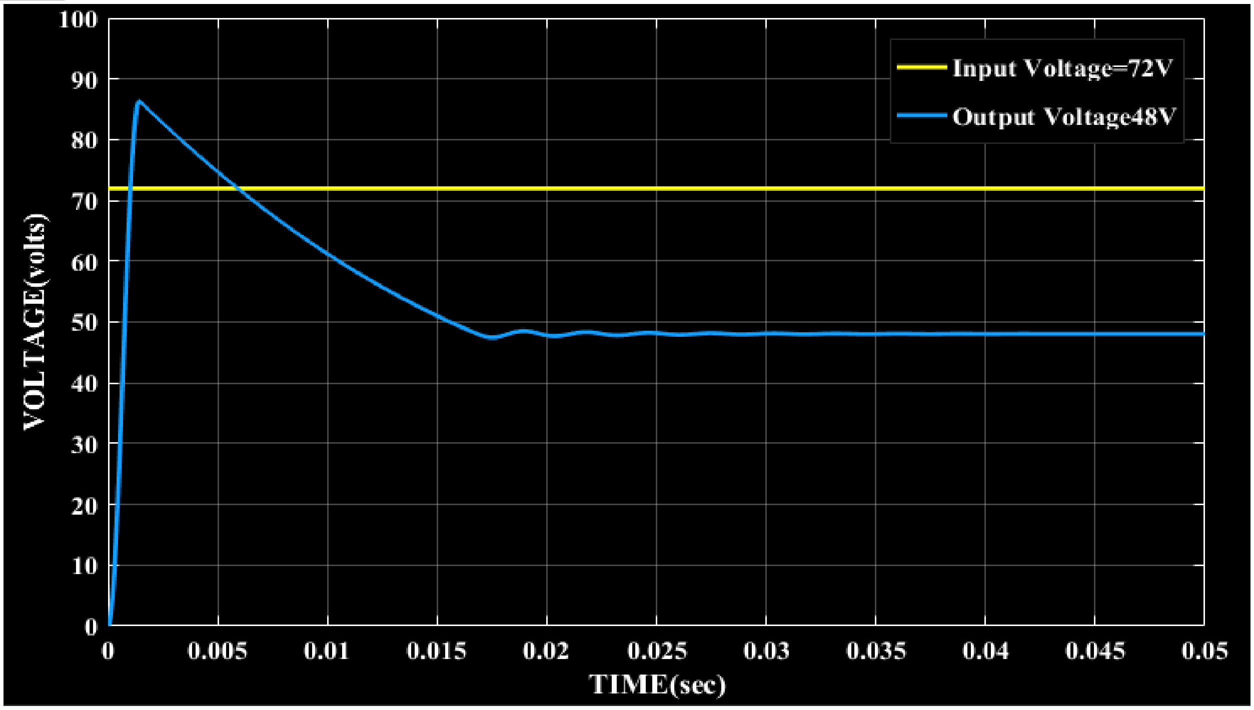

Fig 15. Input voltage and Output voltage waveform

B. Boost Mode

As shown in Table.2. Control scheme referred to boost mode, S1 is on and S2 is switching. The switch S1 is given '1' to keep it continuously on and S2 is given pulse is as shown in Fig.16. The input DC voltage 36V is converted to dc output voltage 48V using buck mode and is shown in Fig.17.

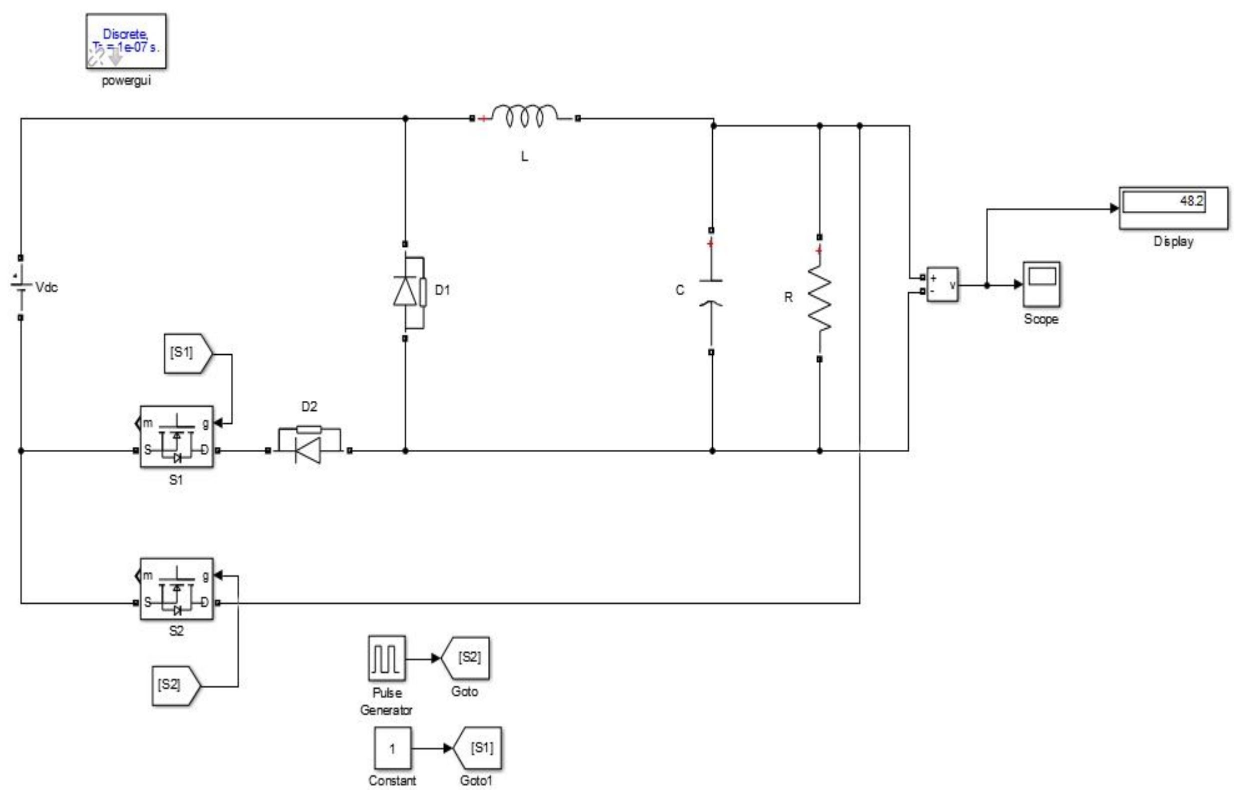

Fig 16. Modified Two switch buck boost converter operating in Boost mode

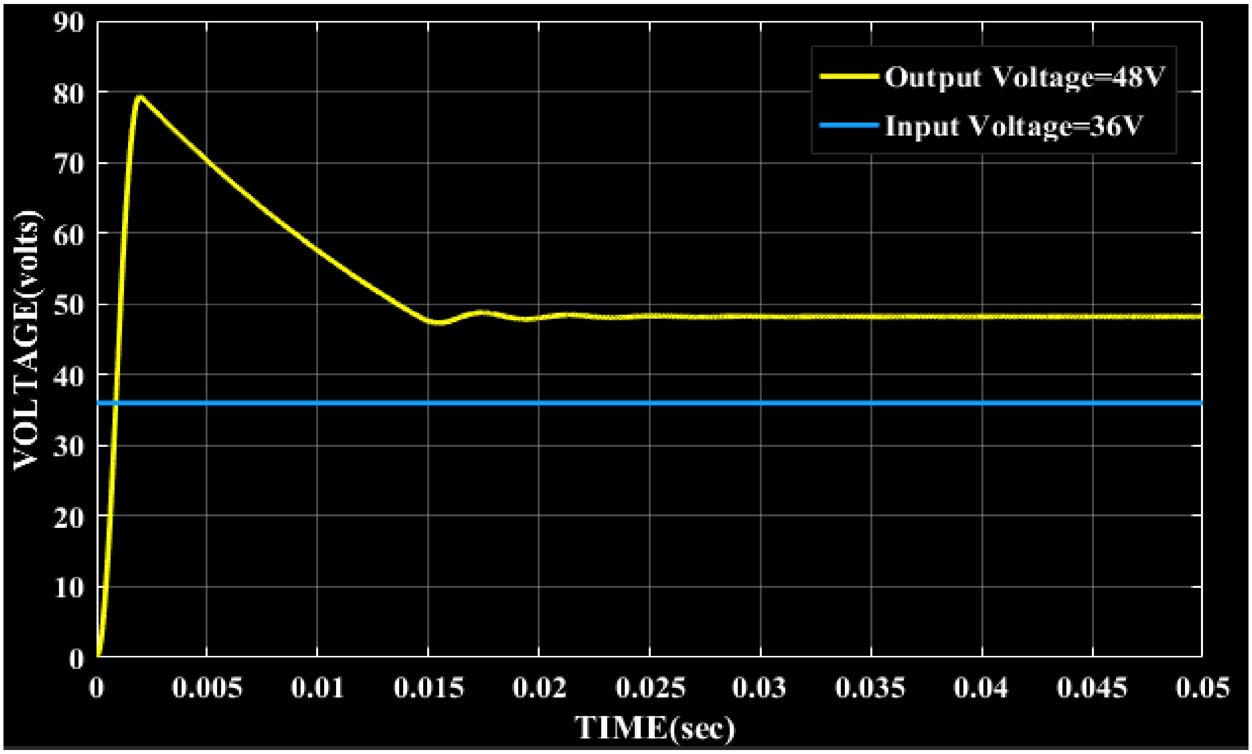

Fig 17. Input voltage and Output voltage waveform

C. *Buck-Boost (Step UP) Mode*

As shown in Table.2. Control scheme referred to buck boost mode, S1 is off and S2 is switching. The switch S2 is given pulse and S1 is kept off by giving ‘0’ value to it as shown in Fig.18. The input DC voltage 36V is converted to dc output voltage 48V using buck boost (step up) mode and its corresponding voltages are shown in Fig.19.

