Research Inventy: International Journal of Engineering And Science
Vol.4, Issue 3 (March 2014), PP -77-87
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

Fuzzy Based Switched Boost Inverter for Microgrid Applications

A.Santosh*, Gandhi**
, EEE Department, SreeDattha Institute of Engineering & Science*

Abstract: *Renewable energy sources (RES) place main role in present days to generate power. The Switched Boost Inverter is a single stage dc-ac power converter, whose output voltage can be either greater or less than its input dc voltage. This converter can supply both dc and ac loads, simultaneously, which makes it suitable for micro grid applications. Also, this converter allows shoot-through of the inverter legs without causing any damage to the converter. In this paper, the principle of operation of the Switched Boost Inverter is explained in detail and the expression for its conversion ratio is derived. Also, a Pulse Width Modulation (PWM) control strategy for the Switched Boost Inverter is formulated and implemented using a simple analog circuit. The harmonics spectrum of the inverter's output voltage with the proposed PWM technique is plotted and compared with that of a traditional voltage source inverter (VSI). Z-Source inverters have recently been proposed as an alternative power conversion concept as they have both voltage buck and boost capabilities. These inverters use a unique impedance network, coupled between the power source and converter circuit, to provide both voltage buck and boost properties, which cannot be achieved with conventional voltage-source and current-source inverters. Fuzzy controller is the best controller compare to PI controller and fuzzy controller is fast response and steady state response time also very less compare with PI controller that reason we use PI replace with fuzzy controller. In this work PV as the input source and the PI placed with fuzzy controller in switched boost inverter is applied to a Microgrid system. The simulations results are obtained by MATLAB/SIMULINK software.*

Keywords: *Renewable energy sources (RES), Pulse Width Modulation (PWM), voltage source inverter (VSI), Switched Boost Inverter, Photovoltaic (PV) system, PI controller and fuzzy controller.*

I. Introduction

The sale of electric energy generated by photovoltaic plants has attracted much attention in recent years. The installation of PV plants aims to obtain the maximum benefit of captured solar energy. The different techniques of modeling and control of grid connected photovoltaic system with objective to help intensive penetration of photovoltaic (PV) production into the grid have been proposed so far in different papers. The Z-Source inverter is a new and attractive topology for the power electronics interface. In recent Years, renewable energy is becoming increasingly important in distribution System, which provide different choice to electricity consumers whether they receive power from the main electricity source or in forming a micro source not only to fulfill their own demand but alternatively to be a power producer supplying a microgrid.

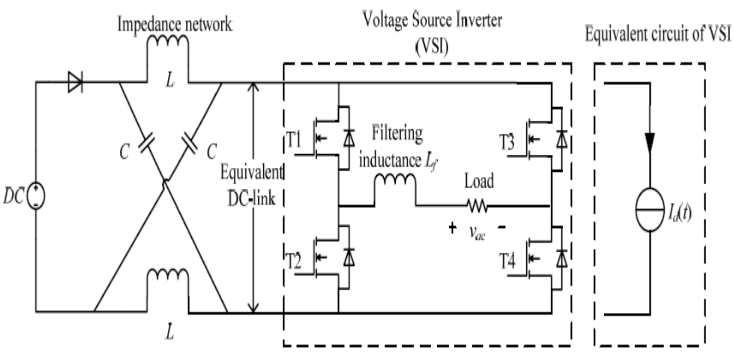

Fig.1 Single-phase full bridge Z-Source inverter

The DC-side of a conventional single-phase full bridge voltage source inverter is modified with a unique X-shape impedance network, which is known as the Z-Source network. Therefore, shoot-through state, which is strictly forbidden in conventional voltage source inverters, is allowed and implemented here for voltage boosting purposes. Since the capacitor in the Z-Source network may be charged to a higher voltage than the DC source, a diode is connected to prevent possible discharging. To realize the bidirectional power flow characteristic, the diode can be replaced with an IGBT with anti-paralleled diode to form a bidirectional Z-Source converter.

A microgrid usually includes various micro-sources and loads. Micro-source categories are comprised of diverse renewable energy applications, Such as solar cell modules and fuel cell stacks. The boost converter is used to increase the output voltage of the micro-source from 230-250V for the dc interface to the main electricity source through the dc-ac inverter [1],[2],[3].Both the single solar cell module and the fuel cell stacks are low voltage sources, thus a high step-up voltage gain dc-dc converter is required to regulate the voltage of the dc – dc interface. The conventional Boost converters cannot provide such a high dc voltage gain, even for an extreme duty cycle. It also may results in serious reverse –recovery problems and increases the rating of all devices. This paper presents a novel power converter called switched boost inverter (SBI) which works similarly to a ZSI. This converter uses more active components and lower number of inductors and capacitors compared to the original ZSI while retaining its operational advantages. As a result, the conversion efficiency is degraded and the electromagnetic interference (EMI) problem is severe under this situation.

