

Grid Connected DC-AC Boost Inverter

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ABSTRACT: The aim of this paper is to analyze the performance of a boost DC - AC converter, referred to as boost inverter, features an excellent property: It naturally generates an output AC voltage lower or larger than the input DC voltage, depending on the duty cycle. This property is not found in the classical voltage source inverter which produces an AC instantaneous output voltage always lower than the input DC voltage. For the purpose of optimizing the boost inverter dynamics, while ensuring correct operation in any working condition. This project deals with simulation of grid connected dc-ac boost inverter which includes a closed loop non linear state variables are used to overcome the difficulties in complex method conversion. The boost inverter convert dc-ac in a single stage operation. The simulation results in matlab software shows the waveforms of load voltage, switching operation, load current, and grid current also measured. In this method to use photovoltaic cell charging the battery to connect input supply and the output connect the grid .

I. INTRODUCTION

The scheme is to develop a new control strategy for boost DC-AC inverter, having a two current bi-directional boost DC-DC converters functioning in a complementary mode. Therefore the main scope of this project work lies in the designing of a simple controller for boost DC-AC inverter. Non-Linear Variable Structure (NLVS) controller is proposed for boost DC-AC inverter. The boost inverter is used to control the variable input DC voltage to constant AC output voltage and also the voltage, frequency, phase angle of controller are measured.

II. BOOST INVERTER AND ITS OPERATION

The grid connected and standalone solar power inverters are generally switched mode power circuits (SMPCs) and their outputs are derived from coupling one or more basic switch topologies. Inverters are inverts the variable dc output of photovoltaic (PV) modules (Alajmi et al 2013) into a constant AC voltage with a fundamental utility frequency that can be fed into the commercial electrical grid or off grid electrical network. The falling of conventional energy sources, increasing of different pollutions and the ever increasing demand of the fossil fuels are motivating the engineering society to involve more investigation in the renewable power generation and the development of alternative energy sources which are less or zero pollution and eco-friendly (Bull 2001). Many renewable sources such as wind energy, biogas and solar are now well developed as the cost effective solution for many applications. Moreover the solar energy has become one of the most hopeful sources of energy as they are pollution less and fuel free. Beside this, solar energy is easy to adopt with existing power converters (Rong-Jong Wai & Wen-Hung Wang 2008, Rafia Akhter 2007, Brad Bryant & Marian Kazimierczuk 2005). In conventional solar power system consists of two or more power conversion stages for satisfying the requirement of single phase ac load or grid.

Therefore the increasing of number of power conversion stages, the system will result in high power loss, large size, high total harmonic distortion, more space, more weight and high cost. Also filter is needed for converting square wave ac voltage into sine wave ac voltage, because output voltage of the voltage source inverter is square wave.

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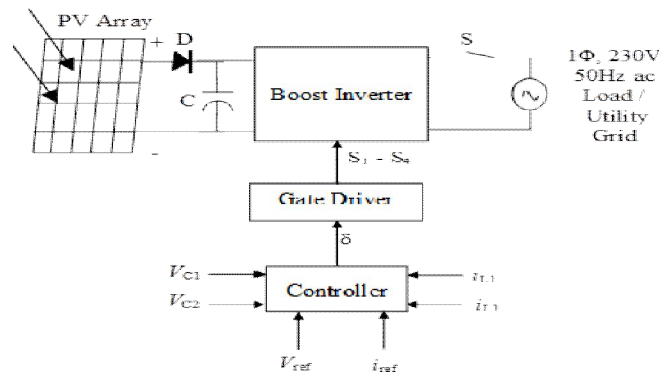


Figure 2.1 Block diagram of proposed single stage solar power generation system

The proposed solar power generation topology overcomes the drawbacks of the conventional solar power generation system. The system consists of solar PV array and boost inverter as shown in figure 5.1. In the proposed inverter topology, a low dc voltage of photovoltaic array is boosted and inverted into a 220V rms AC voltage at a fundamental frequency in a single stage.

Caceres & Barbi (1999) had proposed single stage boost inverter with sliding mode controller previously. Also Pablo Sanchis et al (2005), developed and proposed a new control strategy for this boost DC-AC inverter, having a two current bi-directional boost dc-dc converters functioning in a complementary method. Therefore the main scope of this research work lies in the designing of a simple controller for boost DC-AC inverter.

