A Closed Loop Non - Linear Sinusoidal PWM Control for Semi Z - Source Inverter

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Abstract- **This paper presents a closedloop non-linear sinusoidal PWM control for semi z-source inverter.The semi z-source inverter requires only two active switches compared to traditional z-source inverter and shoot through state is not applicable.By using this proposed control technique desired duty cycle can be generatedto output the sinusoidal voltage. The relation between voltage gain and modulation index is explained in detail and verified by using simulation and experiments.**
A 40W semi z- source inverter for photo voltaic application provides an output voltage of 28V. Efficiency above 95.7% is obtained.

KeyWords- Inverter, Photo voltaic (PV), Semi Z source, Modified PWM.

I.INTRODUCTION

The development and application of renewable energy sources like pvcell, fuelcell,thermo electric generator module (TEG) has been gaining importance due to its small scale, low maintenance, pollution free and clean sources of energy [1].The characteristics of PV is expected to play a major role in power generation. The PV characteristic depends on the environmental conditions like irradianceintensity and temperature.It can output only dc voltage. So an inverter has to be interfaced for grid connected application.There are a lot of inverter topologies for PVsystems [2]-[3].There are two types of inverters used based on galvanic isolation: isolated and non-isolated inverters.There are several popular approaches for inverters, they are characterized by single stage and two stage conversion[4]-[5].Isolated inverters have high voltage gain and safety advantages but it requires more switches with high cost,high complexity and low system efficiency.

For low grid voltage or power below 20KW isolation is not compulsory.Isolated inverters increases the system size,costs and overall efficiency due to presence of high frequency transformers used for isolation. The transformer less inverter topologies reduces the cost and system size with improved efficiency.For transformerless inverter topologies if the input source and ground do not share the same ground it leads to large leakage current,which causes safety and electromagnetic interference problem [6]-[7].Extra switches has to be used in order to overcome the problem but this increases the cost and system size.By considering the cost, size and simplicity doubly grounded non isolated inverters arepreferred in grid connected applications [8].

A semi z source inverter is proposed which needs only two active switches to output the sinusoidal voltage and ground sharing option.This reduces the cost and size. Compared to traditional inverter shoot through state is not applicable. The Z source network used in semi z source inverter is in AC side where as in traditional z source inverter it is used in dc side [9]-[10].This reduces the size of the proposed inverter.Since the input and output voltage has non-linear relationship a modified sinusoidal PWM technique should be used to output the sinusoidal waveform. The block diagram representation is shown in FIG 1

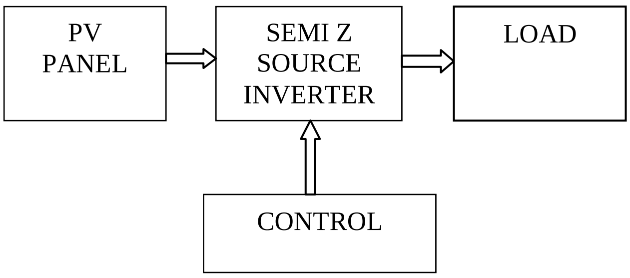

FIG 1 Block diagram

II. OPERATING PRINCIPLES

The proposed semi z- source inverter is illustrated in FIG2. It consists of two switches S_1 and S_2.MOSFET or IGBT are normally used.

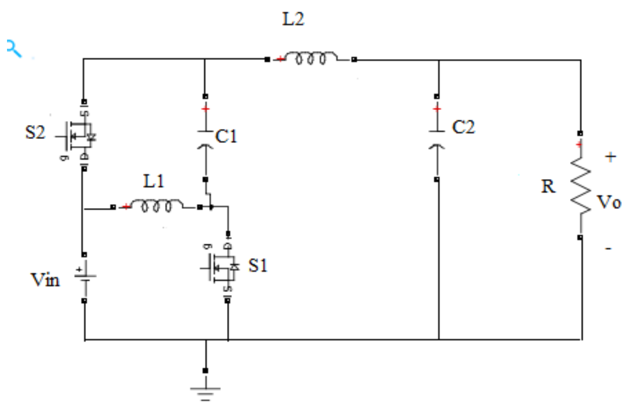

FIG 2 Proposed Semi z source inverter

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FIG 3 shows modes of operation of semi z source inverter in one switching period [11]. In FIG3(a) switch s_1 is conducting and s2 is not conducting In this period the capacitor c_1 and voltage source charges the two inductors and the inductor current get increased.IN FIG3 (b) the inductors will act as source so the inductor current decreases.