II. Switched Boost Inverter

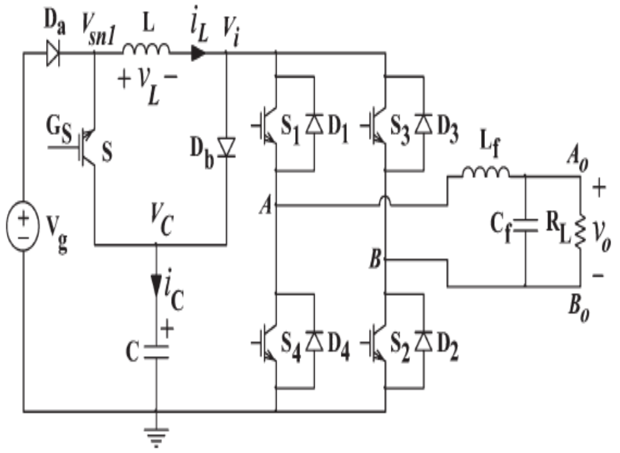

Fig.2 Circuit diagram of SBI topology

Fig. 2 shows the schematic of the SBI in which a switched boost network comprising of one active switch (*S*), two diodes (*Da*, *Db*), one inductor (*L*), and one capacitor (*C*) is connected between voltage source *Vg* and the inverter bridge. A low-pass *LC* filter is used at the output of the inverter bridge to filter the switching frequency components in the inverter output voltage *v*AB. Similar to a ZSI, the SBI also utilizes the shoot-through state of the H-bridge inverter (both switches in one leg of the inverter are turned on simultaneously) to boost the input voltage *Vg* to *VC*.

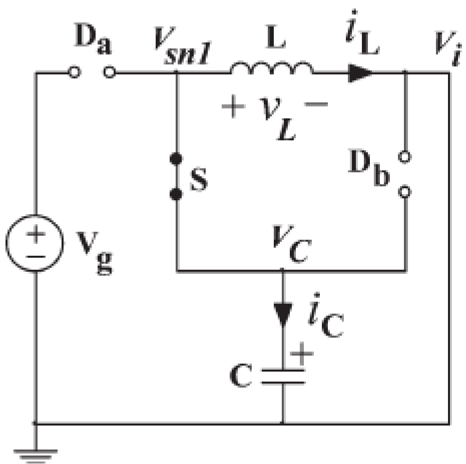

Fig. 3 Equivalent circuit of SBI during *D.TS* interval

The switch *S* is also turned on during this interval. As shown in the equivalent circuit of Fig. 3, the inverter bridge is represented by a short circuit during this interval. The diodes *Da* and *Db* are reverse biased (as *VC* >*Vg*), and the capacitor *C* charges the inductor *L* through switch *S* and the inverter bridge. The inductor current in this interval equals the capacitor discharging current. For the remaining duration in the switching cycle (1 − *D*).*TS*, the inverter is in non-shoot-through state, and the switch *S* is turned off.

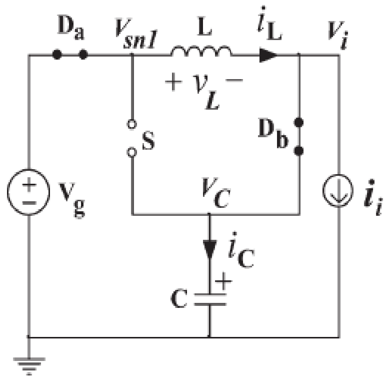

Fig.4 Equivalent circuit of SBI during (1 − D).TS interval

The inverter bridge is represented by a current source in this interval as shown in the equivalent circuit of Fig. 4 Now the voltage source *Vg* and inductor *L* together supply power to the inverter and the capacitor through diodes *Da* and *Db*. The inductor current in this interval equals the capacitor charging current added to the inverter input current. Note that the inductor current is assumed to be sufficient enough for the continuous conduction of diodes *Da* and *Db* for the entire interval (1 − *D*).*TS*.

III. PWM Control Of SBI

The SBI utilizes the shoot-through state of VSI to boost the input voltage *Vg*, whereas the traditional PWM techniques of VSI do not permit the inverter bridge to be in shoot-through state. This section describes two different PWM techniques suitable for SBI.

