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Design And Implementation Of Non-Isolated Half Bridge DC-DC Bidirectional Converter Using Fuzzy Logic

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Abstract

Increasing energy demand and environment constraint of fossil fuels renewable energy is encouraged. Considering increase in energy demand bidirectional converter is widely used. the study aims to design and implement a Half bridge non isolated bidirectional DC to DC converter using fuzzy logic. In the presence of dc mains the converter operates as buck converter and charges the battery. When the dc mains fail, the converter operates as boost converter and the battery feeds the load. In both the modes the power switches are controlled by PWM technique and the PWM pulses are generated by application of fuzzy logic controller. The proposed converter with controller is implemented and simulated in MATLAB and the design is validated.

Keywords: *bidirectional dc-dc converter, fuzzy logic controller, AVR, battery*

INTRODUCTION

Electricity is the most dominant factor in the world. As demand of electricity increased so there is need to adopt renewable energy sources. The output of renewable energy sources like solar must be converted into suitable form of energy. Before the invention of Bidirectional converter it was very complicated to interface with renewable enegy resources. e.g. solar renewable energy system, the output of that system is in the form of dc and it is very low in magnitude.So for this purpose battery is connected to solar pannel,in day-time energy is stored in battery and in night-time energy is delieverd. With the leap in technological advancement renewable energy resources are becoming an attractive and essential power source for both residential and commercial consumers. Integration of various renewable sources can be optimized for efficient economic applications. It not only reduces the cost and improves efficiency, but also improves the performance of the system [1]. In an electric vehicle, an auxiliary energy storage battery absorbs the regenerated energy fed back by the electric machine. In addition, bidirectional dc-dc converter. It has ability to reverse the direction of the current flow, and thereby power, the bi-directional DC-DC converters are being increasingly used to achieve power transfer between two dc power sources in either direction.

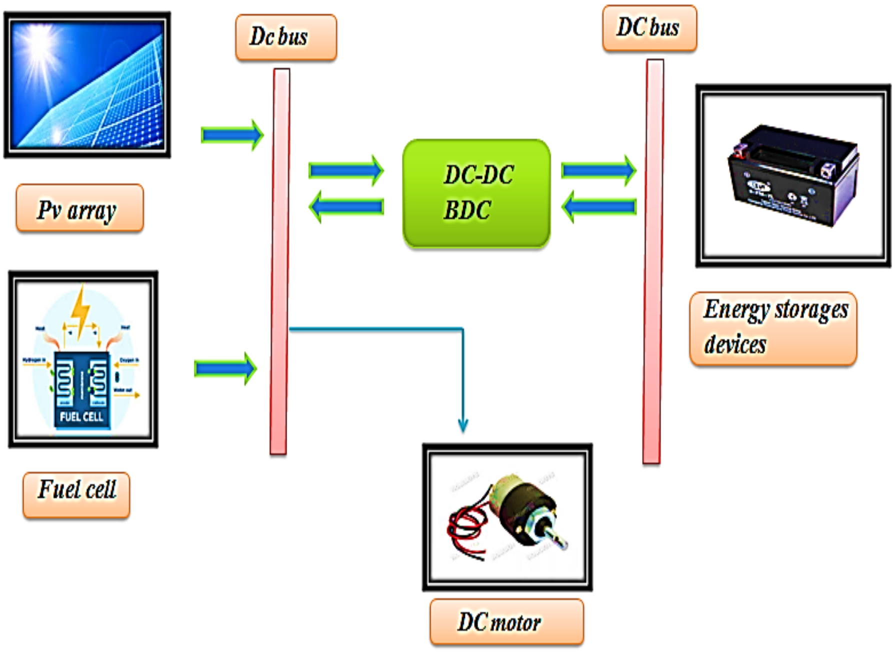

Figure 1: *Typical application of bidirectional DC to DC converter in energy renewable system*

Classification of Bidirectional converter
Classification of Bidirectional DC-DC converter Depending on the isolation between input and output side bidirectional DC-DC converter are of two types:

1. Non-Isolated Bidirectional DC-DC converters
2. Isolated Bidirectional DC-DC converters

Non-Isolated Bidirectional DC-DC converters
Non isolated bidirectional DC to DC is a converter which does not use transformer to provide any electrical isolation between source and load [2]. Hence these converters are not used in high power applications due to safety reasons but in low power application theses converter are more efficient because these are easy to control and light weight due to absence of transformer [3].

Isolated Bidirectional DC-DC converters
Non isolated bidirectional DC to DC converter is not capable to provide the safety standards of galvanic isolation. Hence in many applications, isolated bidirectional DC to DC converter is used in place of Non isolated bidirectional DC to DC converter. In Isolated bidirectional DC to DC converter, high frequency transformer is used to provide galvanic isolation [4]. Galvanic isolation is necessary in many applications for safety of source in overload condition, for noise reduction, for voltage matching between conditions. This converter works in two stages. In first stage dc is converted to ac and second stage ac is converted into dc and both the stages are connected through high frequency transformer [5,6].