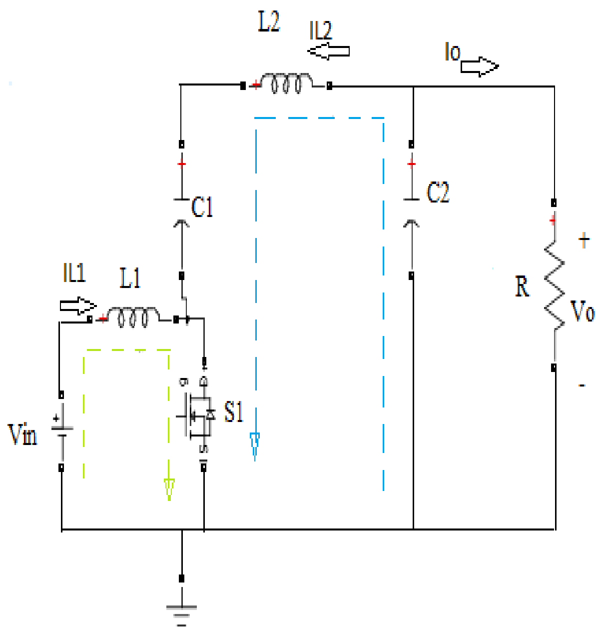

FIG 3(a) Switch S_1 is conducting

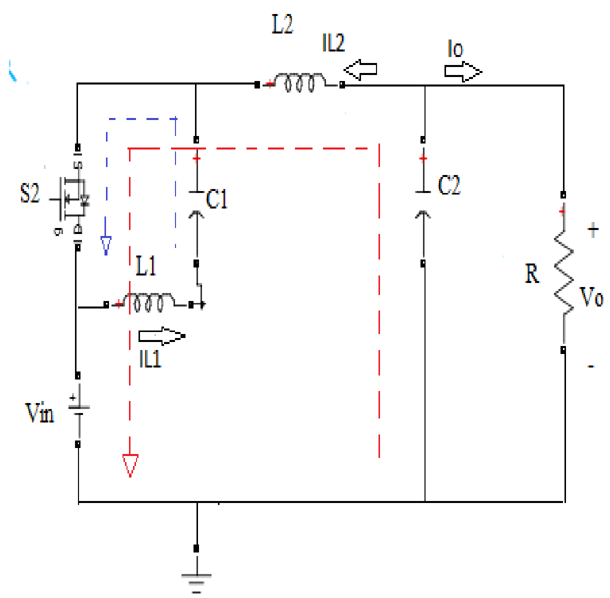

FIG 3(b) Switch S_2 is conducting

During S1 is conducting with duty cycle changing from 0-2/3 the proposed inverter can output same voltage as full bridge inverter. It can output positive voltage when duty cycle is changed from (0-0.5) andnegative voltage when it changes from (0.5-2/3).It can output zero voltage when the duty cycle is 0.5.FIG 4 shows the duty cycle operating region of the proposed inverter.

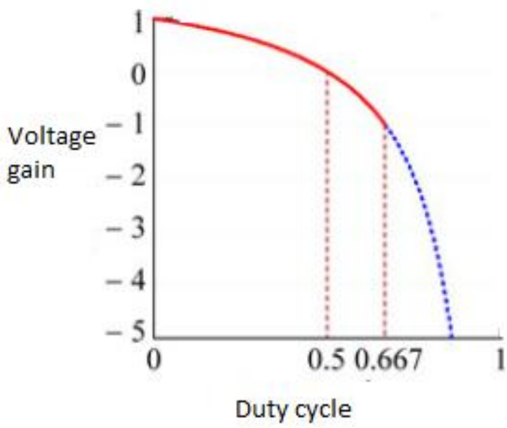

FIG 4 Duty cycle operating region of semi z source inverter

Based on inductor voltage second balance equation and capacitor charge balance equation [12], the steady state equation can be derived as

$$\frac{V_0}{V_{in}} = \frac{1-2D}{1-D} \qquad (1)$$

$$V_{C1} = \frac{D}{1-D} V_{in} \qquad (2)$$

$$I_{L1} = -\frac{D}{1-D} I_o \qquad (3)$$

The inverter output voltage can be represented as (4).The modulation index can be expressed as (5). By combining (4) and (5) and equating into (1) equation (7) can be achieved.Duty cycle of S_2 is derived in (8) as**D'=1-D**.