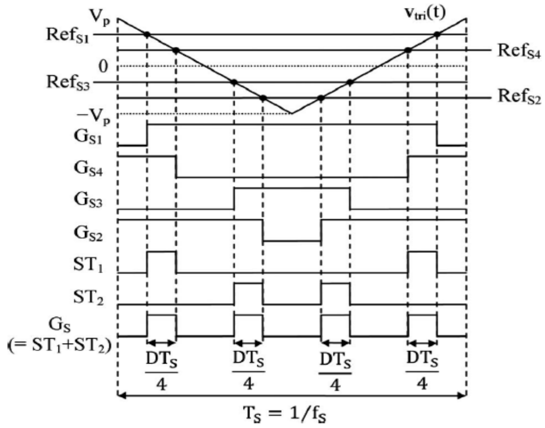

Fig. 5 Generation of control signals for SBI using traditional PWM technique of ZSI

Fig. 5 shows the gate control signals for SBI obtained using the traditional PWM technique of ZSI. In this scheme, the gate control signals *G*SX (*x* = 1 to 4) are generated by comparing the reference signals *Ref*SX (*x* = 1 to 4) with a triangular carrier signal *v*tri(*t*) of amplitude *Vp*. The signal *G*SX becomes high whenever the value of the corresponding reference signal becomes either higher or lower than that of the carrier. The gate control signal (*GS*) for switch *S* is obtained by adding the two individual shoot-through periods *ST*1 and *ST*2 as shown in the figure.

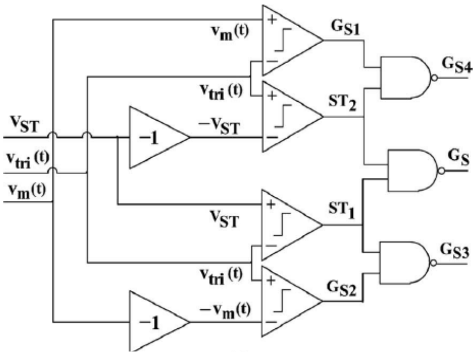

Fig.6 Schematic of the PWM control circuit

Fig. 6 shows the schematic of the control circuit to generate the PWM control signals for the converter using the modified PWM control scheme, The signals $ST1$ and $ST2$ are generated by comparing $v$tri(t) with two constant voltages VST and $-V$ST, respectively. The purpose of these two signals is to insert the required shoot-through interval $D.TS$ in the gate control signals of the inverter bridge. The comparison of SBI and ZSI for the same input voltage, capacitor voltage, output voltage, and output power.

IV. Photovoltaic System

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices.

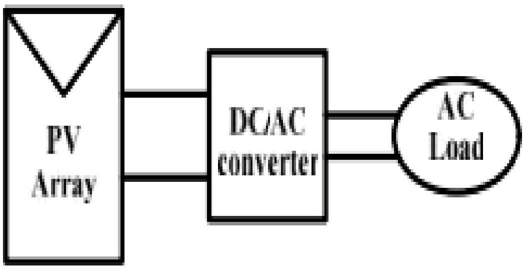

Fig.7. Block diagram representation of Photovoltaic system

This photovoltaic system consists of three main parts which are PV module, balance of system and load. The major balance of system components in this systems are charger, battery and inverter. The Block diagram of the PV system is shown in Fig.7. A photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited1

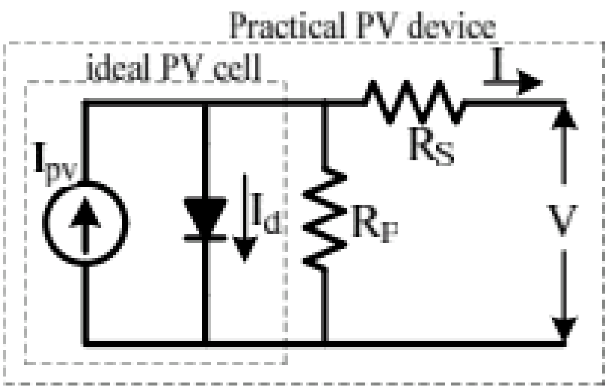

Fig.8 Practical PV device

The equivalent circuit of PV cell is shown in the fig.8 In the above figure the PV cell is represented by a current source in parallel with diode. Rs and Rp represent series and parallel resistance respectively. The output current and voltage form PV cell are represented by I and V. The I-V characteristics of PV cell are shown in fig.9. The net cell current I is composed of the light generated current IPV and the diode current ID.

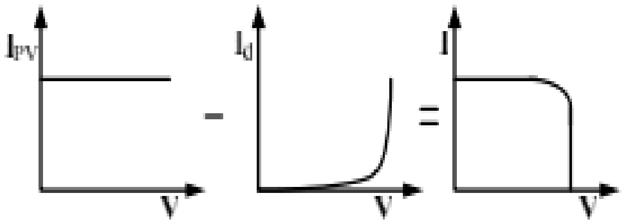

Fig.9 Characteristics I-V curve of the PV cell

V. Introduction To Fuzzy Logic Controller

The first paper on fuzzy set theory in 1965, since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to dc-to-dc converter system. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of dc-to-dc converter and performance of proposed controllers. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of dc-to-dc converters. The basic scheme of a fuzzy logic controller is shown in Fig 10 and consists of four principal components such as: a fuzzification interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action.