NEED OF BIDIRECTIONAL CONVERTER

1. Step up and Step down voltage between its input and output.
2. Power flow capability in both directions.
3. Application in the area of the energy storage system for HEV, UPS, Fuel cell storage system.

PRINCIPLE OF OPRATION OF PROPOSED CONVERTER

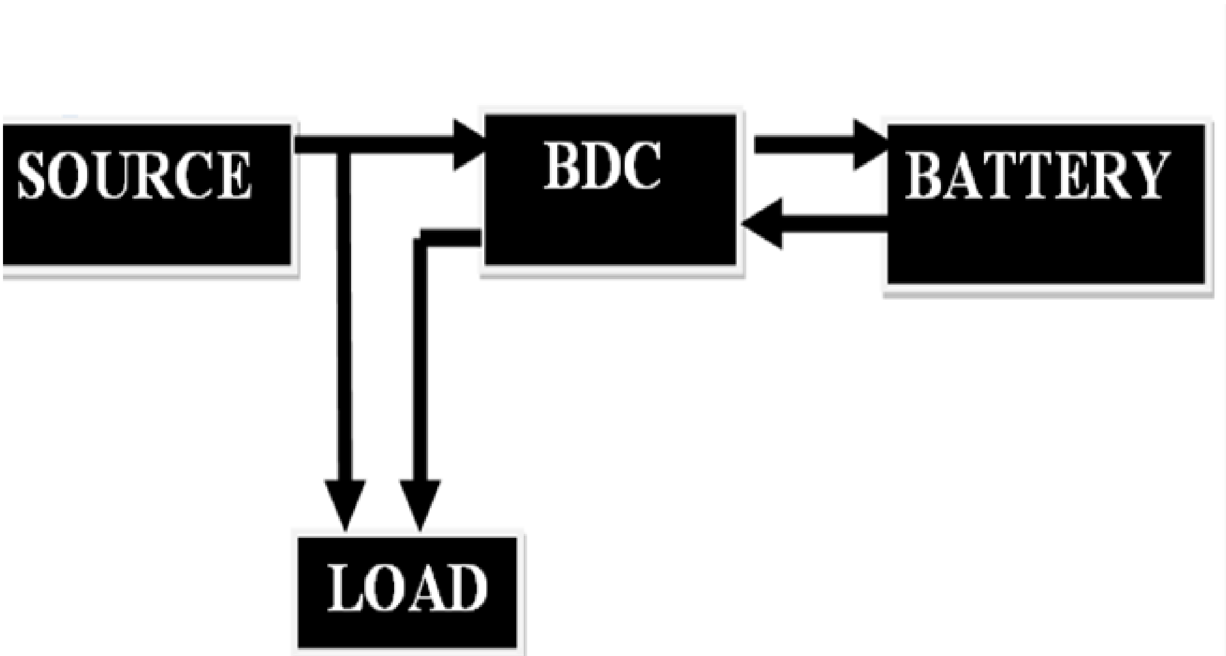

Figure 2: *system diagram*

In the presence of dc mains the converter operates as buck converter and charges the battery. When the dc mains fail, the converter operates as boost converter and the battery feeds the load. In both the modes the power switches are controlled by PWM technique and the PWM pulses are generated by application of fuzzy logic controller**.**

METHODOLOGY

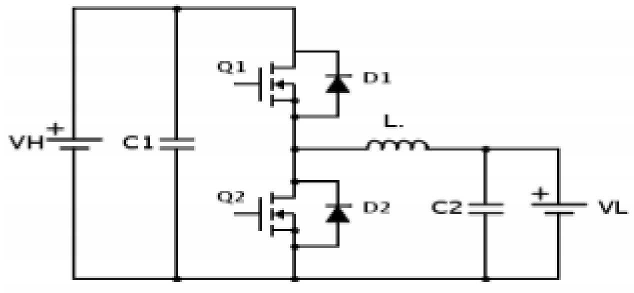

Figure 3: *Half-bridge NIBDC*

PREPARE YOUR PAPER BEFORE STYLING

When the Buck and the boost converters are connected in anti- parallel with each other, the resulting circuit is of same structure as the fundamental Buck and boost structure but with the added feature of bidirectional power flow as shown in Fig. Depending on the switching of MOSFET Q1and Q2, circuit will operate in buck or boost mode. The switches Q1 or Q2 with combination of diode D1or D2 (freewheeling diode) respectively makes the voltage across them either step up or step down. The bidirectional operation of circuit above explained below.