There are four controllers such as Modified Non-Linear State Variable Structure (MNLVS) controller, Sinusoidal Pulse Width Modulation (SPWM) converter. When the switch is OFF, the diotechnique based controller, Fuzzy Logic Controller (FLC) and Comparator based Non-Linear Variable Structure (NLVS) controller are proposed for boost DC-AC inverter. The results of four proposed controllers are compared and analyzed in the further chapters.

2.1 Boost DC-AC inverter

The design and development of boost DC-AC inverter has been elaborated in this chapter in detail. The boost inverter is designed and constructed by the switching device IGBTs, inductors, capacitors and diodes. The switching devices should be switched at the different switching period.

The boost DC-AC inverter consists of two separate current bi-directional boost dc-dc converters (Caceres & Barbi 1999) as shown in Figure 5.2 and Figure 5.4 which produce a dc- biased sine wave output so that each source produces only a unipolar voltage as shown in Figure 5.3.

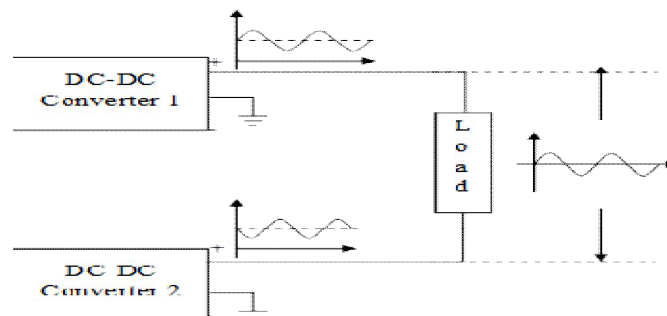


Figure 2.2 Basic arrangements of two current bidirectional dc-dc boost converters

The modulation on each converter is 180° out of phase with the other, which maximizes the voltage available across the load. The load is connected differentially across the two converters. The dc bias voltage of each converter appears at each end of the load and differential dc voltage across the load is zero with respect to ground.

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The main advantage of this single stage boost DC-AC inverter is the reduced number of power conversion stages, because it boosts and inverts in the single stage itself with smooth sine wave output voltage. The output voltage of each converter is

$$V_1 = V_{dc} + V_m \sin \omega t \quad (3.1)$$

$$V_2 = V_{dc} - V_m \sin \omega t \quad (3.2)$$

Voltage across the load is given by

$$V_O = V_1 - V_2 = 2V_m \sin \omega t \quad (3.3)$$

The Equation (3.3) describes the output voltage of the boost inverter which is double the input and also the dc power is boosted and inverted in a single stage.

3 Dc-dc converter-1 circuit description

The operation of the proposed boost dc-dc converter is explained with the help of electrical equivalent circuit of dc-dc boost converter-1 as shown in Figure 5.5.

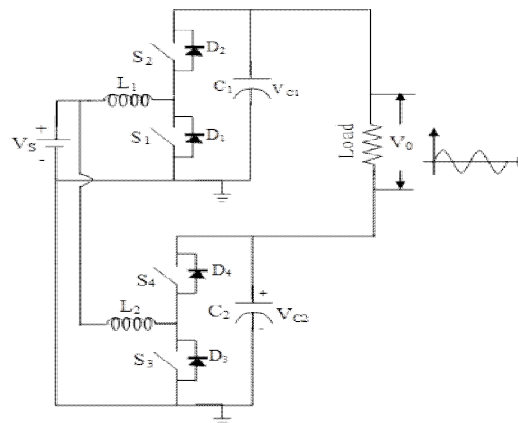


Figure 3.1 Proposed boost DC-AC inverter

The electrical equivalent circuit consists of dc supply voltage Vs, input inductors L1 and L2, power switches S1-S4, capacitors C1 and C2 freewheeling diodes D1-D4 and load resistance RL. Converter-1 operates in a continuous conduction mode when assuming that all the components are ideal and there are two modes of operation.