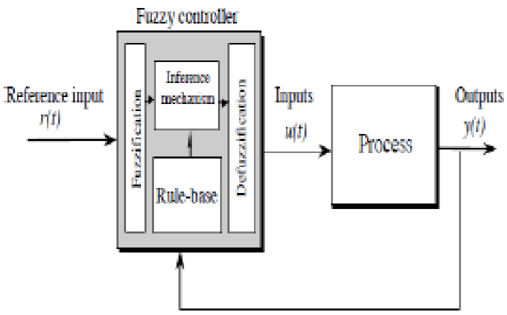

Fig.10 General Structure of the fuzzy logic controller on closed-loop system

The fuzzy control systems are based on expert knowledge that converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model. Simulation is performed in buck converter to verify the proposed fuzzy logic controllers.

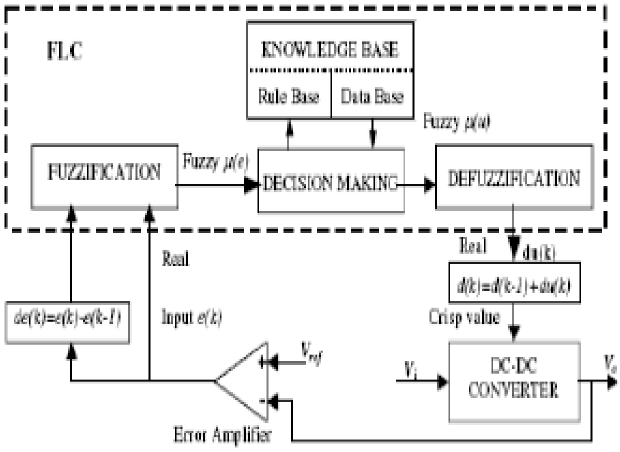

Fig.11 Block diagram of the Fuzzy Logic Controller (FLC) for dc-dc converters

A. Fuzzy Logic Membership Functions:

The dc-dc converter is a nonlinear function of the duty cycle because of the small signal model and its control method was applied to the control of boost converters. Fuzzy controllers do not require an exact mathematical model. Instead, they are designed based on general knowledge of the plant. Fuzzy controllers are designed to adapt to varying operating points. Fuzzy Logic Controller is designed to control the output of boost dc-dc converter using Mamdani style fuzzy inference system. Two input variables, error (e) and change of error (de) are used in this fuzzy logic system. The single output variable (u) is duty cycle of PWM output.