Mode 1 (Boost Mode)

In this mode switch Q1 and diode D2 are off all the time whereas switch Q2 and diode D1 are conducting depending on the duty cycle. This mode is divided into two interval on the basis of conduction of switch Q1 and diode D2. Interval 1 (Q2 on, D2 off; Q1 off, D1 off)

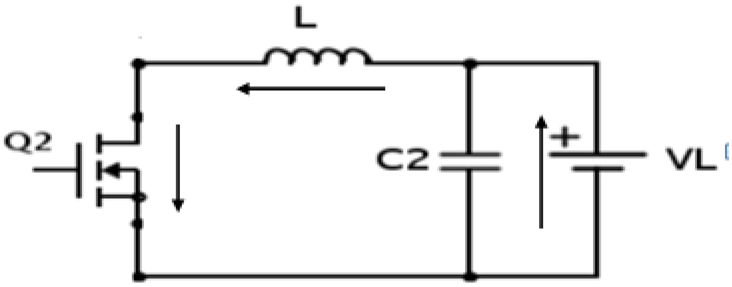

Figure 4: *Boost mode interval 1*

In this period Q2 is on so the inductor get charged by lower battery and its current goes on increasing till the gate pulse is removed from the Q2. Also diode D1 is reverse biased and switch Q1 is off, so no current flows through switch Q1. Interval 2 (Q1 off, D1 on; Q2 off, D2 off)

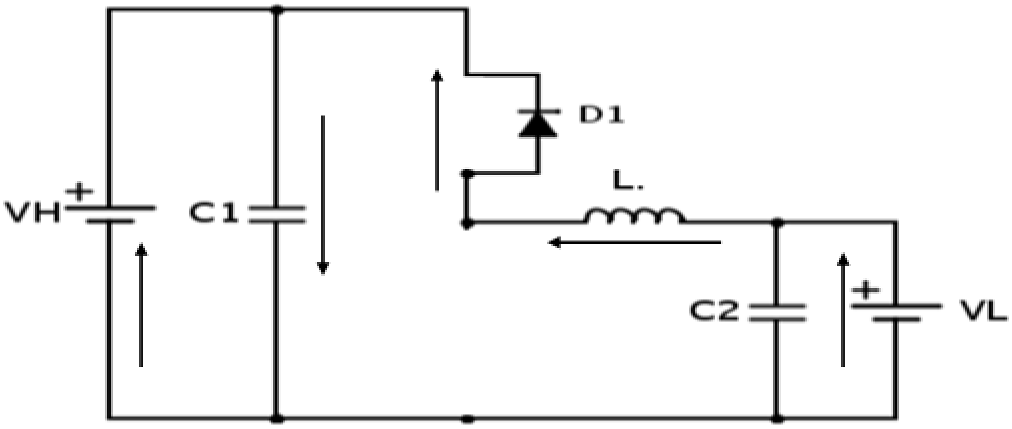

Figure 5: *Boost mode interval 2*

In this mode both Q1 and Q2 are off, since current following through inductor cannot change instantaneously so polarity of voltage is reversed and it starts acting in series with input circuit. Diode D1 is forward bias so inductor current charges the output capacitance hence the output voltage boost up.

Mode 2 (Buck Mode)

In this mode switch Q2 and diode D1 are off all the time whereas switch Q1 and diode D2 conducts depending on the duty cycle. Depending on the conduction of switch Q2 and diode D1 this mode divided into two intervals. Interval 1 (Q2 off, D2 off; Q1 on, D2 off)

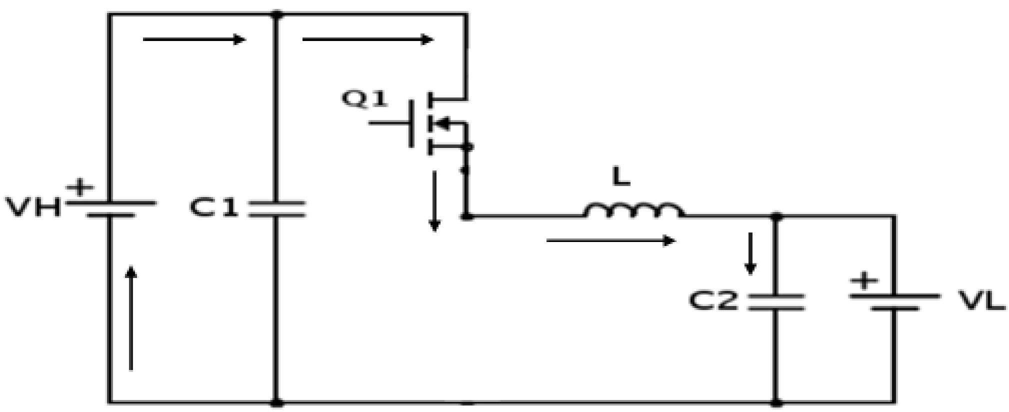

Figure 6: *Buck mode interval 1*

In this period Q2 is off and Q1 is on, So the inductor gets charged by the battery and output capacitor gets charged by it. Interval 2 (Q1 off, D1 off; Q2 off, D2 on)

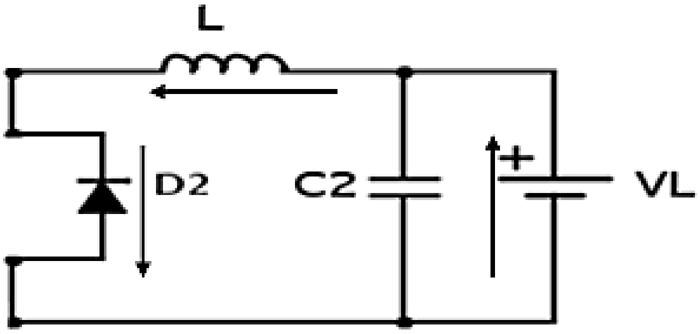

Figure 7: *Buck mode interval 2*

In this period switch Q1 and Q2 are off, So inductor current gets discharged through the freewheeling diode D2 and hence voltage is stepped down across the load.