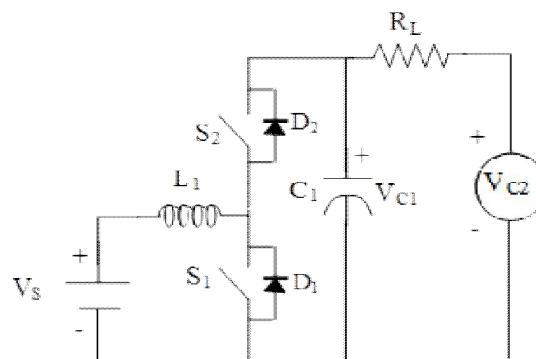


Figure 3.2 Electrical equivalent circuit of dc-dc boost converter-1

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Mode1:

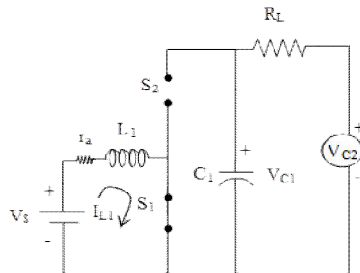


Figure 3.3(a) Operation of the dc-dc boost converter-1; Mode 1: Power switches S1=CLOSED; S2 = OPEN

When the power switch S1 is closed and S2 is open Figure 5.6 (a), the current i_{L1} rises quite linearly, diode D2 is reverse polarized, capacitor C1 supplies energy to the output stage and voltage V_{C1} decreases.

Mode2:

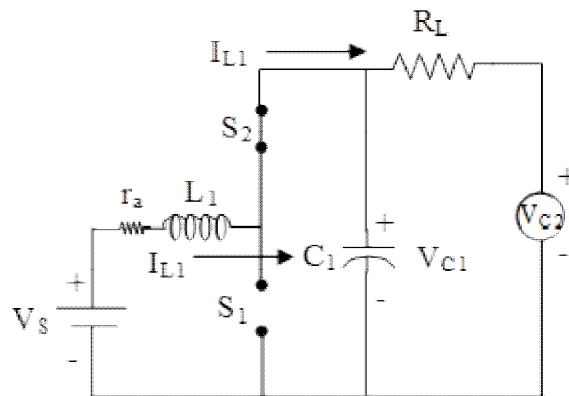


Figure 3.3(b) Mode 2: Power switch S1=OPEN; S2 = CLOSED

When the power switch S1 is open and S2 is closed Figure 5.6 (b), the current i_{L1} flows through capacitor C1 and the load, the current i_{L1} decreases while capacitor C1 recharged.

The conduction mode of the converter-1 is given by and the conduction mode of the converter 2 is given by

Where D is the duty cycle, V_{C1} is the voltage across the capacitor of the converter-1 and V_{C2} is the voltage across the capacitor of the converter-2, V_s is the input voltage to the Boost sine wave DC-AC converter.

Since the two converters are 180° out of phase, the output voltage is given by

$$V_0 = V_{C1} - V_{C2} \quad (3.4)$$

$$\frac{V_s}{1-D} - \frac{V_s}{D} \quad (3.5)$$

$$\frac{V_0}{V_s} = \frac{2D-1}{(1-D)D} \quad (3.6)$$

The gain characteristics of the boost inverter has been shown in the form of Equation (3.6) where zero output voltage is obtained for $D=0.5$. There is an ac voltage at output terminals, if the duty cycle is varies around this point. Also the

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output of the boost inverter is less than or greater than the input voltage depends on the duty cycle (D) as shown in Figure 3.4

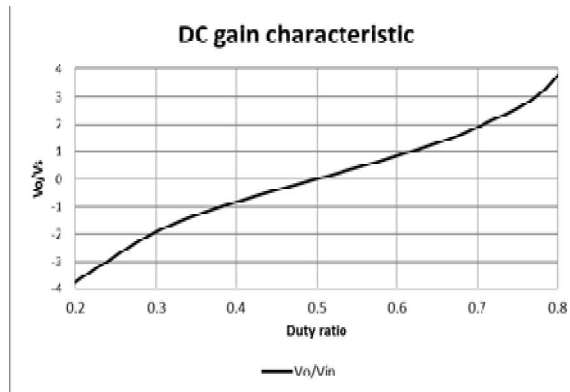


Figure 3.4 DC gain Characteristics

4 Choosing the proper gain values

The state space modeling of the equivalent circuit with state variables i_{L1} and V_{C1} by considering the internal resistance of inductor is

By applying KVL to the mode-1

$$V_S = i_{L1}r_a + L_1 \frac{di_{L1}}{dt} + V_{C1} \quad (3.7)$$

$$\frac{di_{L1}}{dt} = -i_{L1} \frac{r_a}{L_1} - \frac{V_{C1}}{L_1} + \frac{V_S}{L_1} \quad (3.8)$$