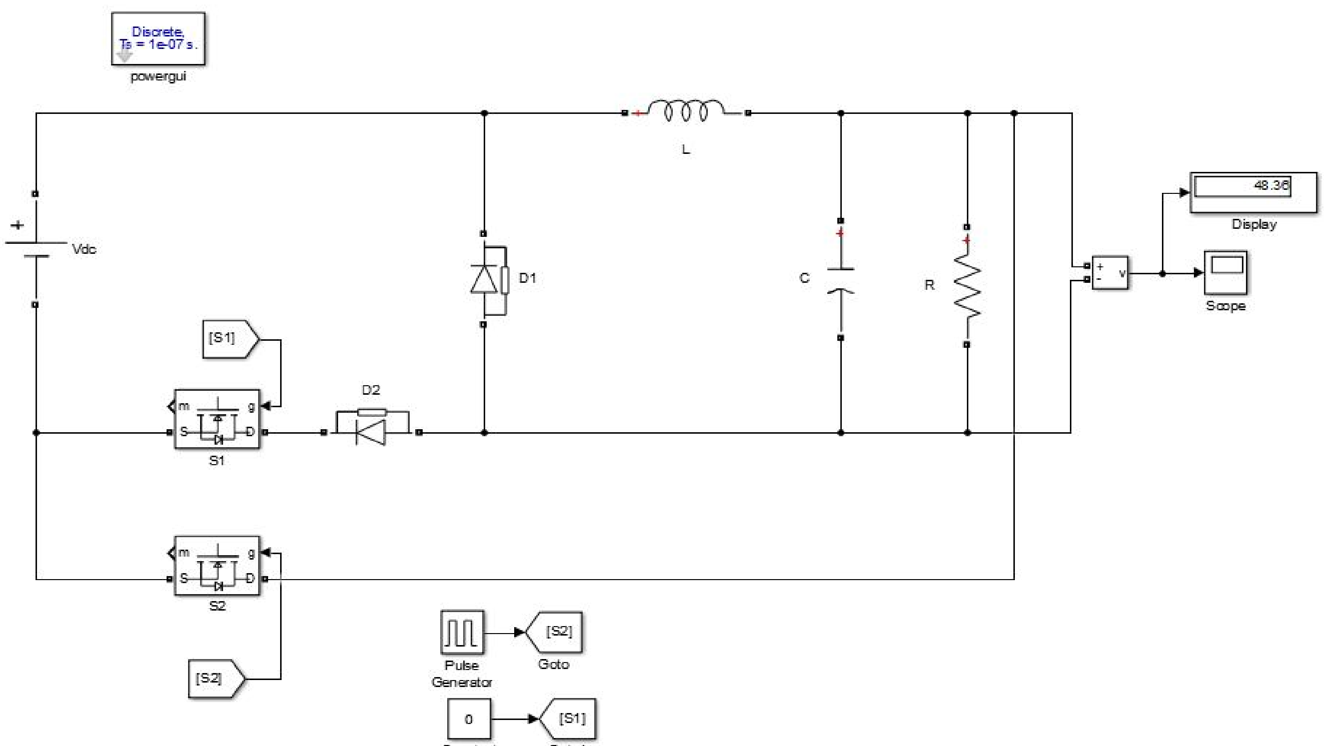

Fig 18. Modified Two switch buck boost converter operating in Buck-Boost (step up) mode

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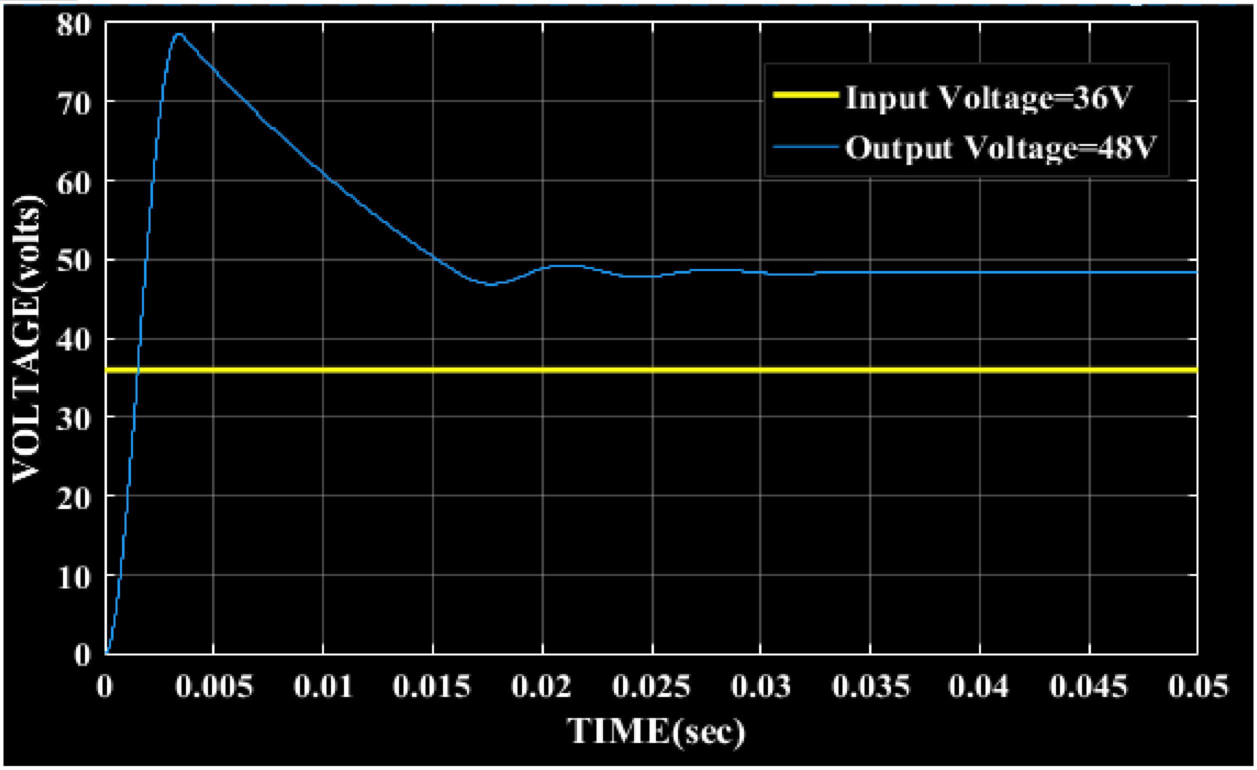

Fig 19 Input voltage and Output voltage waveform

D. Buck-Boost (Step Down) Mode

As shown in Table.2. Control scheme referred to buck boost mode, S1 is off and S2 is switching. The switch S2 is given pulse and S1 is kept off by giving 0 value to it as shown in Fig.20.The input DC voltage 72V is stepped down to dc output voltage 48V using buck mode and the corresponding waveforms are shown in Fig.21.

