FUZZY CONTROLLED SWITCHED INDUCTOR BASED NEW SINGLE PHASE INVERTER

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Abstract : This paper presents fuzzy controlled switched inductors based new single phase inverter featuring higher voltage gain than the existing single phase qZ-source inverter. It is similar to single phase qZ-source inverter and semi Z-source inverter, the presented inverter has common ground between the dc input and ac output voltage, which is useful for photovoltaic inverter system. By coupling inductors maximum current flowing can be reduced. Simulation of inverter is carried out using MATLAB and Fuzzy is use to control the continuous varying voltage to make stable. Experimental prototype is built to verify the performance of the inverter.

Index Terms **- Common ground, dc–ac inverter, high voltage gain, qZ-source inverter, single-phase inverter, switched-coupled inductor (SCL), Z-source inverter.**

I. INTRODUCTION

Present days there is increasing demand for single phase low coast inverter in fuel cell, photovoltaic and battery power system. A conventional inverter can classify into two levels. Conventional classified levels employ to obtain controlled voltage. It has numerous switches to manage current and voltage. Conventional inverter methods are Full Bridge (FB) inverter[1] refers like buck inverter in it input voltage is greater than output voltage. If the input voltage is low, a boost dc-dc converter is inserted between input voltage and FB inverter. Conventional inverters have two different topologies and have different output and input grounds. It might results in huge leakage in current. Applications like transformerless grid attached PV inverter are used. Main drawback of this system is electromagnetic interference and safety problem[2].

To overcome the conventional inverter demerits, a single phase inverters are proposed in large numbers [3]. Z-source inverter topologies can overcome limits mentioned above [4].

Current-fed (CF) single phase qZ-source inverter [5] and semi qZ-source inverter which are enhanced version of CF single phase qZ-source inverter[6]. Both has similar voltage gain and need just two active switches to find alike highest voltage gain as FB inverter.

$$\frac{v_0}{v_{in}} = \frac{2D-1}{D} \quad \text{---------------} \quad (1)$$

Where, D is duty ratio of switch S_2.

Current-Fed (CF) inverters share common ground between $V_{in}$and V_o, so they can reduce the trouble of leakage of current competently if they employ for PV inverter[2]. But the highest voltage gain possible is 1, it means they are not appropriate for purpose wherever input voltage is lower.

To reduce the above mentioned limitations and to maintain doubly ground feature, the three-switch three-state single phase Z-source inverter (TSTS-ZSI) has been introduced[7]. The inverters will have higher voltage gain than the unity, and they include three switches, three capacitors, and three inductors. Even though high voltage gain is attained, the three inductors L_1, L_2 and L_3 in the TSTS-ZSI built the circuit a become large and heavy. And also the switch signals of inverter are all dissimilar and reasonably complex.

In proposed project, a single phase switched coupled-inductor dc/ac inverter is anticipated. Similar to the TSTS-ZSIs, the projected inverter can get high voltage gain than single phase qZ-source inverter and maintain similar ground in V_{in} and V_o.

The projected inverter also needs three active switches, but every inductor in the circuit are coupled together, which go ahead to further compressed and cost effective way than the TSTS-ZSI. And also the switch signal generation is quite simple than the TSTS-ZSI. A projected inverter is built and their performance is confirmed by project.

II. OPERATION PRINCIPAL OF PRESENTED INVERTER

Fig. 3 gives a proposed circuit arrangement. It has the same structure as single phase CF qZ-inverter in Fig. 1(a). But the present circuit has the extra inductor (Lx) coupled with inductor (L2) capacitor (Cx) and switch (Sx).

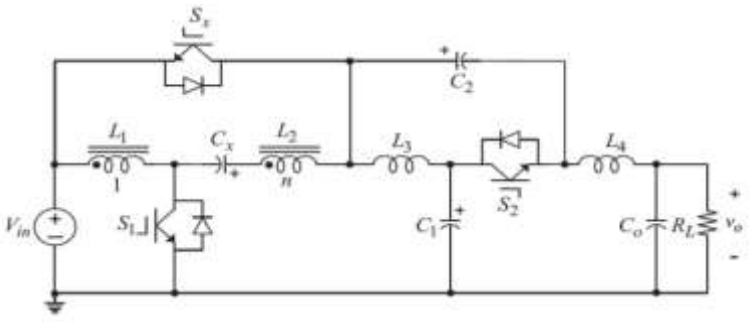
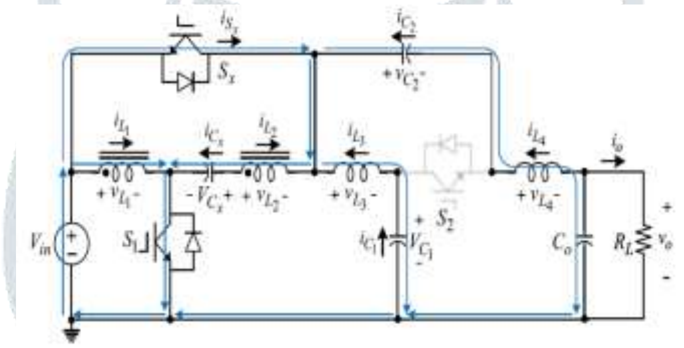