By applying KVL to the mode-2

$$V_S = i_{L1}r_a + L_1 \frac{di_{L1}}{dt} + V_{C1} \quad (3.9)$$

$$\frac{di_{L1}}{dt} = -i_{L1} \frac{r_a}{L_1} - \frac{V_{C1}}{L_1} + \frac{V_S}{L_1} \quad (3.10)$$

By applying KCL to the mode-2

$$i_{L1} = \frac{V_{C1}}{R_L} - \frac{V_{C2}}{R_L} + C_1 \frac{dV_{C1}}{dt} \quad (3.11)$$

$$\frac{dV_{C1}}{dt} = \frac{i_{L1}}{C_1} - \frac{V_{C1}}{R_L C_1} + \frac{V_{C2}}{R_L C_1} \quad (3.12)$$

The state space model with state variables i_{L1} and V_{C1} from above Equations (3.8) and (3.12)

$$\begin{bmatrix} \frac{di_{L1}}{dt} \\ \frac{dV_{C1}}{dt} \end{bmatrix} = \begin{bmatrix} \frac{-r_a}{L_1} & \frac{-1}{L_1} \\ \frac{1}{C_1} & \frac{-1}{R_L C_1} \end{bmatrix} \begin{bmatrix} i_{L1} \\ V_{C1} \end{bmatrix} + \begin{bmatrix} \frac{V_S}{L_1} \\ \frac{-i_{L1}}{C_1} \end{bmatrix} \gamma + \begin{bmatrix} \frac{V_S}{L_1} \\ \frac{V_{C2}}{R_L C_1} \end{bmatrix}$$

$$\dot{x} = Ax + B\gamma + C \quad (3.13)$$

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Where γ is the status of the switches, and x are the vectors of the state variables

$$\gamma = \begin{cases} 1 \rightarrow S1ON, S2OFF \\ 0 \rightarrow S1OFF, S2ON \end{cases}$$

The variable structure control equation in the state space expressed by a linear combination of state variable errors ε_1 and ε_2 are gives a good transient response for the output voltage

$$\gamma(i_{L1}, V_{C1}) = k_1 \varepsilon_1 + k_2 \varepsilon_2 = 0 \quad (3.14)$$

Where coefficients K_1 and K_2 are proper gains

$$\varepsilon_1 = i_{L1} - i_{Lref} \quad (3.15)$$

$$\varepsilon_2 = V_{C1} - V_{Lref} \quad (3.16)$$

By substituting Equations (3.14) and (3.15) in (3.13),

$$\gamma(i_{L1}, V_{C1}) = k_1(i_{L1} - i_{Lref}) + k_2(V_{C1} - V_{Lref}) \quad (3.17)$$

The system response is determined by the state equations of circuit parameters and coefficients Equation (3.16). the values of K_1 and K_2 are obtained from the sliding mode control. The values of K_1 and K_2 are 0.197 and 0.020 respectively. These values of K_1 and K_2 produce fast response and good stability.

V. SIMULATIONS FOR DC-AC BOOST INVERTER

The optimum component values of L_1 , L_2 , C_1 and C_2 are obtained from the design and fine tuned based on simulation results. The simulation of the complete system is carried out in the MATLAB/SIMULINK environment.

5.1 Software Requirements

We are using mat lab Software with Version MATLAB 7.8.0. Which has two library Function called 1) SIM POWER SYSTEM 2) LIBRARY POWER LIB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or FORTRAN.

5.2 Interfacing Electrical Circuit with SIMULINK

The Voltage Measurement block acts as an interface between the Sim Power Systems blocks and the Simulink blocks. For the system shown above, you implemented such an interface from the electrical system to the Simulink system. The Voltage Measurement block converts the measured voltages into Simulink signals. Similarly, the Current Measurement block from the Measurements library of power lib can be used to convert any measured current into a Simulink signal. We can also interface from Simulink blocks to the electrical system. For example, we can use the Controlled Voltage Source block to inject a voltage in an electrical circuit. Fig.6.1 shows different load and voltage curve.

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To demonstrate the effectiveness of the proposed converter analysis, a simulation model of the proposed inverter is built and tested in the MATLAB simulink environment.

The closed-loop control unit of this circuit is based on microcontroller. The parameters of the boost inverter are described in Table 5.1.

