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Voltage Regulation in BDC Based on Fuzzy Logic Controller using Solar Power Generation

K. Balaji, D. Vidhyalakshmi

Abstract: ***The PhotoVoltaic (PV) based grid system coupled with Bidirectional DC-DC Converter (BDC) utilize Fuzzy Logic Controller (FLC) for increasing voltage gain and reduce the settling time of DC link voltage than conventional is presented. BDC satisfied the load requirements, and control the power flow from different sources such as PV, grid, and battery. However, problems in conventional system are high Total Harmonic Distortion (THD), DC link voltage gain and settling time of capacitor voltage. The generated power is used for improving the power quality at the output of the inverter using Sliding Mode Controller (SMC). The converter and inverter operate has bidirectional performance and utilize the hybrid power generation as mentioned. The battery can act as a load based on operating modes of BDC and power generation. It provides a comparative analysis of Proportional Integral (PI) and FLC method that is effectively performs harmonic reduction in BDC.***

Keywords: ***Bidirectional Converter, Fuzzy Logic Control, Sliding Mode Control.***

I. INTRODUCTION

In recent era population growth is increased in urban countries and also high in environmental problems. There is demand of power generation in all areas, so the generation of renewable power is increased to meet out the necessity. The hybrid power generation is more useful to satisfy the load demand [1] [2]. The photovoltaic power generation is clean power source and battery is used as both source and load. The solar power is generated and fed into the grid using bidirectional converter [3]-[5]. During day time the solar generates power and transferred to grid system. During night the absence of solar the battery is utilized for power generation and transfer to grid [6]. Increasing the utilization of bidirectional converter such as electric vehicle, house hold and grid application. In conventional converter utilize transformer to perform bidirectional action and also it performs both step up and step down voltage [7]. The converter has more switches which increase the cost and the switching losses. In fly back converter used to attain high voltage step ratios but they require a transformer to enhance the voltage gain [8]-[10]. This converter has high complexity and less efficiency of this device. The battery is used has a source when solar is not available and also store the power from grid when reverse direction operates. The BDC used as important in electric vehicle application [11]-[14]. The works of this converter as both buck and boost operation. In forward direction the converter boost/step-up the voltage and in reverse direction the buck/step-down operation is performed. The controller used in bidirectional converter is PI and its settling time is high [15] [16]. The pulse width modulation is implemented in three phase inverter and converts the DC to AC and the power is transferred to load. In conventional the Model Predictive Controller (MPC) used to regulates the inverter current and the THD is high compared to sliding mode controller (SMC). The grid connected BDC transferred the power from source to load [17]-[19]. The presented topology takes on the BDC based on grid system. The foremost objective is to maintain and reduce the dc link voltage and settling time of DC link, harmonic distortion using FLC control method. PV and battery used as a source when forward direction of BDC and grid used as source when BDC is reverse power flow. When PV, battery and grid are available, battery power is used for some other application. FLC is to enhance the voltage gain and also decrease the dc link voltage settling time. The sliding mode controller is designed for reducing the harmonic distortion in inverter.

II. PROPOSED SYSTEM AND MATERIALS USED

In proposed method decreases the settling time of dc link voltage and improve the voltage gain of the system using FLC. Fig. 1 shows the methodology of proposed grid connected system.

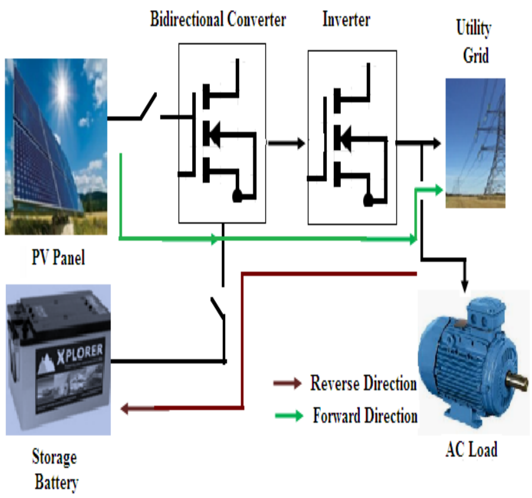

Fig. 1.Methodology of Proposed Grid Connected System

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A. Photovoltaic Power Generation

The modelling of two diodes PV is to produce the characteristics of PV and VI curve by varying the irradiation and series resistance value. The PV is a passive capacitive filter which decouples the input voltage and current from power by decreasing the current and voltage ripples. The utilization of power electronic devices is increased such as UPS, power converter, air conditioner; regulator etc connected to the point of coupling the non-linearity. The non-linearity load leads to increase the harmonics present in the system and it enhance the losses. It will affect the load, heating effect of transformer and shunt capacitor. Fig. 2 shows the equivalent circuit of PV model.