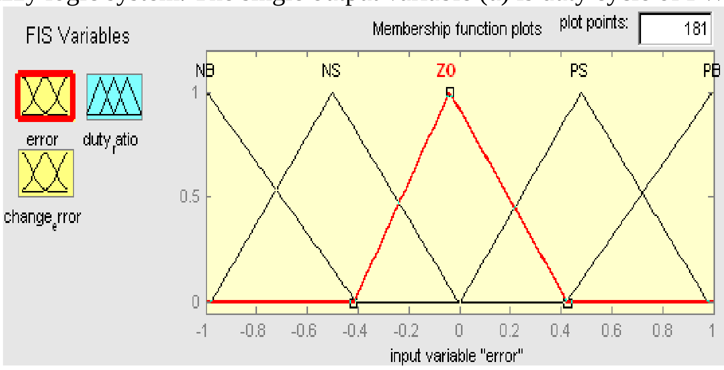

Fig. 12 The Membership Function plots of error

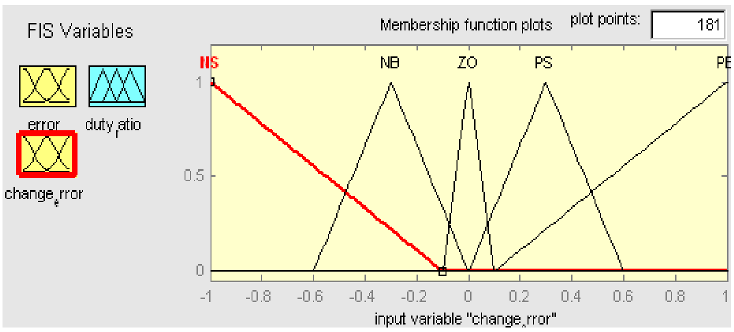

Fig.13 The Membership Function plots of change error

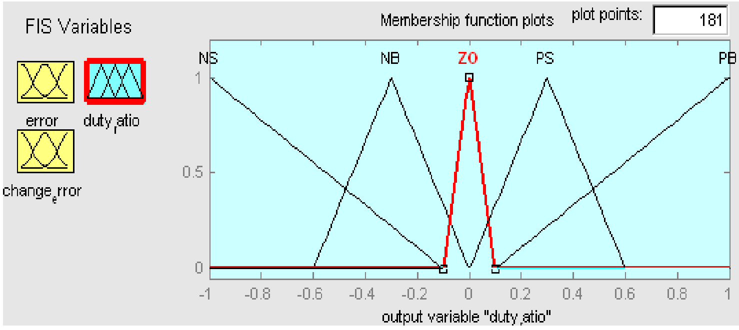

Fig.14 The Membership Function plots of duty ratio

B. *Fuzzy Logic Rules:*

The objective of this dissertation is to control the output voltage of the boost converter. The error and change of error of the output voltage will be the inputs of fuzzy logic controller. These 2 inputs are divided into five groups; NB: Negative Big, NS: Negative Small, ZO: Zero Area, PS: Positive small and PB: Positive Big and its parameter. These fuzzy control rules for error and change of error can be referred in the table that is shown in Table as per below:

Table I Table rules for error and change of error

(e) / (de)	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	ZO
NS	NB	NB	NS	ZO	PS
ZO	NB	NS	ZO	PS	PB
PS	NS	ZO	PS	PB	PB
PB	ZO	PS	PB	PB	PB

VI. Simulation Results

Here the simulation results carried out by two cases. 1) proposed switched boost inverter 2) SBI with fuzzy controller.

CASE-1 proposed switched boost inverter

The below figures shows the MATLAB/SIMULINK results of the proposed system, The below figure shows the MATLAB/SIMULINK circuit of the proposed system