$$V_0 = V \sin\omega t \qquad (4)$$

$$M = \frac{V}{Vin} \qquad (5)$$

$$D = \frac{1-M\text{sim}\omega t}{2-M\sin\omega t} \qquad (6)$$

$$D' = \frac{1}{2-M\sin\omega t} \qquad (7)$$

III. DESIGN CONSIDERATION

The capacitor voltage and inductor current is stated by (8) and (9).It is obtained from (2),(3),(6).By considering L_1=L_2 the current ripple of inductor and voltage ripple of capacitor is stated in (10) and (11).

$$V_{C1} = \frac{D}{1-D} V_{in} = (1-M\sin\omega t)\, V_{IN} \quad (8)$$

$$I_{L1} = -\frac{D}{1-D} I_O = -(\sin\omega t - M(\sin\omega t)^2)\, I \quad (9)$$

$$\Delta V_{C1} = \frac{-\sin\omega t + M(\sin\omega t)^2 T_s I}{(2-M\sin\omega t) C_1} \quad (10)$$

$$\Delta I_{L1} = \frac{V_{in} T_s (1-M\sin\omega t)}{L_1 (2-M\sin\omega t)} \quad (11)$$

The value of inductance and capacitance can be selected by considering the peak ripple value of voltage and current.

TABLE 1
DESIGN SPECIFICATIONS

Parameter	Value [units]
Input DC voltage	40 [V]
Efficiency	Up to 95%
Output AC voltage	28 [V]
Output current	1.5 [A]
Output power	40 [W]
Switching frequency	50 [kHz]

IV. MODIFIEDCONTROL STRATEGY

The traditional inverter has linear relation between voltage gain and duty cycle. So sinusoidal PWM technique can be used to output the sinusoidal voltage.The proposed semi z source inverter has nonlinear relation between voltage gain and duty cycle.A modified sinusoidal PWM technique is used to output the sinusoidal voltage.

The modified sinusoidal voltage reference is compared with carrier signal. When the reference is greater than carrier, pulse for switch for S_2 is produced and S_2 gets turned on.Switch S_1 operates complementary with switch S_2. The modified sinusoidal reference signal is derived in (7). The modulation index is in the range of (0-1).The duty cycle is limited to (0-2/3) inorder to output sinusoidal voltage.

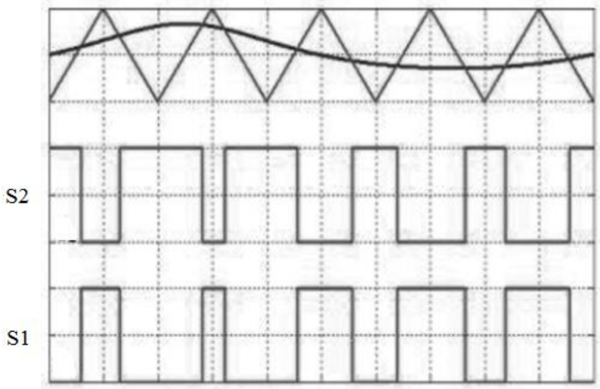

FIG 5 Modified sinusoidal PWM control of semi z source inverter

To make it closed loop amplitude of the output voltage (V) is measured. Instead of giving a constant value to modulation index the value V/Vin is given as modulation index. For any change in input value, the modulation index changes to getthe corresponding output voltage.

V. SIMULATION AND EXPERIMENTAL RESULTS

The performance of the inverter for both open and closed loop is evaluated using PSIM. Simulation circuit and results are shown.