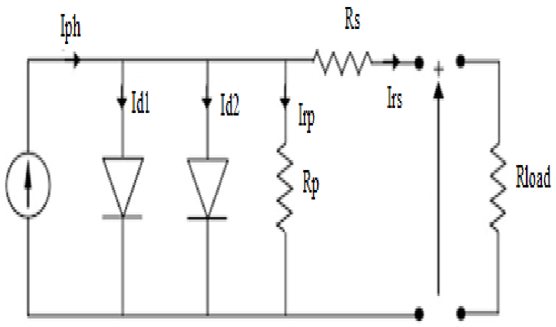

Fig. 2.Two diode PV cell equivalent circuit

The non ideal single diode and two diode of PV cell are expressed in below equation,

$$I = I_{photo} - I_{se}\left(\exp\frac{V + R_{se}I}{V_t} - 1\right) - \frac{V + R_{se}I}{R_{sh}} \quad (1)$$

$$I = I_{Photo} - I_{D1} - I_{D2} - I_{sh} \quad (2)$$

$$I_{Photo} = I_{ShrtCrt} + K_I(T_{Cell} - T_{ref})G \quad (3)$$

$$I_{D1} = I_{01}\left[e^{\left(\frac{V+IR_S}{\alpha_1 V_T}\right)} - 1\right]$$

(4)

$$I_{D2} = I_{02}\left[e^{\left(\frac{V+IR_S}{\alpha_2 V_T}\right)} - 1\right]$$

(5)

$$I_{Sh} = \frac{V + IR_S}{R_p}$$

(6)

The harmonics is eliminated by using shunt active filter connected to inverter. In solar power system the photo energy is greater than band gap, the photo current is proportional to the solar radiation. The two diode PV cell has more accurate characteristics under intermittent energy resource. Power electronics converters are connected at load side to maintain the voltage and current, and also used to control the power flow in grid power system.

B. Bidirectional Converter

The BDC act as buck boost converter and operates in both forward and reverse direction based on the switching configuration and it circuit diagram represent in fig. 3. The switching configuration is based on the switch and utilizes the fuzzy controller for voltage control across the output of bidirectional converter. The application of bidirectional are industrial application, electric vehicle, auxiliary system and in battery charging/discharging converters in UPS. In forward conduction mode photovoltaic or battery is used as a source and generated power fed to bidirectional converter. It works as boost converter and fed to three phase inverter.

In reverse conduction mode the grid used as a source and generate power transferred to battery. The three phase inverter operate has rectifier and converter act as buck converter and power transferred to battery. In battery the state of charge has increased and battery is charging and used for further application.

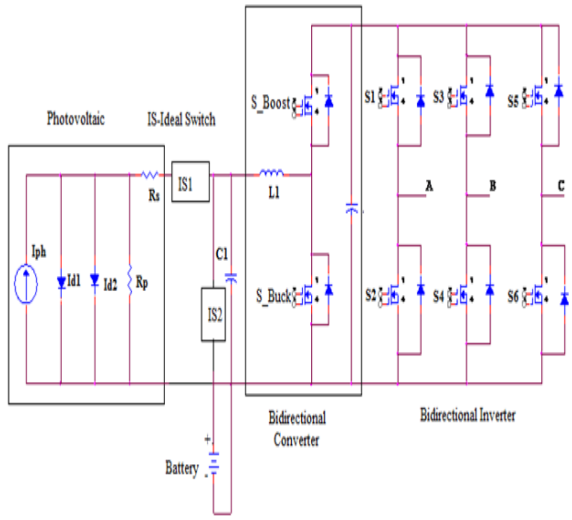

Fig. 3. Proposed Circuit diagram of bidirectional converter fed grid connected system

III. METHODS OF CONTROL SYSTEM

In proposed grid connected photovoltaic based converter utilized the FLC. The sliding mode control involved in inverter for improves the efficiency of the presented system. The characteristic of fuzzy control is easy to evaluate by using the optimization method.