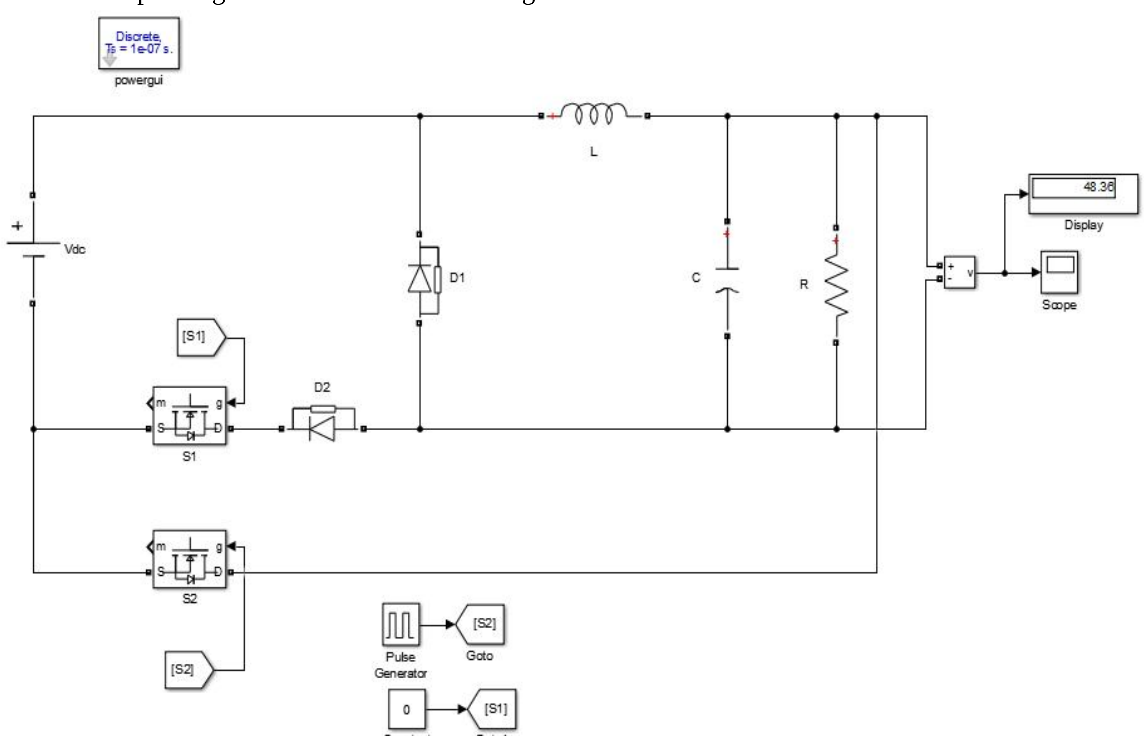

Fig 20 Modified Two switch buck boost converter operating in Buck-Boost (step down) mode

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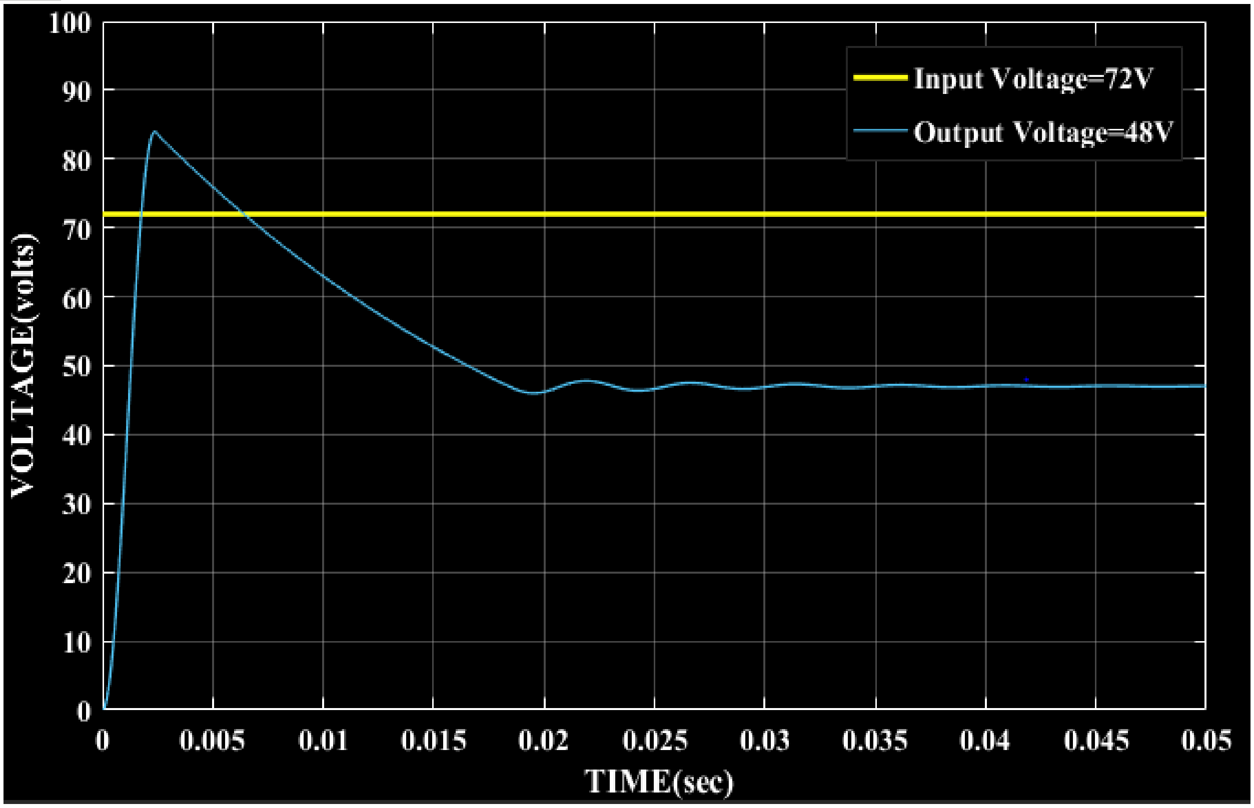

Fig 21 Input voltage and Output voltage waveform

V. MODIFIED TWO SWITCH BUCK BOOST CONVERTER WITH FUZZY LOGIC CONTROLLER

In this paper, the concept of converting input DC voltage (36V or 72V) to a DC output voltage of 48V [1] using Fuzzy logic controller is shown in Fig 22. Here, 48V is taken as reference voltage. The output voltage Vo from the Modified Two switch Buck Boost converter (TSBB) is compared with the Reference voltage Vref=48V and the difference between these two values is considered as error 'e' i.e., error e=Vo~Vref. This error and the change in error de/dt are given as input1 and input 2 respectively to III. Fuzzy logic controller. The available output from the controller is processed through PWM technique. The PWM compares the de-fuzzified output with a repeating sequence and generates the PWM signals. This signals or pulses are given to S1 and S2 switches of Modified TSBB.

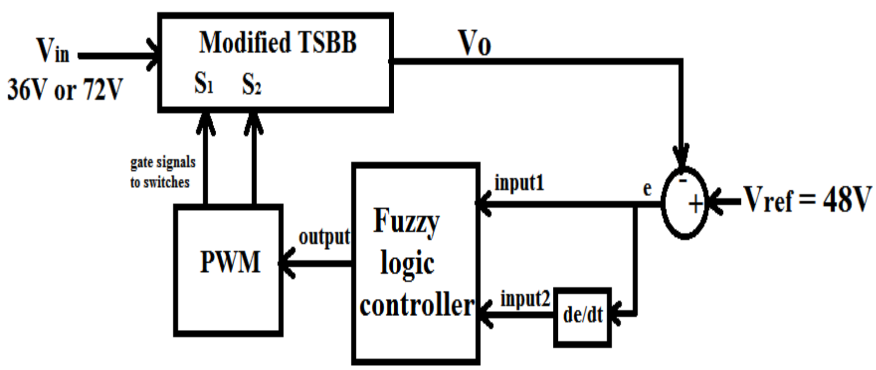

Fig 22. Concept of Fuzzy Logic controller for Modified TSBB

The Modified Two Switch Buck Boost converter operates: Buck mode, Boost mode, Buck-Boost (step up) mode and Buck-Boost (step down) mode depending on the gating pulses given to the switches of the converter. The sequence of the pulses to the switches is as shown in Table 4. Below.

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Table 4 Control Scheme for Modified TSBB

MODE	CONTROL SCHEME
Buck	S1: switching S2:off
Boost	S1:on S2:switching
Buck-Boost	S1:off S2:switching

1) *Buck mode*, the switch S1 is turned ON by giving gating pulse and the switch S2 is made OFF or not conducting by giving '0' pulse to it as shown in Fig 23. In this mode, the input voltage is 72V. The output voltage 48V is obtained using Fuzzy logic controller and corresponding Input, Reference and Output voltages are shown in Fig 24.
2) *Boost mode*, the switch S1 is always ON by giving a constant value '1' and the switch S2 is given pulses by Fuzzy logic controller as shown in Fig 25. The input 36V is converted to 48V in this mode. The corresponding Input, Reference and Output voltages are shown in Fig 26
3) *Buck-Boost (step up) mode*, the switch S1 is not conducting, hence a constant '0' value is assigned to it. The switch S2 is switching i.e., gating pulse is given to S2 by Fuzzy logic controller as shown in Fig 27. The input voltage of 36V is stepped up to an output voltage of 48V. The corresponding waveforms of Input voltage, Reference voltage and Output voltage are shown in Fig 28.
4) *Buck-Boost (step down) mode*, the input voltage 72V is stepped down to an output voltage of 48V. The switch S1 is given '0' constant since S1 to be in OFF. S2 is conducting by giving pulse via Fuzzy logic controller as shown in Fig 29. The corresponding Input voltage, Reference voltage and Output voltage waveforms are shown in Fig 30.