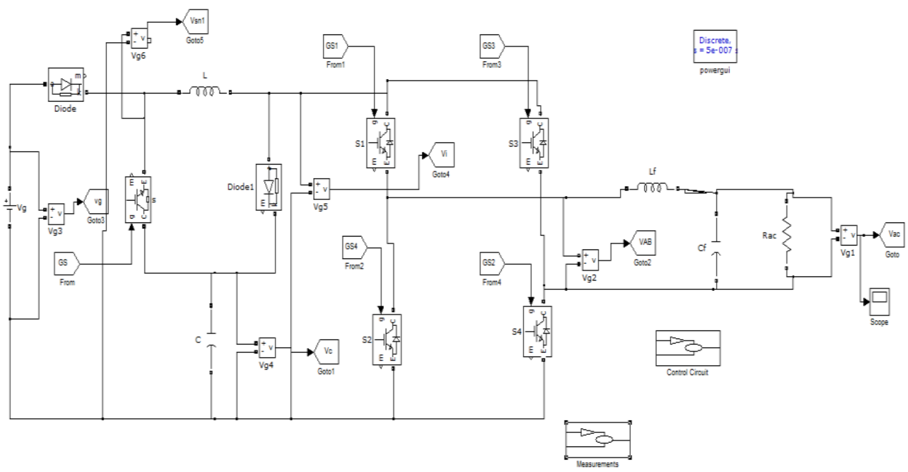

Fig. 15 Matlab/simulink model of switched boost inverter

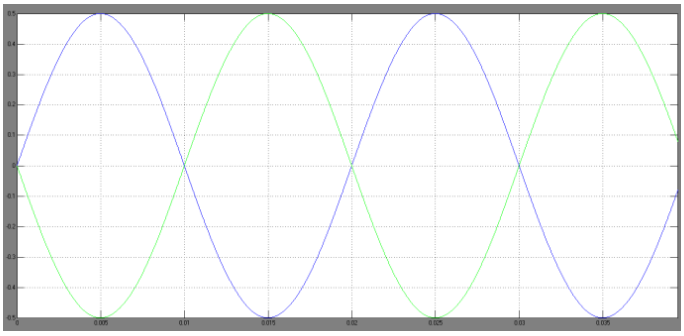

Fig.16 Sinusoidal modulation signals $vm(t)$ and $-vm(t)$ of SBI

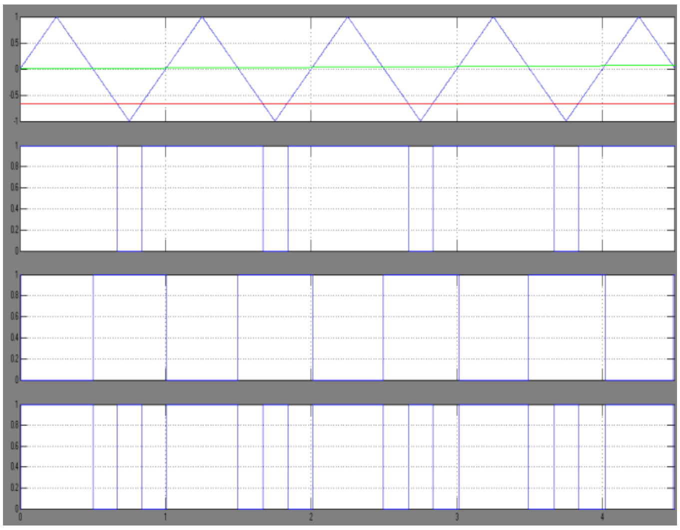

Fig.17 Generation of shoot-through in leg A,

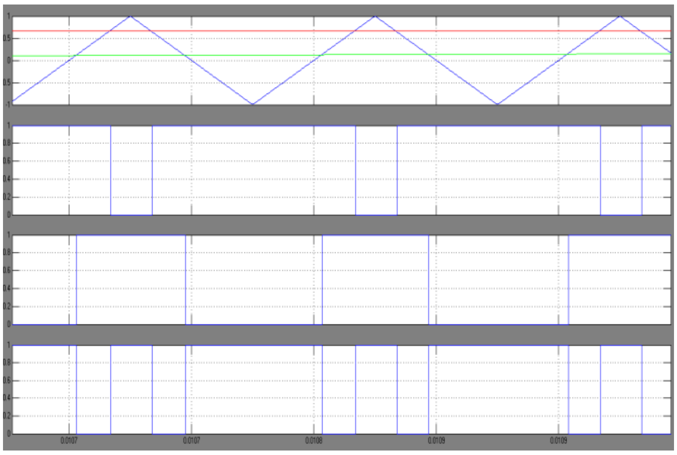

Fig.18 Generation of shoot-through in leg B

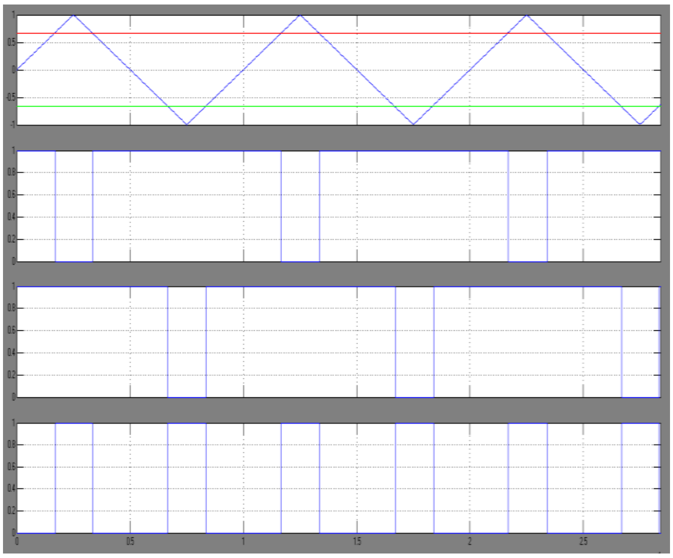

Fig.19 Generation of gate signal for switch *S*

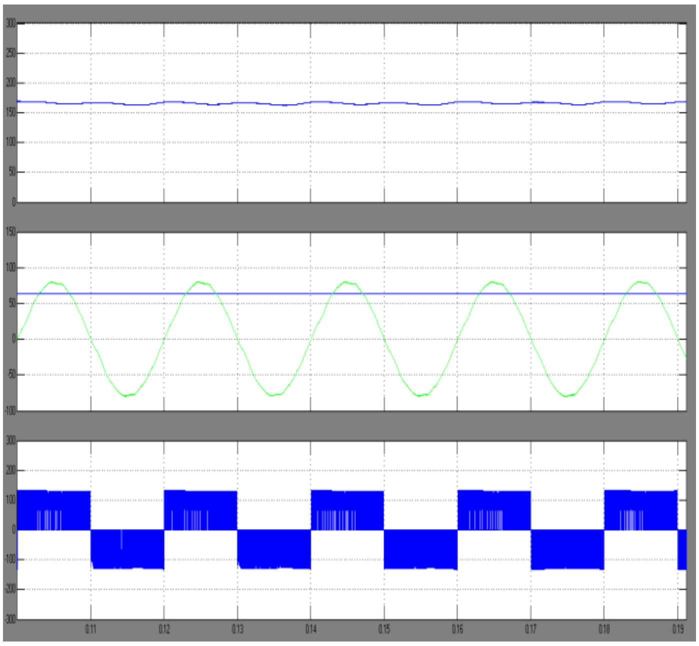

Fig.20 Steady-state operation of the SBI Input voltage (*Vg*), capacitor voltage (*VC*), output voltage of H-bridge (*V*AB), and load voltage (*VO*)