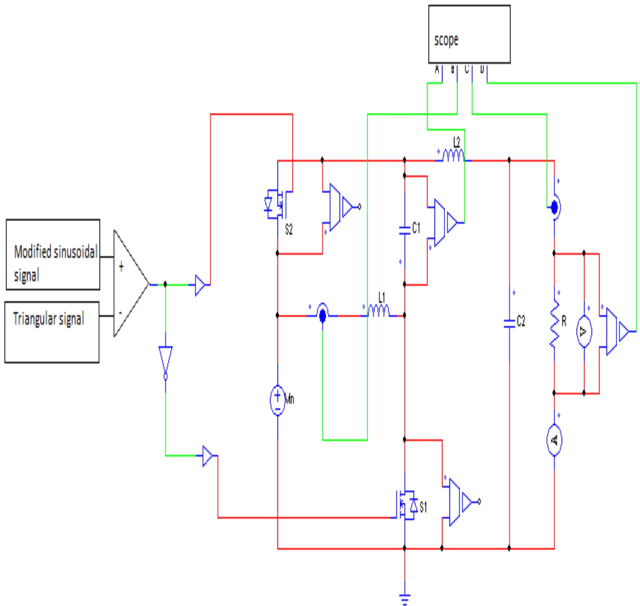

FIG 6 Simulink model of semi z source inverter

FIG 6 shows the Simulink model of the semi z source inverter. The modified reference signal is shown in FIG 7.FIG 8(a) and (b) shows the capacitor voltage waveform and inductor current waveform respectively.

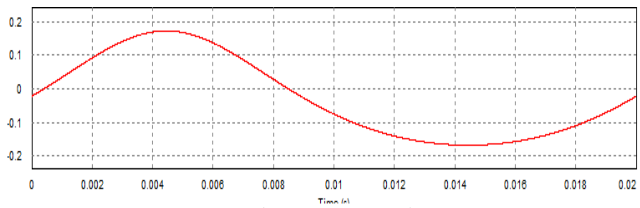

FIG 7 Modified sinusoidal reference signal

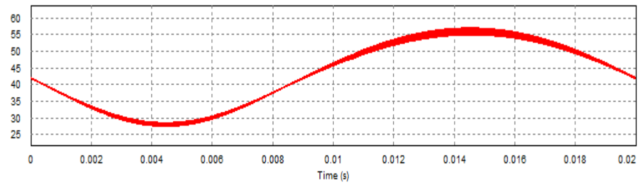

FIG 8(a)

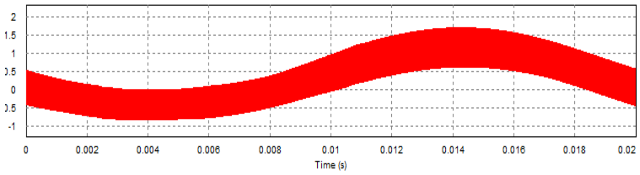

FIG 8(b)

FIG8 (a) simulation results of capacitor voltage (b) simulation results of inductor current.

The output voltage and output current for an input of 40 V and modulation index 0.7 is shown in FIG 9(a) and 9(b)..

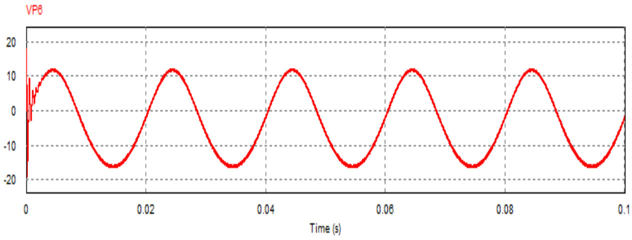

FIG 9(a) simulation result of output voltage

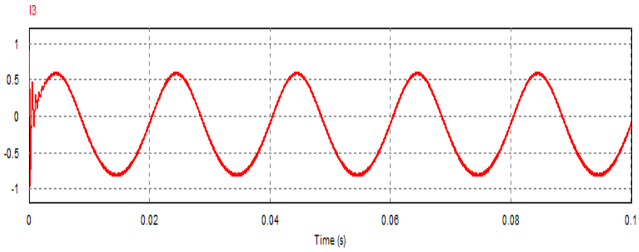

FIG 9(b) simulation result of output current

A 40W semi z source inverter with input voltage of 40V and 28V output is built. The switching frequency is 50KHZ.Two MOSFETS of 200V rating are used as switching devices.The inductor value of L1 is calculated from (11) which is 400μH.The capacitor value can be calculated from (10) which is 4μF.

VI. CONCLUSION

In this paper a semi z source inverter and the closed loop control is described.The proposed inverter uses only two switches and thereby reduces the size and cost. The two switches are controlled complimentary. A closed loop modified sinusoidal PWM method is used to eliminate the nonlinear voltage gain problem.

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