A. Buck Mode

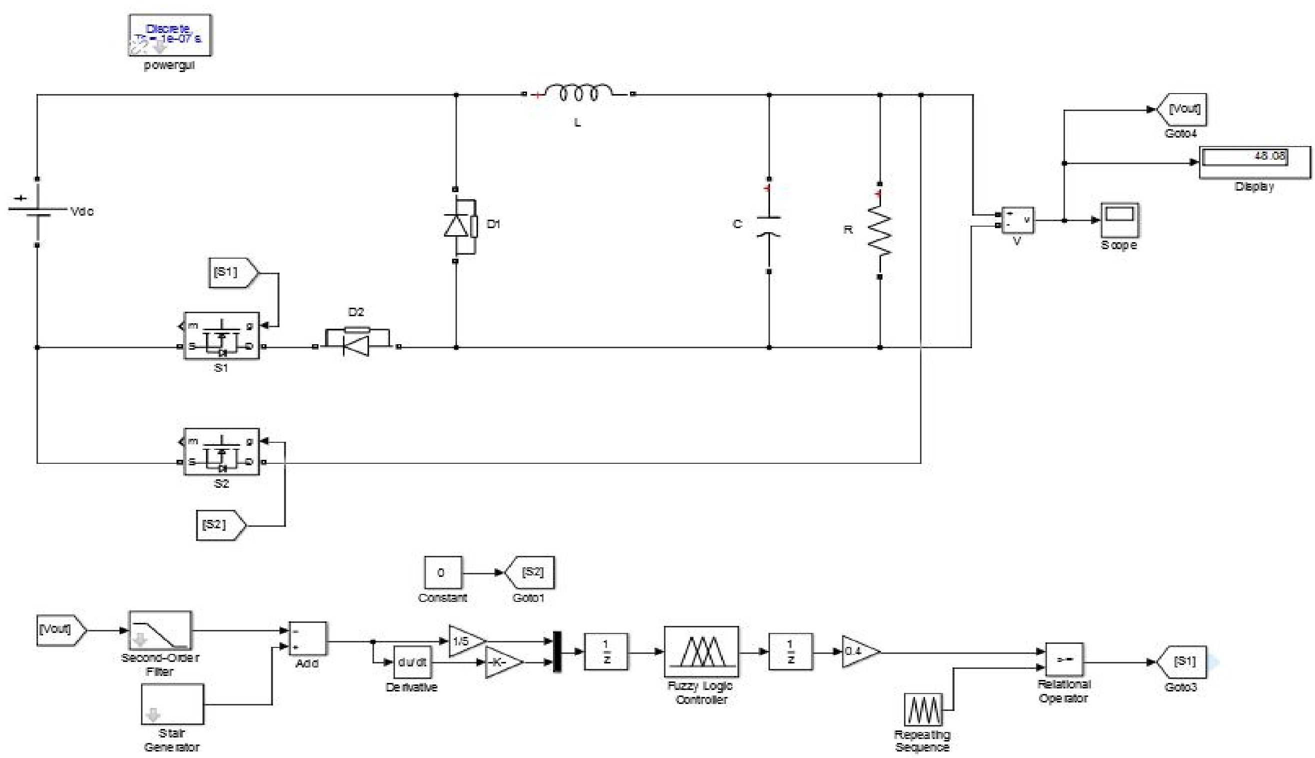

Fig 23. Modified Two switch buck boost converter operating in Buck mode

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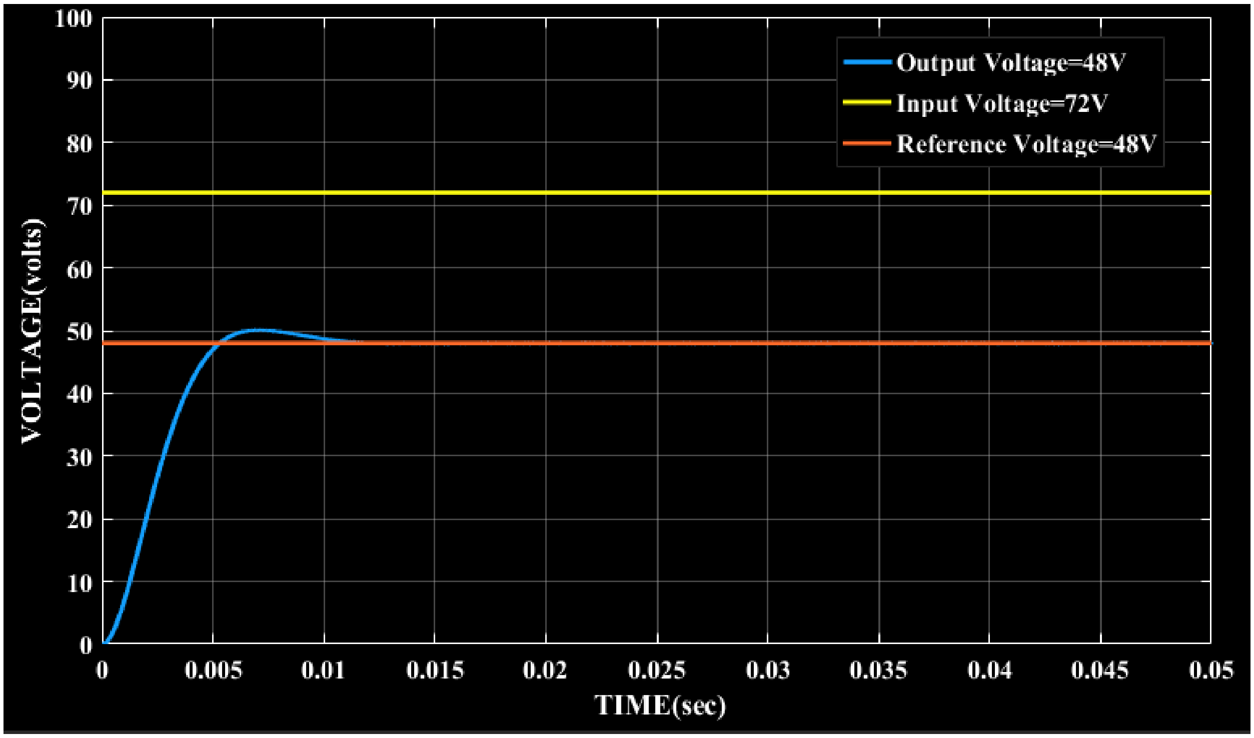