Table 5.1: DATA UTILIZED COMPONENTS AND PARAMETERS OF PROTOTYPE

PARAMETERS	VALUES
Series RLC load	230V,50HZ
Ideal switch	0.001 Ohm
IGBT/Diode	1e ⁻³
Snubber circuit	1e ⁵
PV-controlled current source	DC
Inductance	65e ⁻³
capacitance	85e ⁻⁶

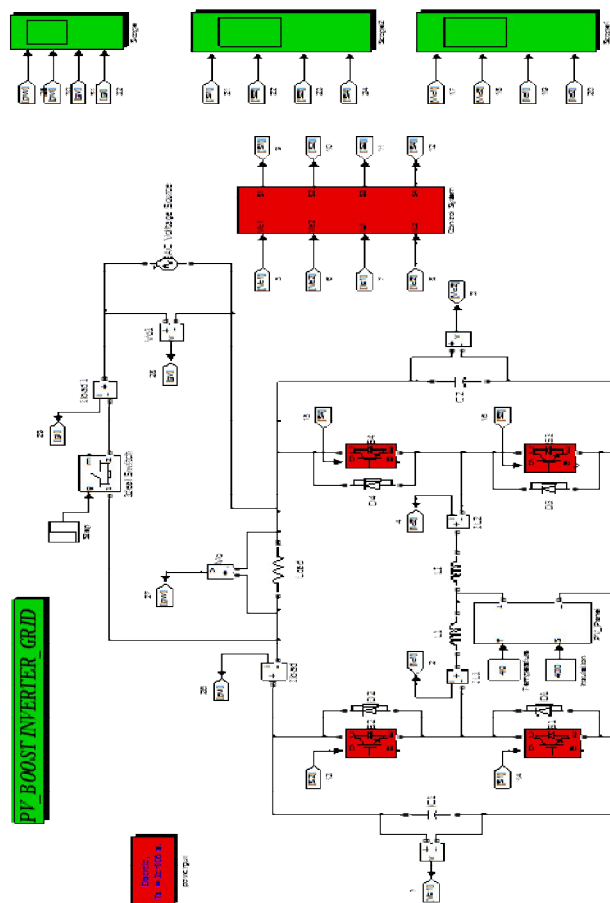


Figure 5.5 Simulation model of proposed grid connected photo voltaic boost DC-AC inverter

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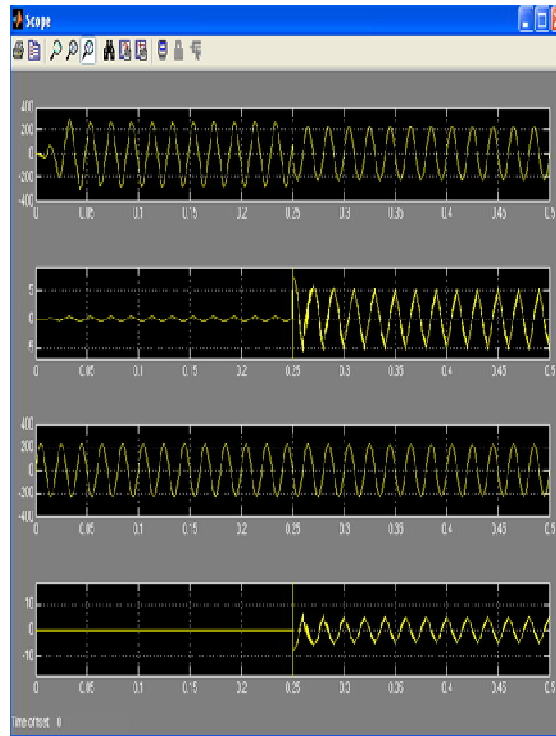
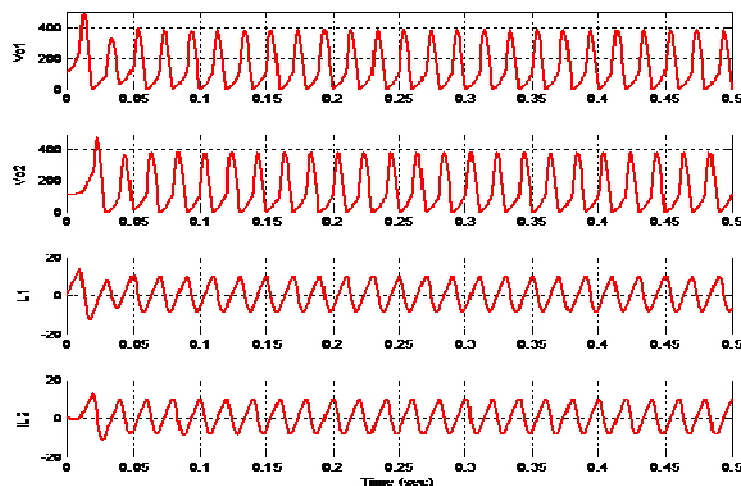


Figure 6.1 Load and Grid connected wave forms

From figure.6.1 scope 1 produce outputs are pw load output voltage, pv load output current, gv grid output voltage, grid output current .