A. Fuzzy Logic Controller

The fuzzy logic controller is implemented for dc voltage regulation at the converter output. The error and change in error is the two input of fuzzy and the output is designed by the Membership Function (MF) and centroid method is used. Process of FLC is representing in fig 4 and it contains FU, DMU, and DU. The membership function of FLC is shown in Fig. 5, 6 and 7.

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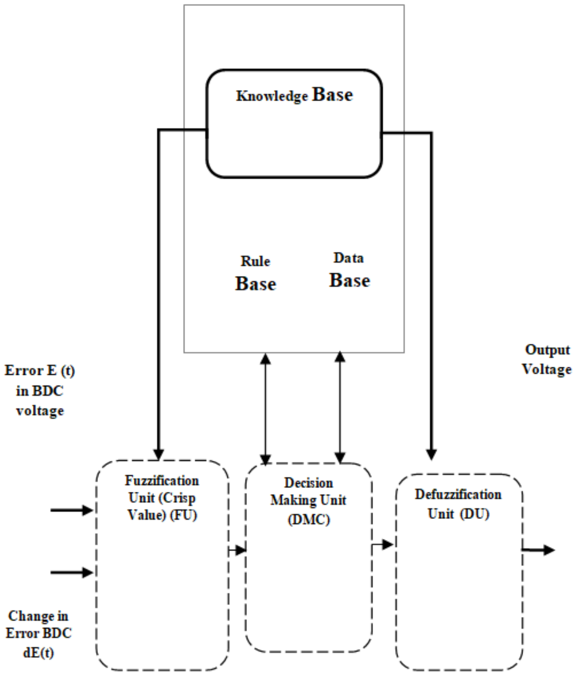

Fig. 4.Block diagram of FLC controller

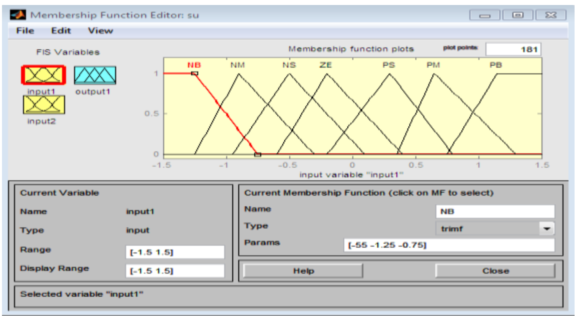

Fig. 5.Membership Function (MF) of input 1

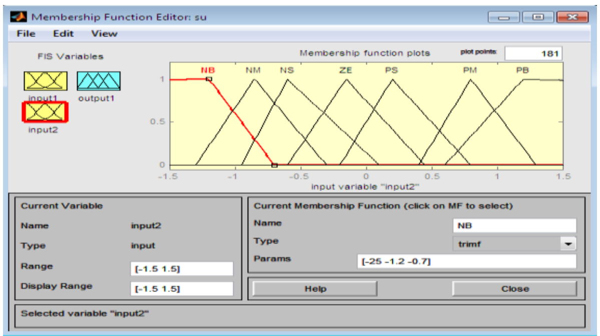

Fig. 6.Membership Function (MF) of input 2

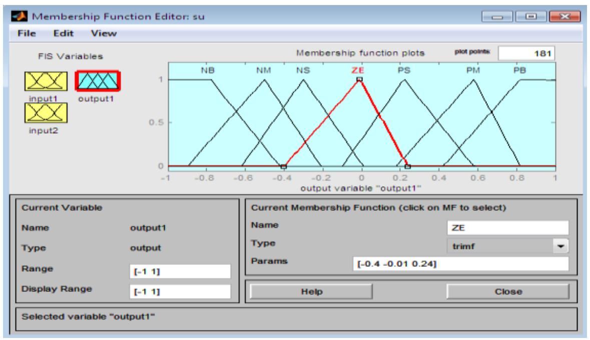

Fig. 7.FLC output

The FLC is linguistic variables use MF and rules and it process the input and generate the output. This control method is faster and simple control method.