PID Controller (Ziegler- Nichols Method)
PID control is one of the control system design methods. PID controller is to adjust an appropriate proportional gain, integral gain, and differential gain to achieve the optimal control performance.

Fuzzy Logic Controller (FLC)

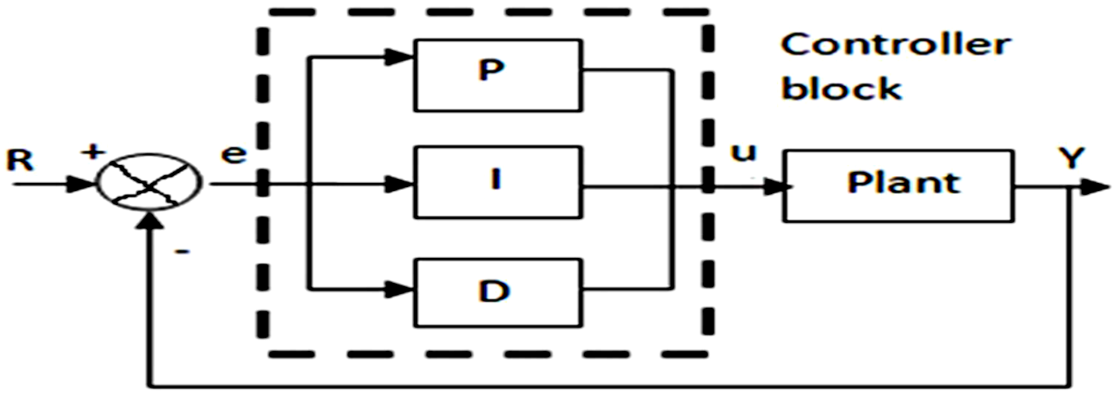

Figure 8: *PID controller*

PID controllers are tuned in terms of and Ziegler- Nichols is a type of continuous cycling method for controller tuning. Continuous cycling is a continuous oscillation with constant amplitude. It is based on the trial and error procedure of changing the proportional gain is increased from small value until the point at which the system goes to unstable. Thus the gain at which system starts oscillating is note as the gain and period of oscillations is the time period. These two parameters, and are used to find the loop-tuning constants of the PID controller. PID controller is used for controlling the switches.

Fuzzy logic controller
FLC presents a methodology for controlling the system, depending on expert knowledge. Fig.3 illustrates the basic structure for the FLC, where it consists of four parts: (1) fuzzification, which converts the input value to the corresponding linguistic value, (2) knowledge base, which consists of a database and rule base, (3) inference

engine, which emulates the human thinking to make decision, and (4) defuzzification, which produces a crisp value.