Fig 24 Input voltage, Reference voltage and Output voltage waveform

B. Boost Mode

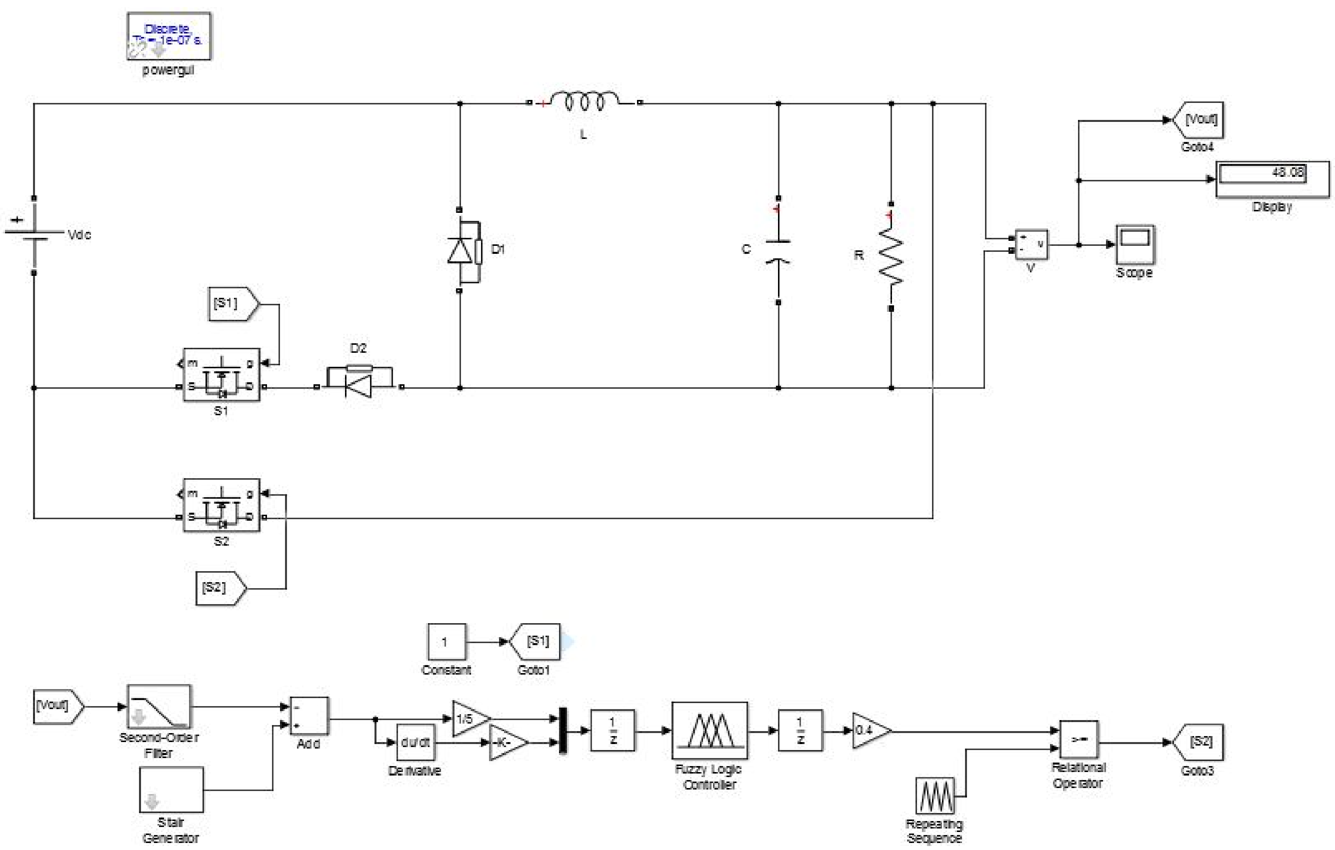

Fig 25 Modified Two switch buck boost converter operating in Boost mode

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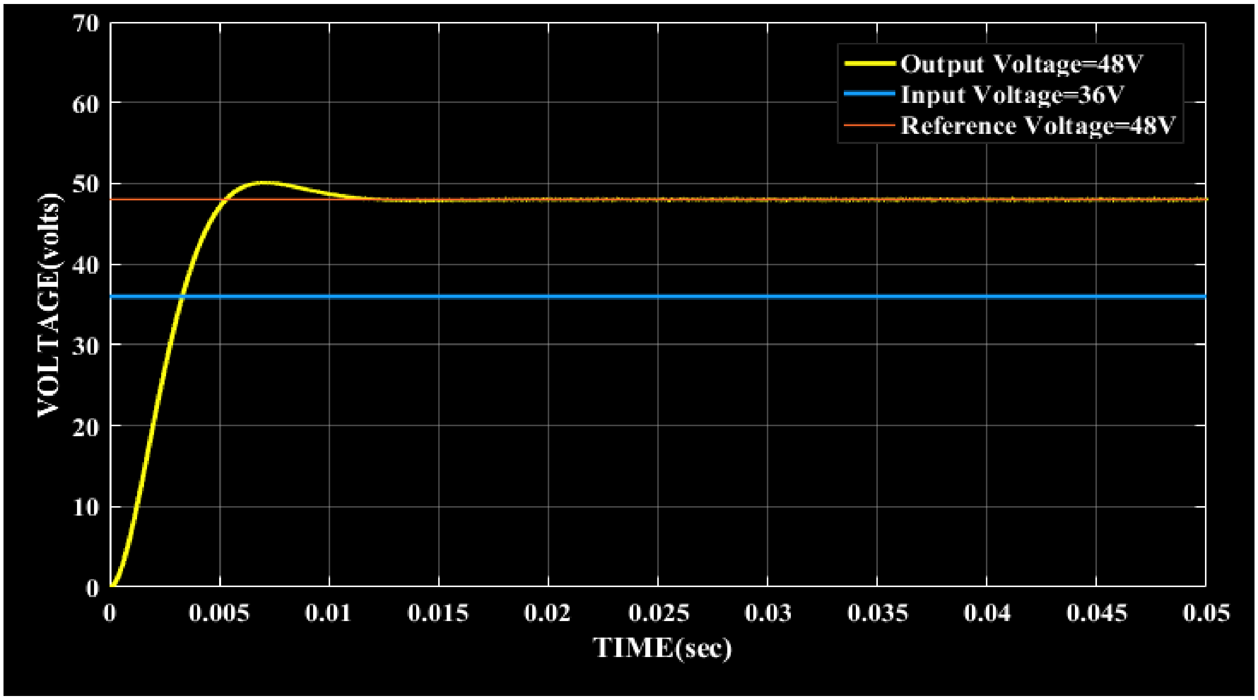

Fig 26 Input voltage, Reference voltage and Output voltage waveform

C. Buck-Boost(Step Up) Mode

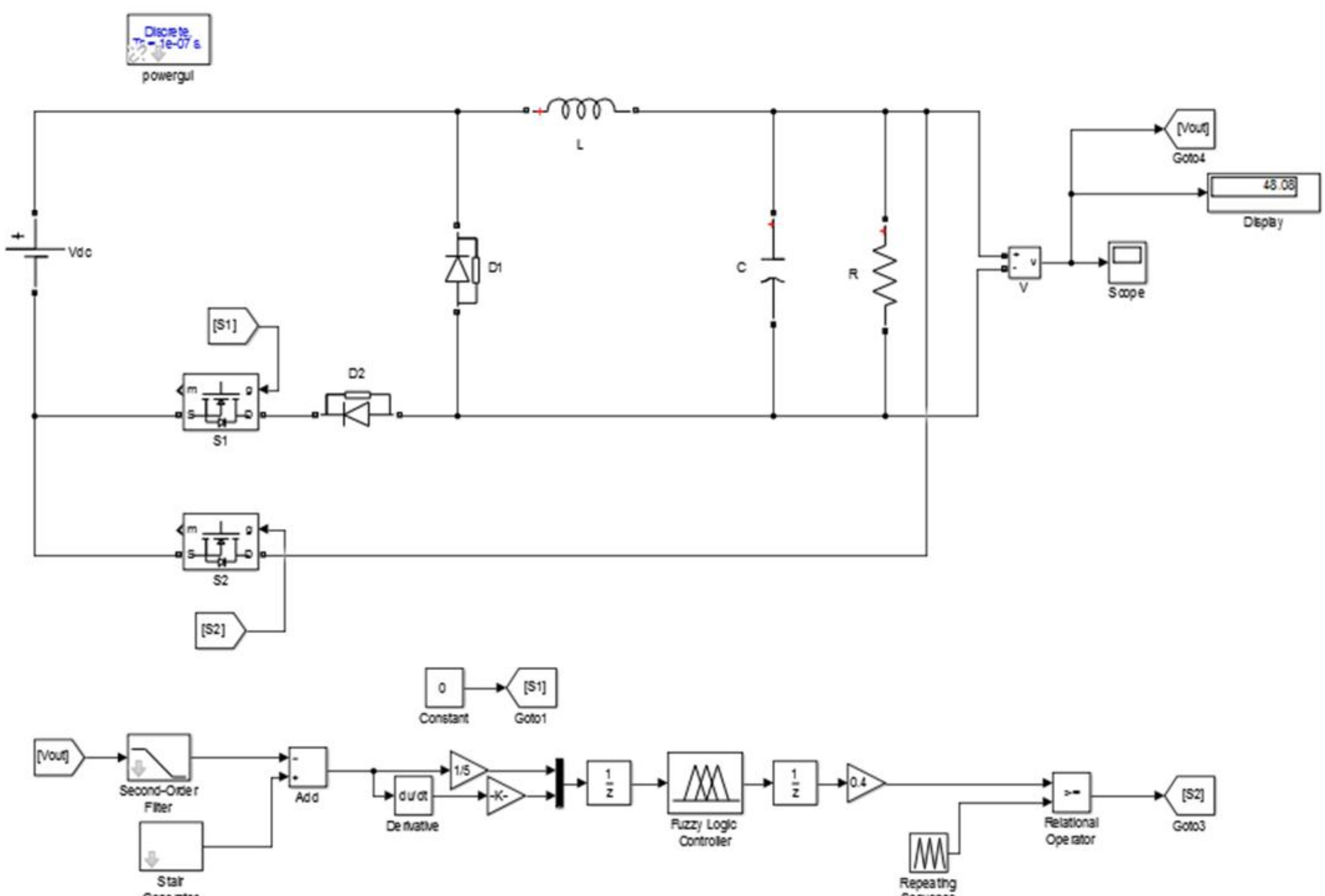

Fig 27 Modified Two switch buck boost converter operating in Buck-Boost (step up) mode

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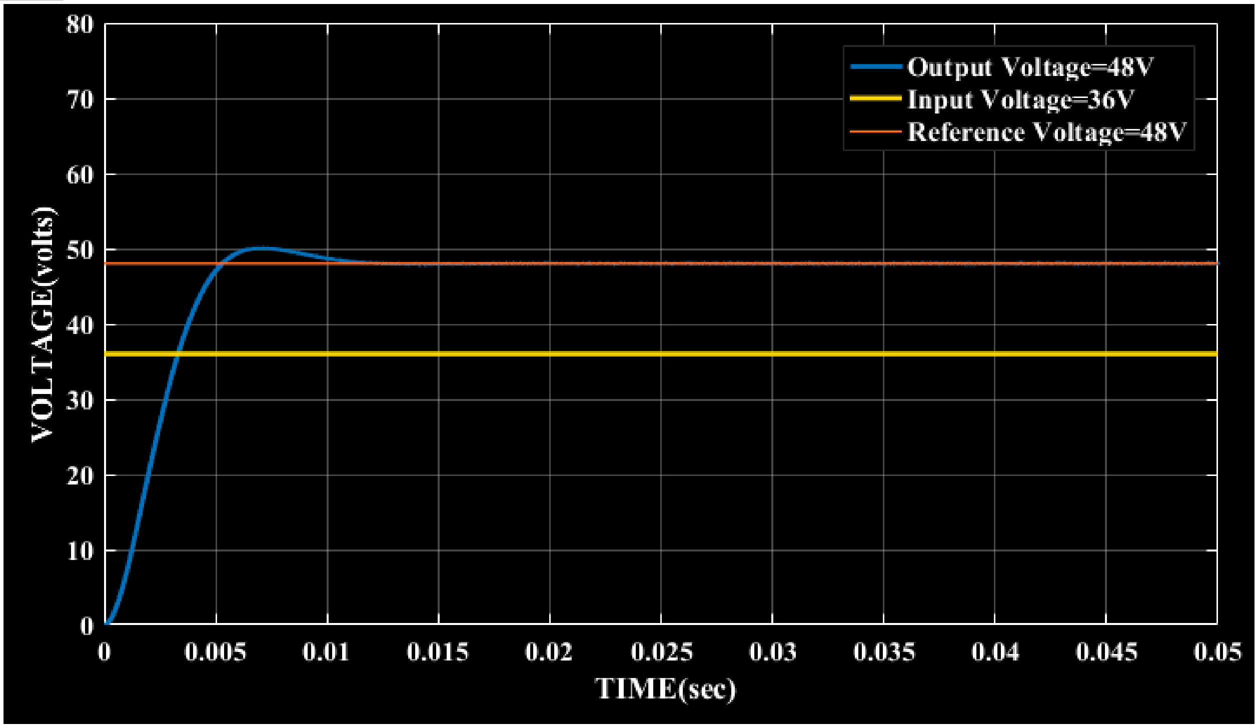