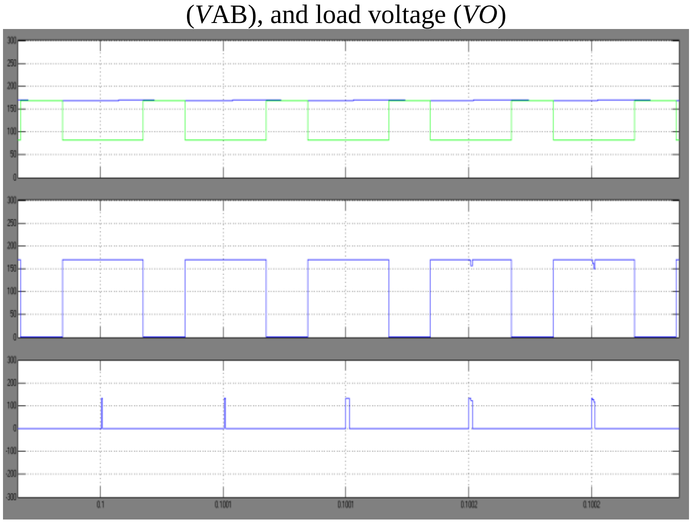

Fig.21 capacitor voltage (*VC*), switch node 1 voltage (*V*sn1), output voltage of H-bridge (*V*AB), and inverter input voltage (*Vi*).