The electrical equivalent circuit consists of dc supply voltage V_s , input inductors L_1 and L_2 , power switches S_1 - S_4 , capacitors C_1 and C_2 freewheeling diodes D_1 - D_4 and load resistance R_1 . Converter-1 operates in a continuous conduction mode when assuming that all the components are ideal and there are two modes of operation. Figure 3.6 shows two topological modes for period of operation

Figure 6.2 Input and output voltage wave forms



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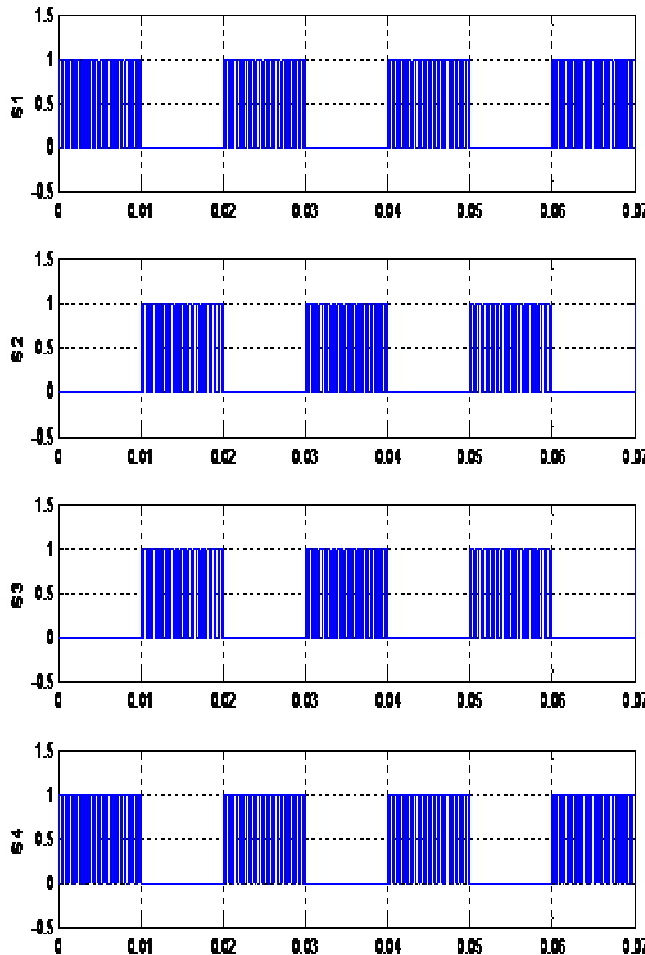


Figure.6.3 switching waveform of S1,S2,S3 and S4

The power switch S1 is closed and S2 is open Figure 3.6 (a), the current i_{L1} rises quite linearly, diode D2 is reverse polarized, capacitor C1 supplies energy to the output stage and voltage VC1 decreases. The power switch S1 is open and S2 is closed Figure 3.6 (b), the current i_{L1} flows through capacitor C1 and the load, the current i_{L1} decreases while capacitor C1 recharged. Where D is the duty cycle, VC1 is the voltage across the capacitor of the converter-1 and VC2 is the voltage across the capacitor of the converter-2, Vs is the input voltage to the Boost sine wave DC-AC converter.

VI. CONCLUSION

In this case, the boost inverter output load and grid voltage, current, switching frequency varies depending on the working point. By means of this controller, the converter generates a sinusoidal output voltage with a total harmonic distortion lower than 2% the circuit operation has been described and discussed. The performance are verified in simulation result.

A new closed loop boost inverter has been proposed. As the proposed method uses Simple circuit, reduce the number of conversion, cost also reduce. The simulation result shows that good closed loop can be achieved. In existing system to connect dc-dc converter, inverter, and transformer were used. It gave the poor performance, circuit complex

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design and cost. In the proposed inverter topology, a low dc voltage of photovoltaic array is boosted and inverted into a 220Vrms ac voltage at a fundamental frequency in a single stage. In the system to use industrial applications..

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