Fig 28 Input voltage, Reference voltage and Output voltage waveform

D. Buck-Boost(Step Down) Mode

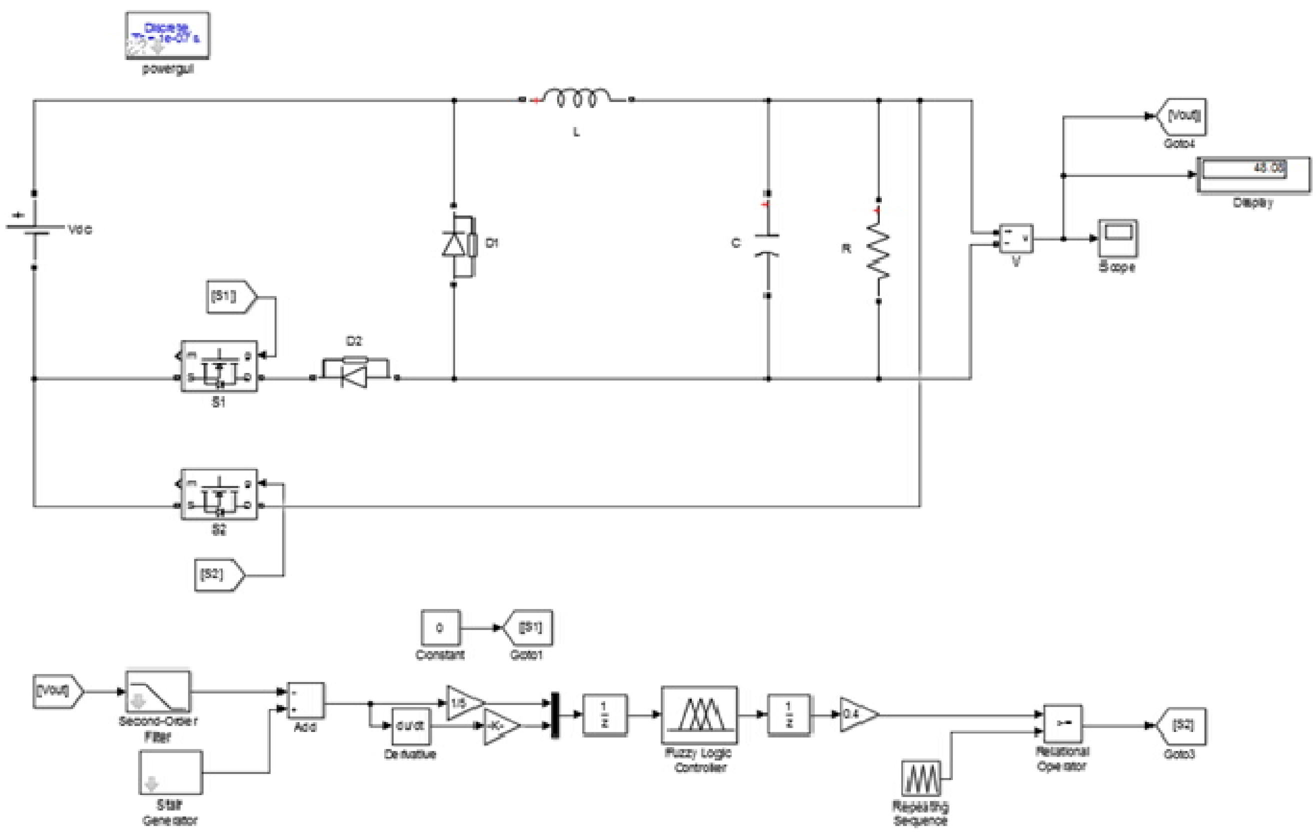

Fig 29 Modified Two switch buck boost converter operating in Buck-Boost (step down) mode

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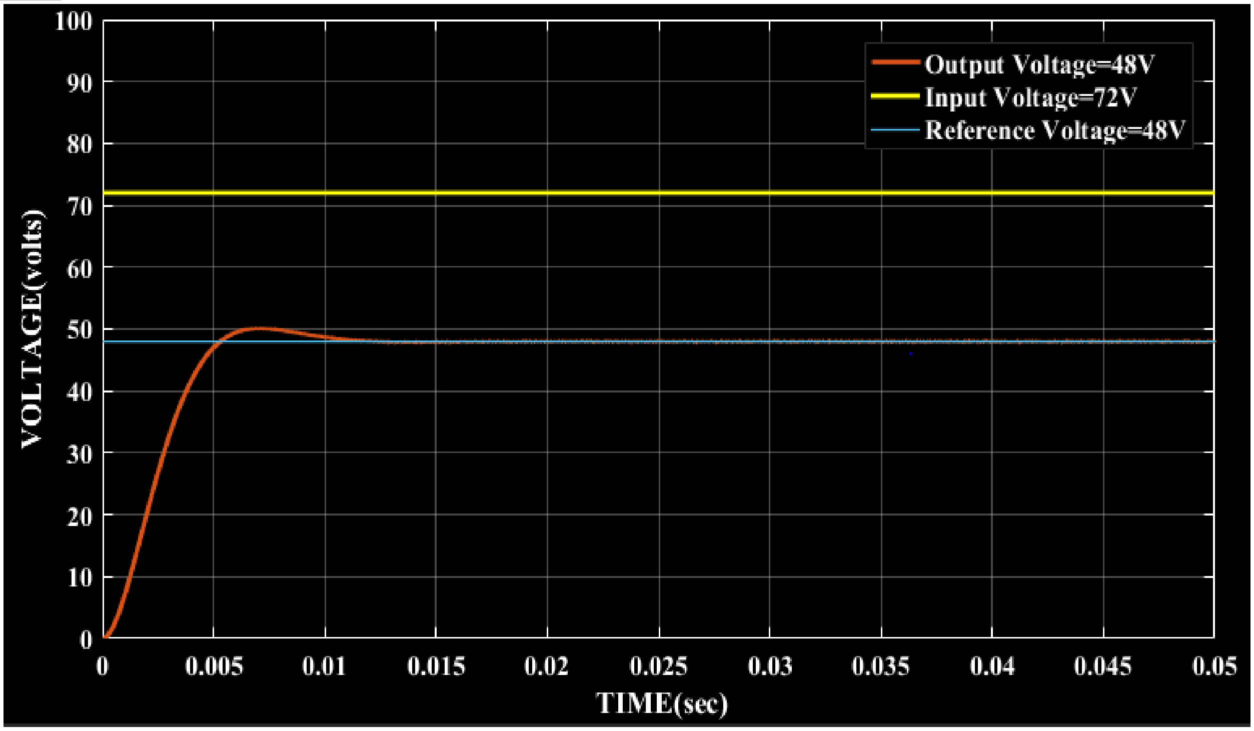

Fig 30. Input voltage, Reference voltage and Output voltage waveform

VI. COMPARISONS

All modes of Modified two switch buck boost converter are simulated in open loop and by using Fuzzy logic controller. Thus obtained simulated results of open loop analysis and Fuzzy logic controller are analysed and compared in terms of peak voltage and settling time.

A. Buck Mode

The input voltage of 72V is bucked to 48V using open loop and Fuzzy controller.48V is taken as reference voltage. When simulated in open loop, the output voltage waveform raised to a peak voltage of 87V and settled to 48V at 0.03 sec. Using Fuzzy Logic controller, the output voltage waveform raised to a peak voltage of 50V and settled to 48V at 0.012 sec. This is clearly observed from Fig 31.