B. Sliding Mode Controller

In SMC utilized in grid connected inverter for reducing the THD in inverter current. The error input is calculated from the differences of inverter output voltage (V_O) and reference voltage (V_{ref}). The block diagram of sliding mode controller is shown in Fig. 8. SMC decreases the steady state error (E_S) because the converter maintained the stable frequency. The controller increase the capability of system order reduction and on off power semiconductors, and robustness. E_S

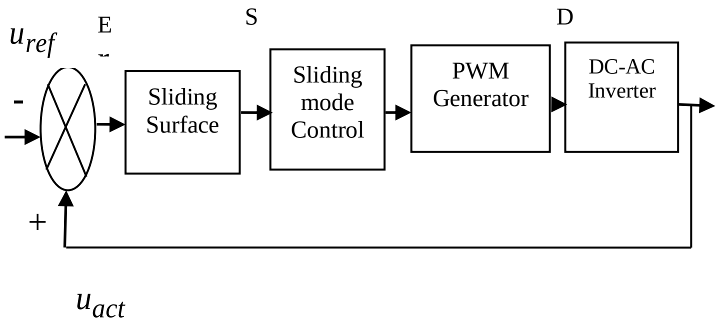

Fig. 8.Block Diagram of Sliding Mode Controller

The sliding surface S is chosen is given in equation.

$$Error = u_{act} - u_{ref} \tag{8}$$

$$S = C \cdot Error + \dot{Error} \tag{9}$$

Where C is a positive constant, Error is the tracking voltage of inverter output, $\dot{Error}$ is the derivative of Error. The sliding mode controller has generate the duty cycle is given in equation.

$$D = \frac{1}{2}\left[1 + \frac{L_{ac}C_{ac}}{u_{dc}}\left(\ddot{u}_{ref} + \frac{\dot{u}_{act}}{R_L C_{ac}} + \frac{u_{act}}{L_{ac}C_{ac}} - C\,\dot{Error} - KS\right)\right] \tag{10}$$

Where K is positive constant.

IV. SIMULATION RESULTS

The comparison of fuzzy control in bidirectional converter fed grid system for photovoltaic power generation is simulated using MATLAB/Simulink. The Simulink platform is used for modeling, simulating and analyzing the performance of proposed grid based BDC system. The control scheme of fuzzy and SMC is used to improve the efficiency in a grid connected bidirectional converter and inverter. The simulation results are validated and presented according to the following measurements: THD and voltage regulation. The overall circuit configuration of simulation block represent in Fig. 9. Fig. 10 shows the Simulink Model of SMC.

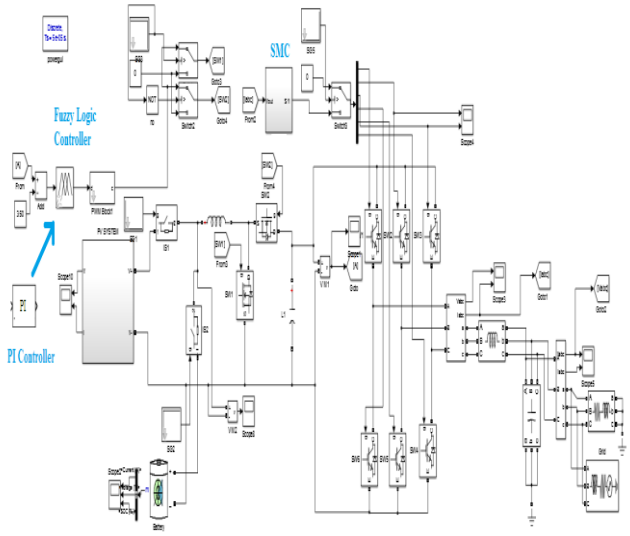

Fig. 9.Simulink Model of Overall Grid Connected Bidirectional Converter

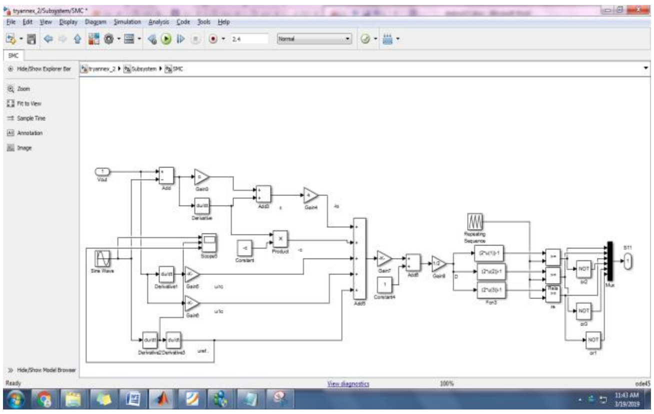

Fig. 10. Simulink Model of Sliding Mode Controller

The DC link voltage of BDC using fuzzy control is shown in Fig. 11. The output voltage and current of the bidirectional inverter is shown in Fig. 12. The total harmonic distortion of grid connected inverter using fuzzy has shown in Fig. 13. Table 2 represents the comparison of DC link voltage and %THD values PI and fuzzy control. The simulation parameters are given in table I. Table II gives the comparison %value of THD using PI and fuzzy control.