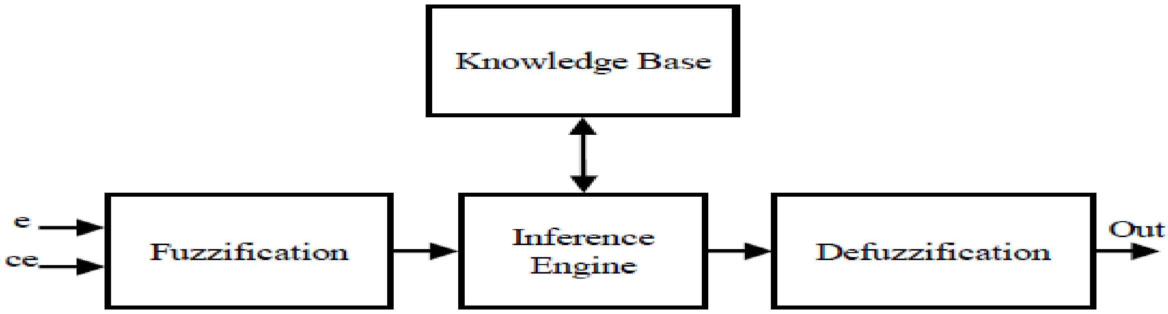

Figure *9: Block diagram of fuzzy logic controller*

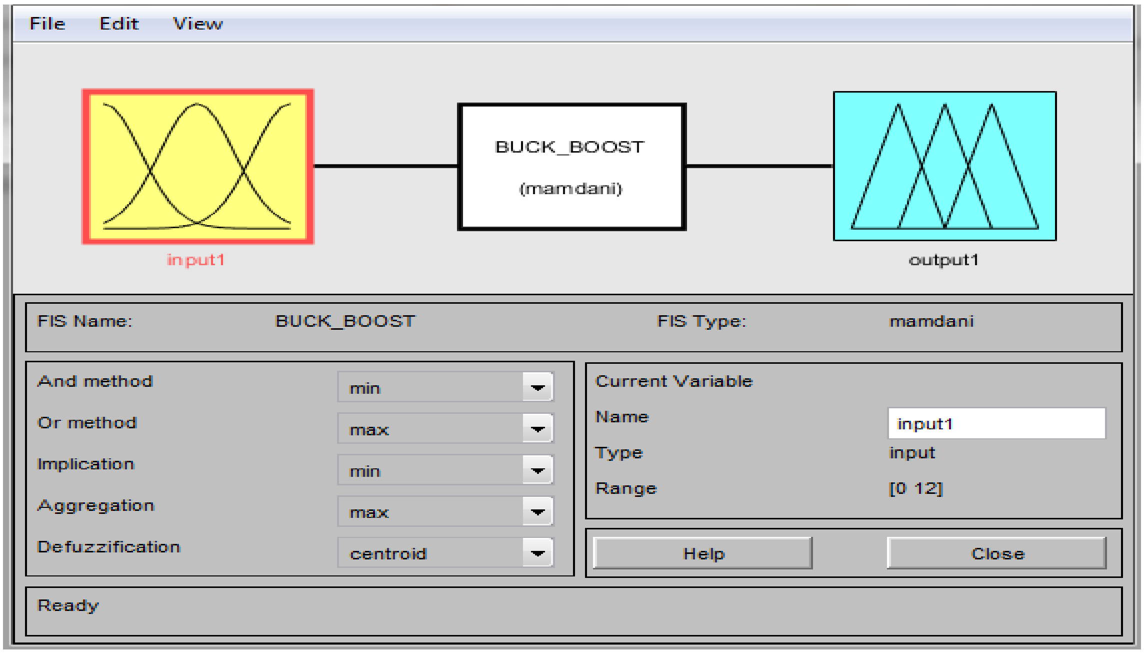

Figure 10: *fis editor*

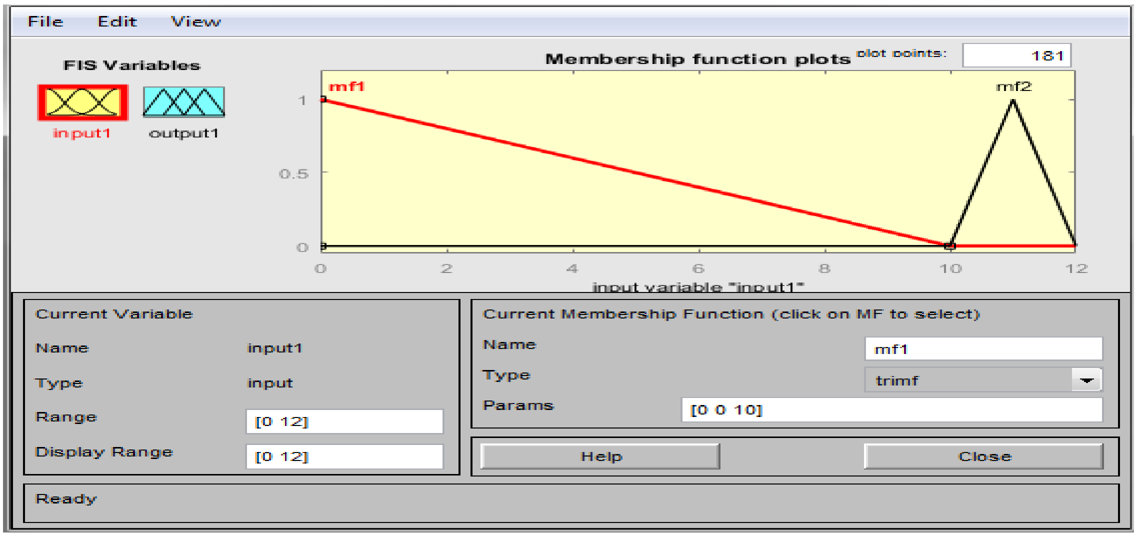

Figure 11*: MF for variable input*

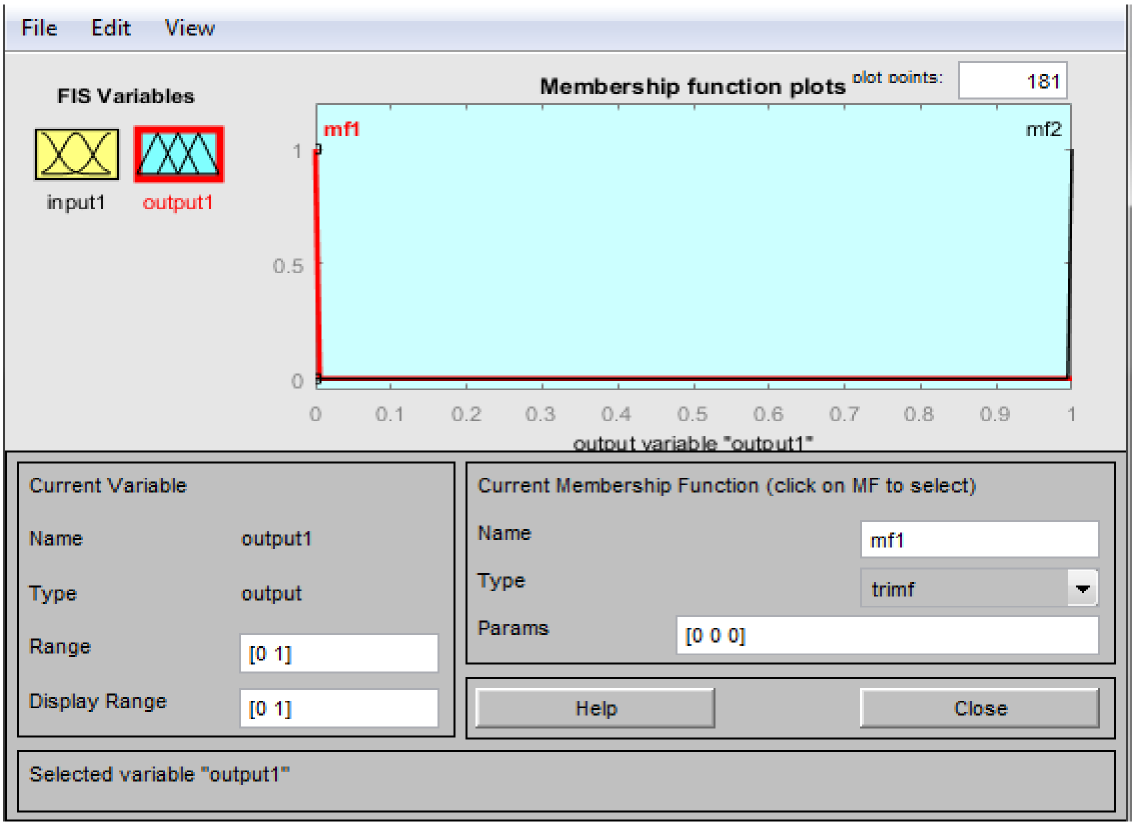

Figure 12: *MF for variable output*

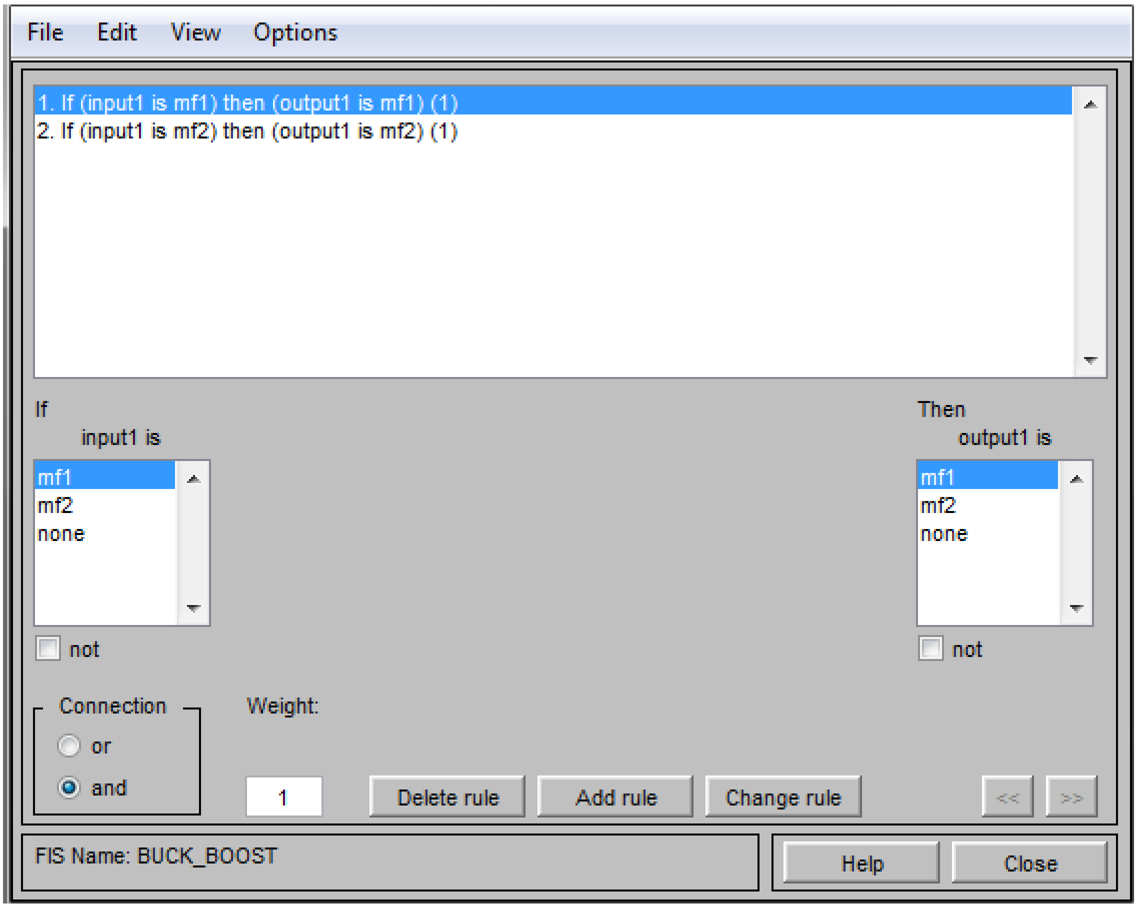

Figure 13: *rule editor*

SIMULATION

This is a MATLAB closed loop simulation system of bidirectional converter along with fuzzy controller, it consist with three passive elements like resistor, inductor and capacitor. It has two switching elements MOSFET and diode. For