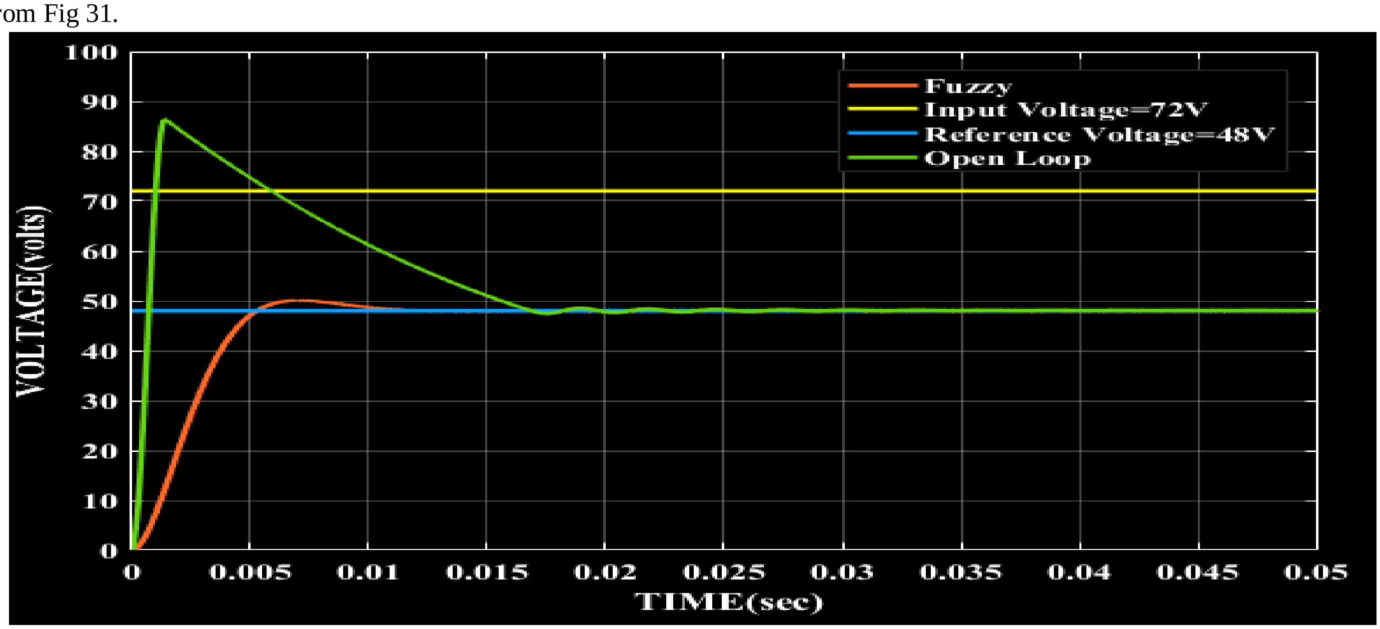

Fig 31. Input voltage, Reference voltage, Open loop and Fuzzy Output voltage waveform

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B. Boost Mode

The input voltage of 36V is converted to 48V using open loop and Fuzzy controller.48V is taken as reference voltage. When simulated in open loop, the output voltage waveform raised to a peak voltage of 79V and settled to 48V at 0.036 sec. Using Fuzzy Logic controller, the output voltage waveform raised to a peak voltage of 50V and settled to 48V at 0.012 sec. This is clearly observed from Fig 32.

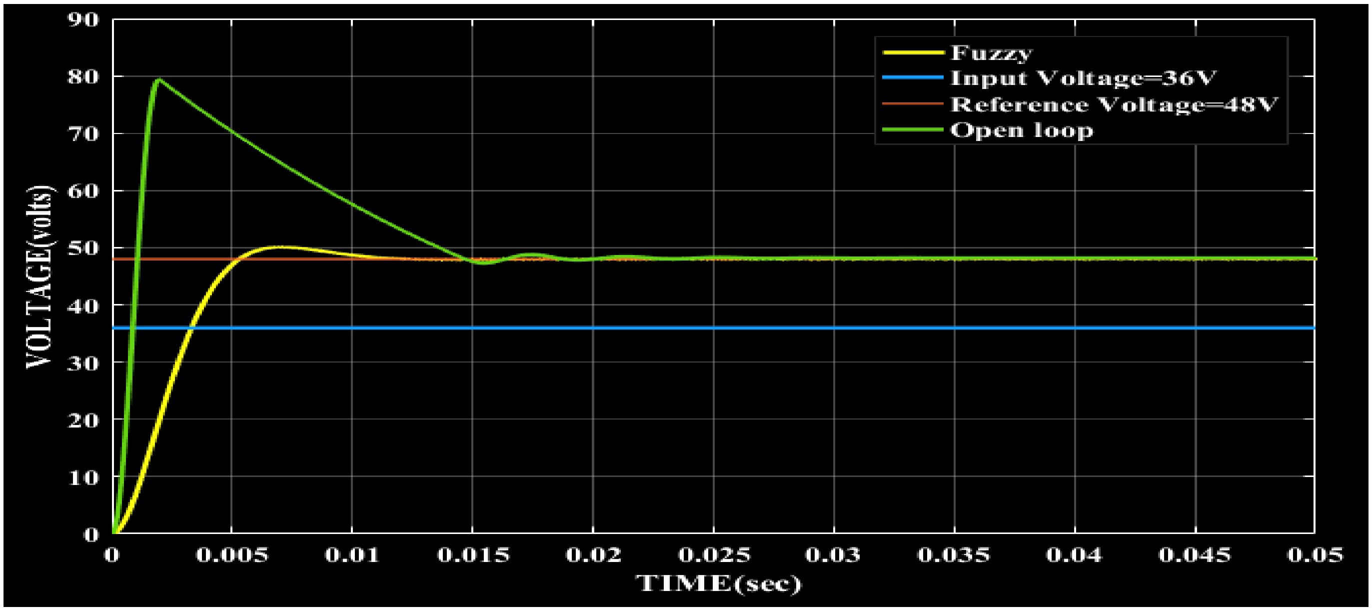

Fig 32. Input voltage, Reference voltage, Open loop and Fuzzy Output voltage waveform

C. Buck-Boost (Step UP) Mode

The input voltage of 36V is converted to 48V using open loop and Fuzzy controller. 48V is taken as reference voltage. When simulated in open loop, the output voltage waveform raised to a peak voltage of 78V and settled to 48V at 0.037 sec. Using Fuzzy Logic controller, the output voltage waveform raised to a peak voltage of 50V and settled to 48V at 0.012 sec. This is clearly observed from Fig 33.

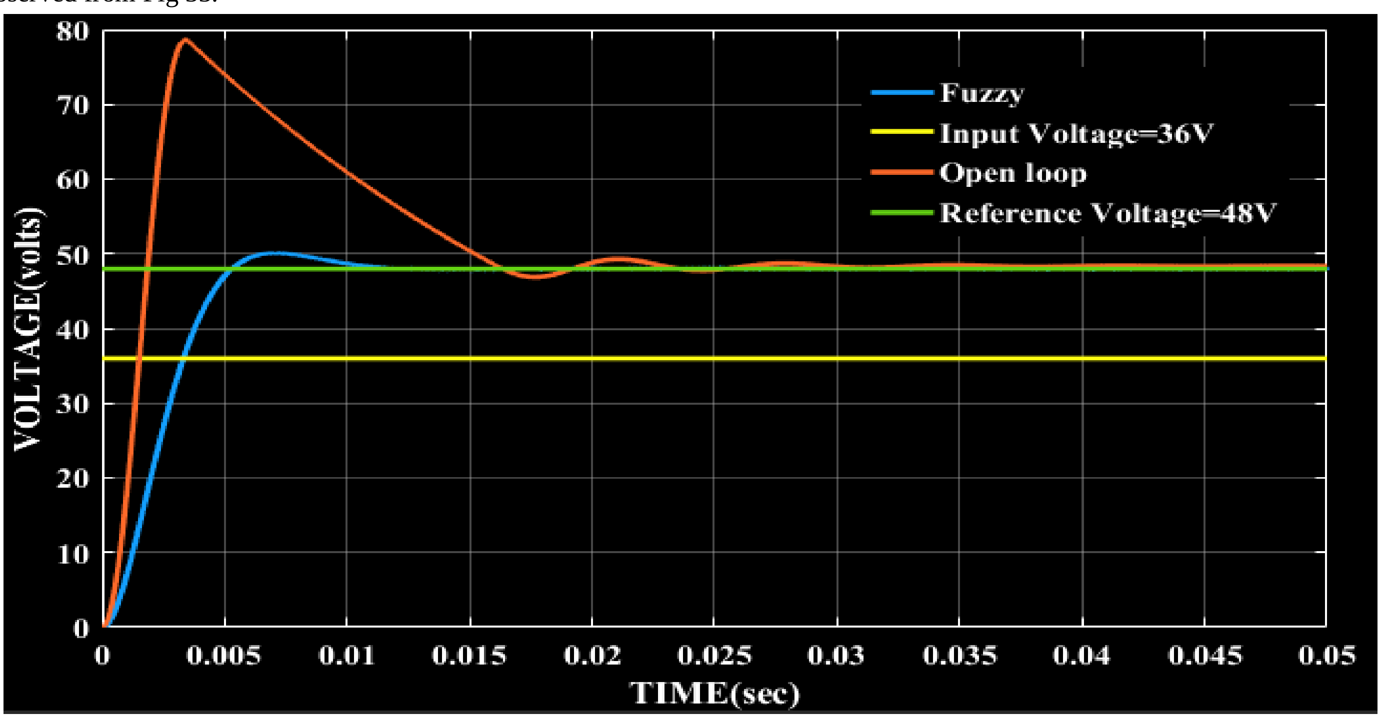

Fig 33. Input voltage, Reference voltage, Open loop and Fuzzy Output voltage waveform

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D. Buck-Boost (Step Down) Mode

The input voltage of 72V is converted to 48V using open loop and Fuzzy controller. 48V is taken as reference voltage. When simulated in open loop, the output voltage waveform raised to a peak voltage of 83V and settled to 48V at 0.004 sec. Using Fuzzy Logic controller, the output voltage waveform raised to a peak voltage of 50V and settled to 48V at 0.012 sec. This is clearly observed from Fig 34.