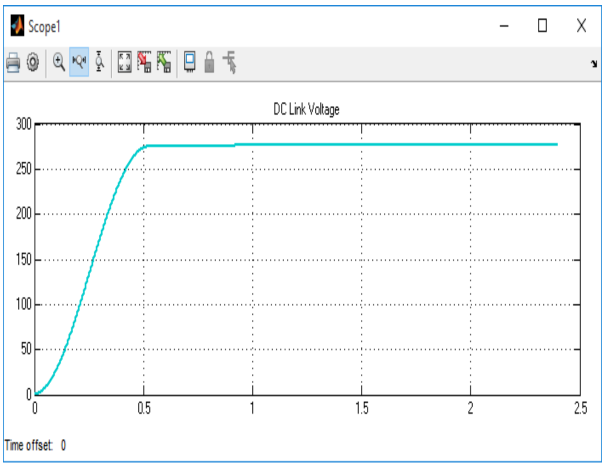

Fig. 11. DC Link Voltage of Bidirectional Converter System using FLC

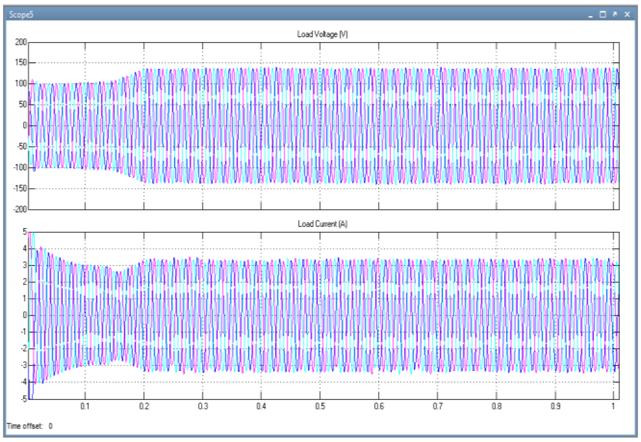

Fig. 12. Three Phase Voltage and Current waveform across Grid System

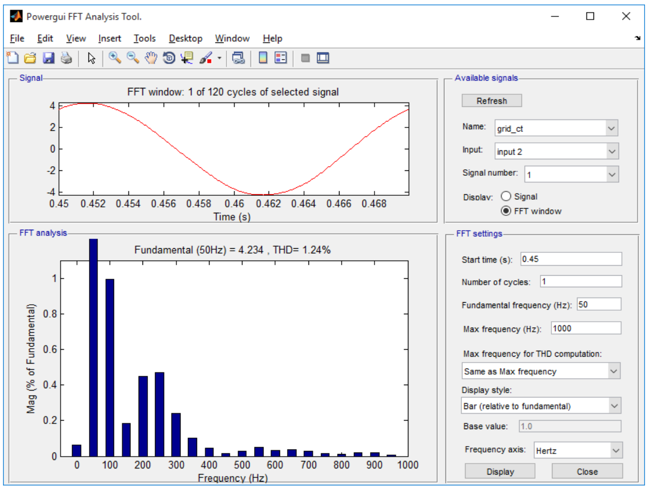

Fig. 13. Total Harmonic distortion in Grid current using FLC

Table- I: Simulation Parameter

Parameter	Value
Solar Voltage (V)	110V
Battery Capacity and Voltage	110V
Switching Frequency	5000Hz
Bidirectional Inductor	5mH
Bidirectional Capacitor	130mF
Inductive Filter	47mH
Capacitive Filter	80e-6F

Table- II: DC link, %THD of PI Control and Fuzzy

Parameter	DC Link Voltage (V)	THD (%)
PI	160	1.47
Fuzzy	280	1.24

V. CONCLUSION

The hybrid energy generation system based on bidirectional converters are utilized FLC control for voltage improvement, reduce the settling time and reduce the total harmonic distortion.

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The solar and battery used to extract the maximum power using FLC and fed to bidirectional converter followed by bidirectional inverter. The control methods of converter have fuzzy control for voltage regulation and enhance the voltage gain. The sliding mode controller is utilized in bidirectional inverter for decrease the THD. The proposed BDC fed grid method is operated in both forward and reverse power and it is verified in simulation results.

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