checking the result of MATLAB simulation we have measurement block the input voltage is given to bidirectional converter simulation is 24 V, which is from grid output.

The value of inductor is 4.8µH, capacitor 1000µF and the value of resistor is 1k. In this simulation for feedback path one reference block is used, which compare the output of bidirectional converter with actual value and output of block is given to the fuzzy logic controller, which controls duty cycle of MOSFET switch. As we know that PI controller is most commonly used controller for the industry application, but this controller has some disadvantages like high settling time and rise time. One these problem statement we have used fuzzy logic controller.

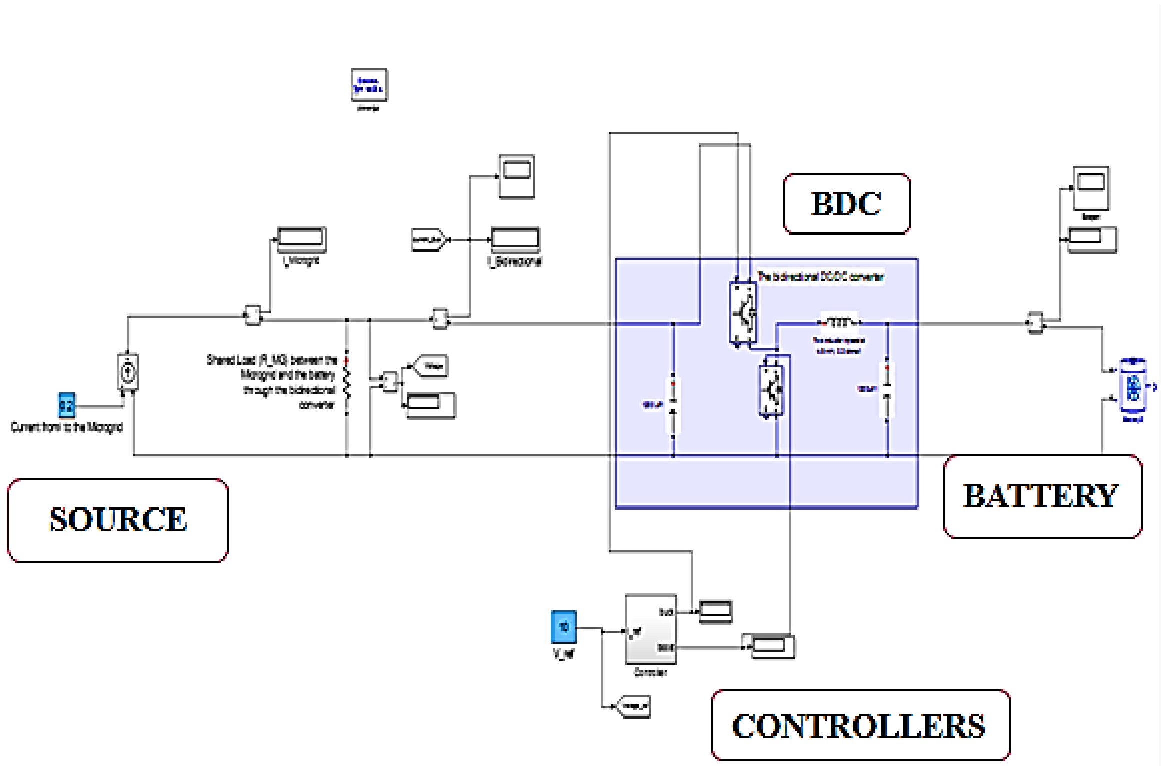

Figure 14: *Simulation of proposed converter*

Simulation result

If the voltage measured is higher than the reference voltage, then the bidirectional should send some current to the battery (i.e. buck converter), if V_measured < V_reference ---> bidirectional should send current to the R_MG (i.e. boost converter)

PROTOTYPE SPECIFICATION AND COMPONENT RATING

Parameters	Values(Unit)
Input voltage	24
Output voltage	12
Switching frequency	20KHz
Capacitor	1000 µf
Power MOSFET	IRFZ44N
Inductor	4.8µH