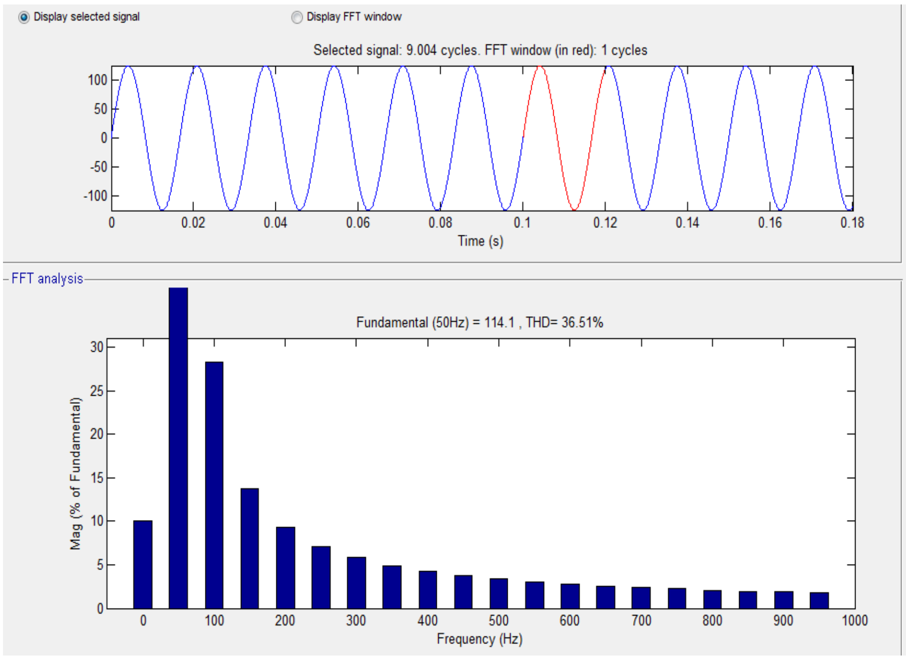

Fig.22 FFT analysis of inverter output voltage with PI controller is 36.51%

CASE-2 SBI with fuzzy controller

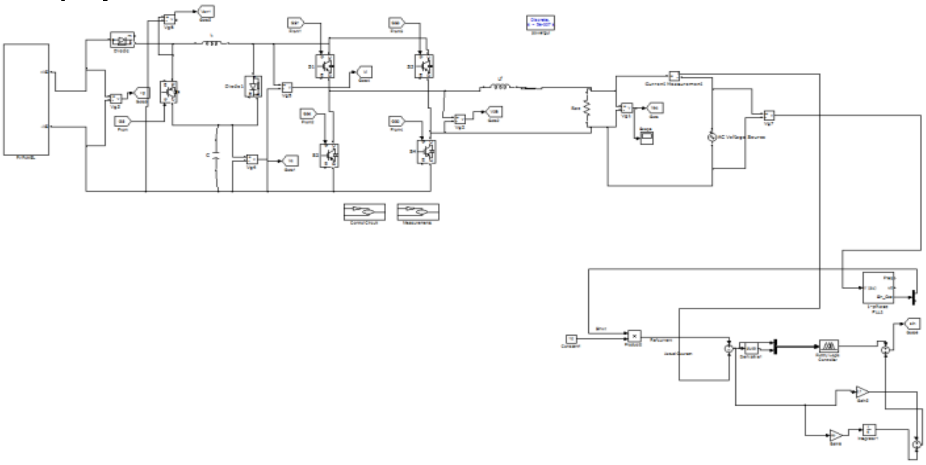

Fig.23 Matlab/simulink model of switched boost inverter with fuzzy controller

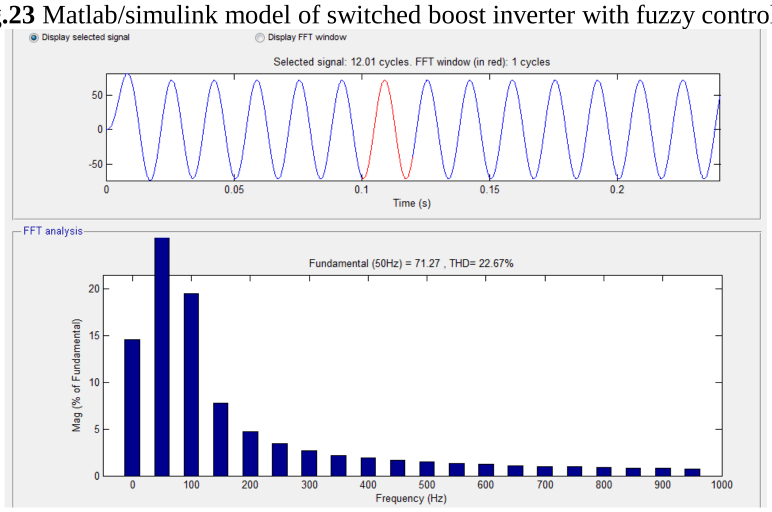

Fig.24 FFT analysis of inverter output voltage with fuzzy controller without filter is 22.67%

VII. Conclusion

In this paper mainly reduced the total harmonic distortion (THD) value of the inverter output voltage using fuzzy logic controller in the place of PI controller. The switched boost inverter output voltage THD value with PI controller is 36.51% and using fuzzy logic controller is 22.67%. This study has developed a high voltage gain Boost converter to achieve the High step-up voltage gain with voltage. The proposed converter has been highly efficient because it recycles the energy stored in leakage inductor. Comparison of the SBI and ZSI with the same input and output parameters are placed in this paper. It was shown that this topology exhibits properties similar to that of ZSI with lower number of passive components. We can use the filter to reduce the THD value less than 5% by place the different sizes of filters. This may lead to significant reduction in the size, weight, and cost of the power converter and makes it suitable for low-power applications. Total simulation results are verified by using MATLAB/SIMULINK software.

References

[1]. J.L. Davies, M. Malengret , "Ap p lication of induction motor for solar water p ump ing" , AFRICON '92 Proceedings., 3rd AFRICON Conference, pp. 209 – 212, 1992.

[2]. B. Krop oski, R. de Blasio, "Technologies for the new millennium: Photovoltaics as a distributed resource," Proc. IEEE Power Eng. Soc. Summer Meeting,Vol. 3, pp. 1798–1801, 2000.

[3]. Pollikas A., Implementation of distributed generation technologies in isolated power, *Renewable and Sustainable Energy Reviews,* Vol. 11, 2007, pp. 30-56.

[4]. Q. Li, and P. Wlfs, A review of single phase photovoltaic module integrated converter topologies with three different DC link configurations, *IEEE Transactions on Power Electronics,* Vol. 23, No. 3, May 2008, pp. 1320-1333.

[5]. M. Calais, J. Myrzik, T. Spooner, and V.G. Agelidis, Inverters for single-phase grid connected photovoltaic systems-An overview, *IEEE Proceedings PESC,* Vol. 4, 2002, pp. 1995-2000.

[6]. J. Liu, J. Hu, and L. Xu, "Dynamic modeling and analysis of Z source converter-derivation of ac small-signal model and design-oriented analysis," *IEEE Trans. Power Electron.*, vol. 22, no 5, pp. 1786–1796, Sep. 2007.

[7]. R. W. Erickson and D. Maksimovic, *Fundamentals of Power Electronics,*2nd ed. Norwell, MA: Kluwer, Jan. 2001.

[8]. N. Mohan, T. Undeland, and W. Robbins, *Power Electronics: Converters, Applications and Design,* 2nd ed. New York: Wiley, 1995.

[9]. P. C. Loh, D. Vilathgamuva, Y. S. Lai, G. Chua, and Y. Li, "Pulse-width modulation of Z-source inverters," *IEEE Trans. Power Electron.*, vol. 20, no. 6, pp. 1346–1355, Nov. 2005.

[10]. Z. J. Zhou, X. Zhang, P. Xu, andW. X. Shen, "Single-phase uninterruptible power supply based on Z-source inverter," *IEEE Trans. Ind. Electron.*, vol. 55, no. 8, pp. 2997–3004, Aug. 2008.

[11]. S. Upadhyay, S. Mishra, and A. Joshi, "A wide bandwidth electronic load," *IEEE Trans. Ind. Electron.*, vol. 59, no. 2, pp. 733–739, Feb. 2012.