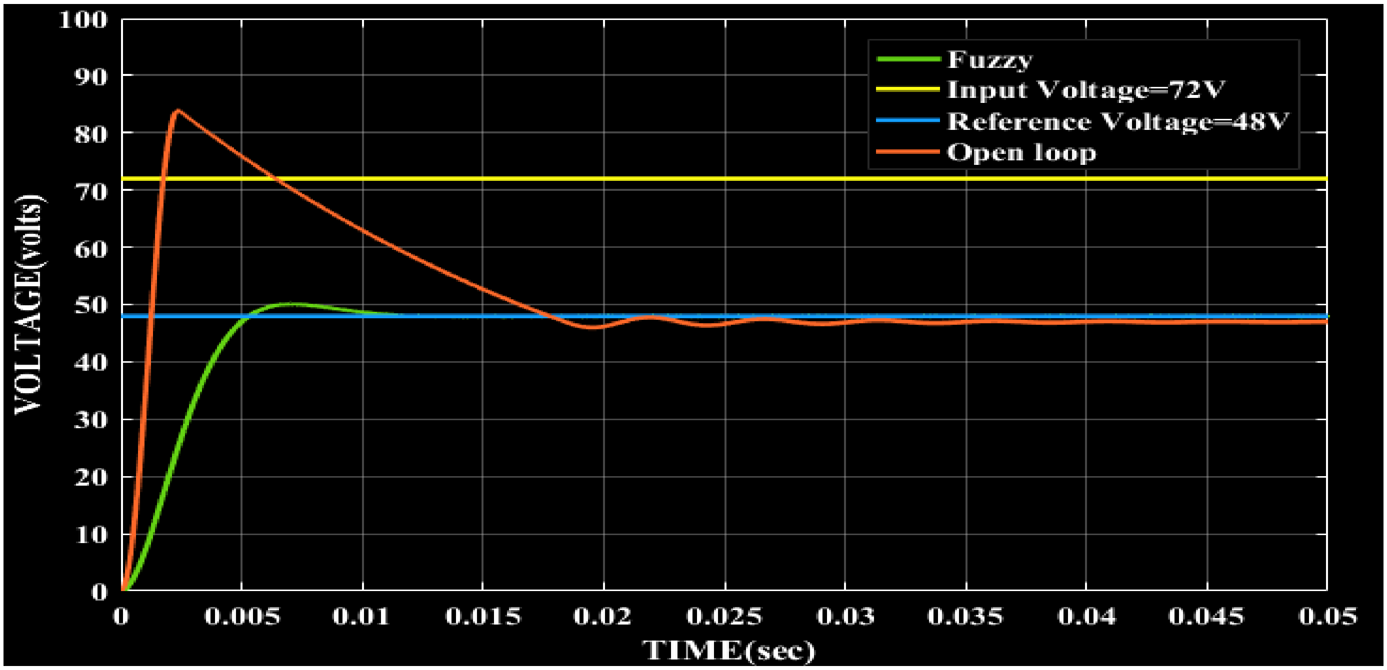

Fig 34. Input voltage, Reference voltage, Open loop and Fuzzy Output voltage waveform

1) *Peak Voltages:* The peak voltages of Modified Two switch Buck Boost converter operating in different modes are as follows:

Table 5: Peak Voltage (volts) Comparison

Operation mode	Open loop	Fuzzy
Buck mode	87V	50V
Boost mode	79V	50V
Buck boost (step up)	78V	50V
Buck boost (step down)	83V	50V

2) *Settling Time:* The settling time (sec) of Modified Two switch Buck Boost converter operating in different modes are as follows:

Table 6: Settling time (sec) Comparison

Operation mode	Open loop	Fuzzy
Buck mode	0.03	0.012
Boost mode	0.036	0.012
Buck boost(step up)	0.037	0.012
Buck boost(step down)	0.04	0.012

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VII. CONCLUSIONS

The Modified Two Switch Buck Boost converter in this paper is used to convert a DC input voltage: 72V to 48V Output voltage in Buck and Buck-Boost (step down) modes; 36V to 48V in Boost and Buck-Boost (step up) modes. The converter is simulated in open loop and with Fuzzy Logic controller. The corresponding simulated results in each mode are compared. The peak voltages are very high in open loop compared to Fuzzy control as shown in Table 5. For ex: In Buck mode, the peak voltage in case of open loop is 87V whereas by using Fuzzy controller, it is reduced to 50V. The Output voltage 48V settling time in both cases are as tabulated in Table 6. For ex: In Buck mode, the Output voltage 48V is settled at 0.012sec in Fuzzy control whereas by using open loop it took 0.03sec.Thus by using Fuzzy Logic controller, the peak voltage and the settling time are reduced compared to open loop. Fuzzy Logic controller reduces too long mathematical calculations and rise in peak voltage at the initial operating of converter. The settling response of the Fuzzy Logic controller is faster compared to open loop.

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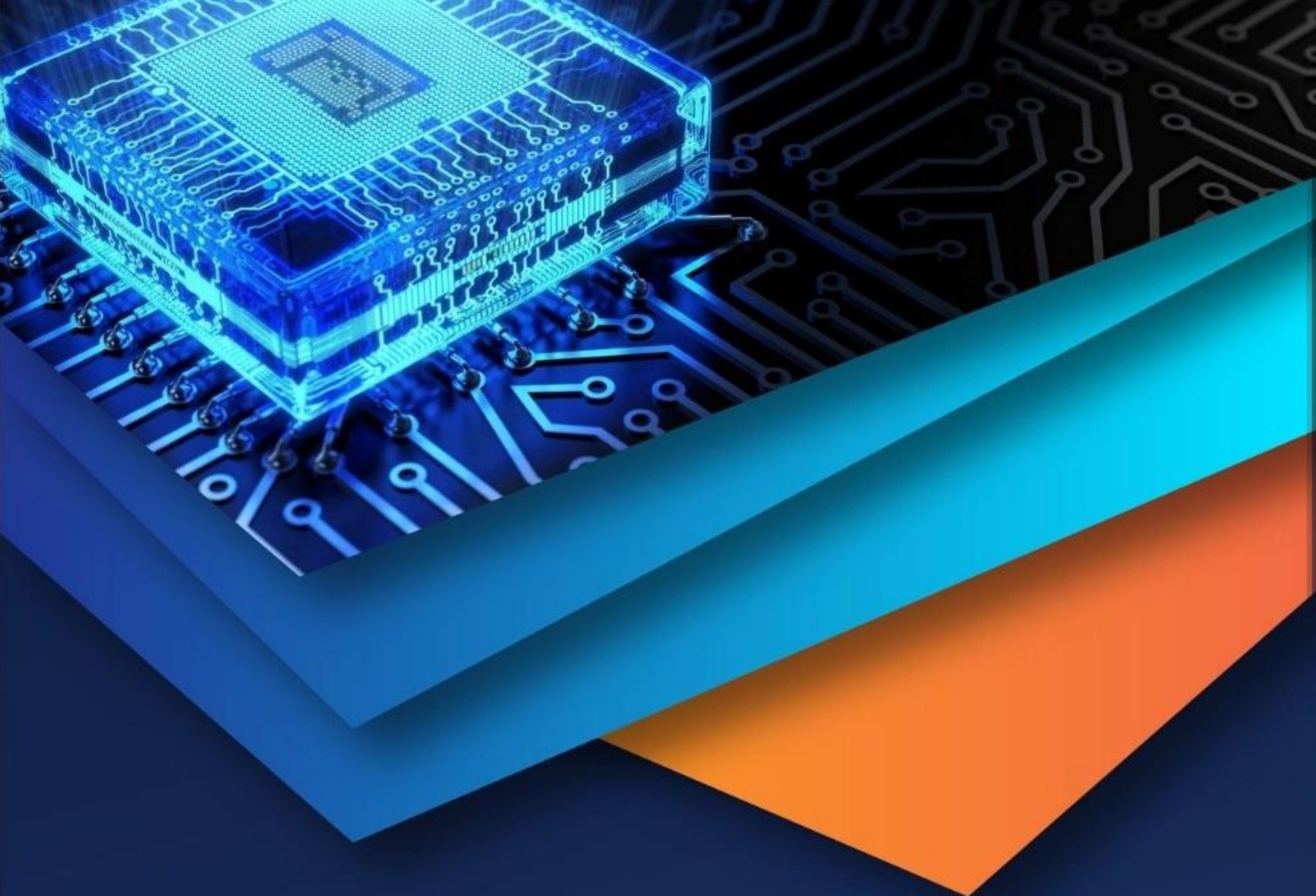

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