Design consideration

Calculate the Maximum Switch Current Switch current is calculated to determine the duty cycle and minimum input voltage. The minimum input voltage is used because this leads to maximum switch current.

$$D = 1 - \frac{V_{IN(min)} \times \eta}{V_{OUT}}$$

VIN (min) = minimum input voltage
VOUT = desired output voltage
η = efficiency of the converter

For calculating inductor ripple current maximum switch current is determined. To calculate inductor selection of this application note.

$$\Delta I_L = \frac{V_{IN(min)} \times D}{f_S \times L}$$

Inductor Selection

As the inductor value is increases, the output current is also increases as ripple current of inductor is small.

$$L = \frac{V_{IN} \times (V_{OUT} - V_{IN})}{\Delta I_L \times f_S \times V_{OUT}}$$

HARDWARE

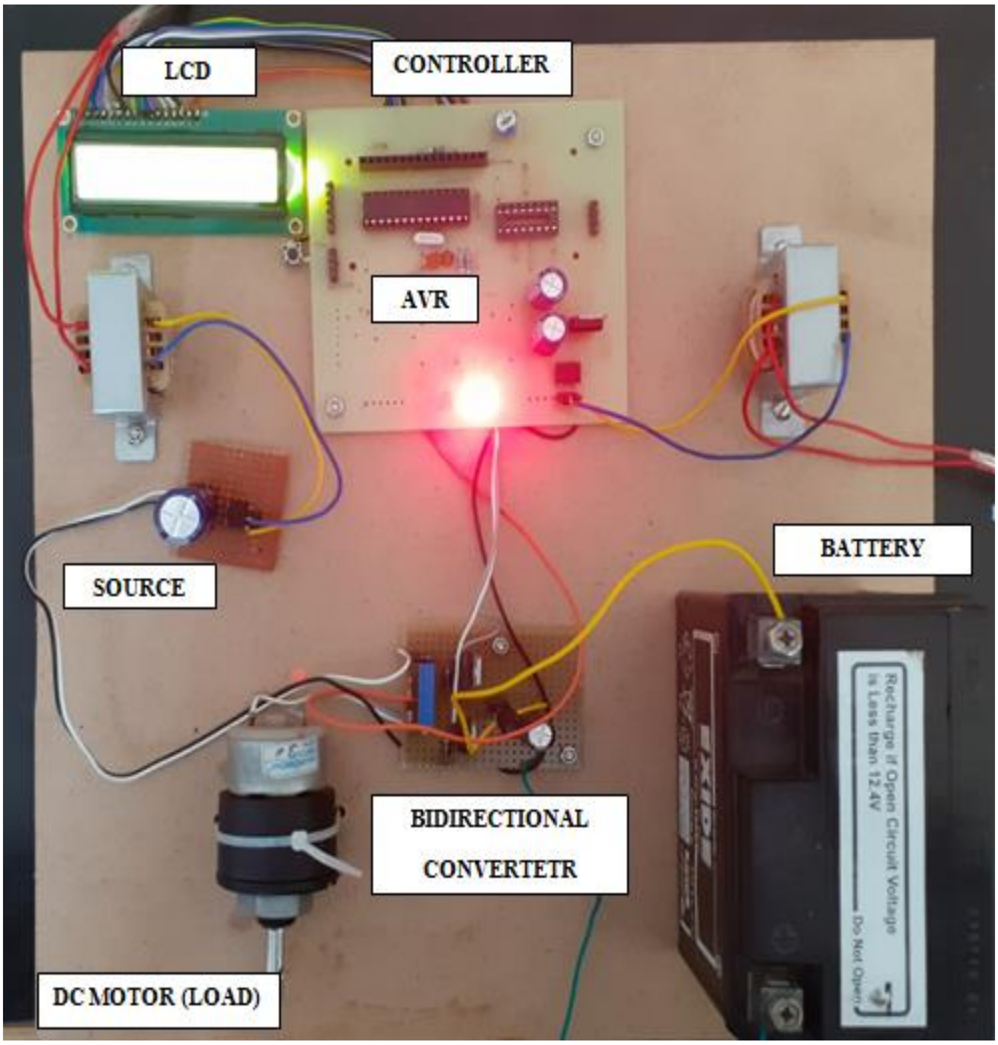

Figure 15: *Photograph of proposed NIBDC*

System consist of dc-dc bidirectional converter unit, AVR microcontroller, battery. It operates in two modes:

1) Buck mode (Charging mode)
2) Boost mode (Discharging mode)

Hardware results

Modes of operation	Source voltage	Battery	Load
Buck mode	24V	Charging mode	23.6V
Boost mode	00	12V	23.4V

CONCLUSION

In this paper, half bridge topology of non isolated dc-dc bidirectional converter is proposed. This converter is successfully simulated. For this topology, we use two controllers, one is PID controller for controlling the switches and other is fuzzy logic controller for controlling the mode of operation of proposed converter. The power of boost mode was operated in low voltage input mode and the power in buck mode was operated in high voltage input mode. The two modes of control were used buck mode and boost mode for control voltage.

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