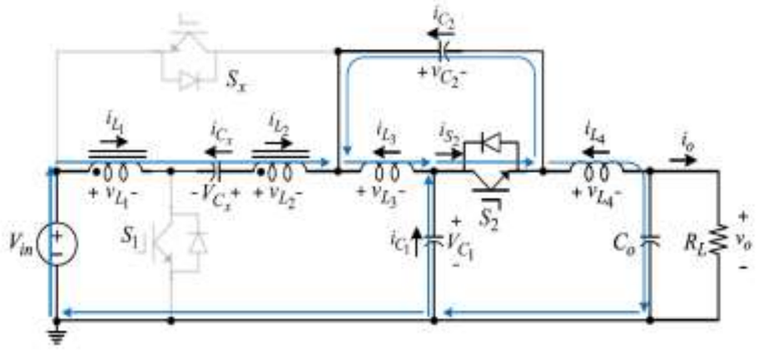
Fig 3 Proposed Dc-Ac Inverter

Inductors L_1 and L_2 connected in 1: n turn ratio. Also the inductors in proposed inverter are coupled together. The coupled inductors L_1 and L_2 contribute to raise voltage gain. Even though coupled inductor may has spike acrossS_1, its spike is not main problem for the reason that voltage spike and S_1 voltage are small. When leakage inductance is not considered it found that voltage stress S_1 is always half of S_2 or S_x. Thus the voltage overshoot by leakage inductor is not so high. Voltage stress S_2 is greater thanS_1. There is an issue for selecting switching devices as S_1. leakage inductance useful to limit current passing throughC_x. Where S_1 and S_2 are complementary in 1-Ø qZ-source inverter and also S_1 is coordinated with the S_x.

A. Mode Analysis



(a)



(b)

Fig. 4 Mode analysis of the proposed inverter (a) 1st Mode (b) 2nd Mode

Fig. 4 shows operations of the proposed inverter and there are two modes of operation, In first switching round. At 1stmode, switches S_1 and $S_x$is turn ON, and S_2 is turn OFF. At 2nd mode, switches $S_1$and $S_x$are turn OFF, and S_2 is turn ON. Followings are the full mode study of the proposed inverter. In 1st mode, the capacitor $C_x$is charged to $(n + 1)V_{in}$. So the$C_x$is being charge and discharged in one switching time, its voltage has swell and the swell voltage depend on the output power. As voltage difference among $(n + 1)V_{in}$ and $C_x$is higher, relatively higher surge (charging) current will flow through $V_{in}- D_x(S_x)$

$-L_2- C_x- S_1$ and the switching devices in this path (S_x and S_1) can be spoiled. In order to prevent the high surge current, a current preventive inductor is needed compulsory. The leakage inductance is generated by coupling of L_1 and L_2 inductors and serve as the current prevent inductor. From Fig. 4.2(a), the voltage and current relations in 1st mode are obtain as,

$$V_{cx}=V_{in} + V_{L2}= (n+1)V_{in} \quad \text{------------ (2)}$$

$$\left.\begin{aligned} V_{L1} &= V_{in} \\ V_{L3} &= V_{in} - V_{c1} \\ v_{L4} &= V_{in} - V_{C2} + v_o \end{aligned}\right\} \quad \text{------------- (3)}$$

$$\left.\begin{aligned} i_{c1} &= i_{Ls} \\ i_{C2} &= i_{L4} \\ i_{cx} &= i_{in} - i_{L1} + i_{L3} + i_{L4} \end{aligned}\right\} \quad \text{------------ (4)}$$

In 2nd mode, capacitor C_x is discharged by the inductor current i_{L1}. From Fig. 5(b), the voltage and current relations in 2nd mode are obtaining as follows.

$$\left.\begin{aligned} (1+n)V_{L1} &= V_{in} + V_{cx} - V_{C2} - V_{C1} \\ V_{L1} &= V_{C2} \\ V_{L4} &= V_{C1} - V_o \end{aligned}\right\} \quad \text{------ (5)}$$

$$\left.\begin{aligned} i_{C1} &= -i_{L1} - i_{L4} \\ i_{C2} &= -i_{L1} - i_{L3} \\ i_{C3} &= -i_{L1} \end{aligned}\right\} \quad \text{------- (6)}$$

From the aforesaid equations, voltage relations are obtaining as follows.

$$V_{L4}= V_{C2} + V_o \quad \text{-------------------------- (7)}$$

$$V_{C1} = (n+1)V_{in} \quad \text{-------------------------- (8)}$$

From the flux (volt–second) balance state on L_3, the capacitor C_2 voltage is obtain as follows

$$V_{C2}=\frac{(1+D)(n+1)}{D}V_{in} \quad \text{--------------------------- (9)}$$

Where, D is duty cycle of the switch S_2.

By equation (7) & (9), the voltage gain of the proposed inverter is obtain as follows

$$\frac{V_o}{V_{in}} = \frac{(2n+3)(n+1)}{2D} \leq n+2 \quad \text{------------------ (10)}$$

Fig. 5 show the voltage gain of the proposed inverter when n = 1 and It is found that the proposed inverter has a high voltage gain than the usual inverters shown in Figs. 4.3.

According to the charge balance condition on C_x, C_1 , and C_2 , the inductor currents averaged in one switching period are obtain as follow

$$i_{L1.avg} = \frac{(2D-1)(n+1)}{D} i_o \quad \text{------------------- (11)}$$

$$i_{L2.avg} = 0 \quad \text{---------------------- (12)}$$

$$i_{L3.avg} = i_{L4.avg} = i_o \quad \text{----------------- (13)}$$

$$i_{S2.avg} = i_{Sx.avg} - i_o \quad \text{------------------ (14)}$$

Currents of inductors L_1 and L_2 are different in respective mode unlike inductor currents i_{L3} and i_{L4}. In mode 1, where current ripple is ignored, they are obtain

$$i_{L1} = \frac{(2D-1)(n+1-D)}{D(1-D)} i_o \qquad \text{------------- (15)}$$

$$i_{L2} = -\frac{(2D-1)}{(1-D)} i_o \qquad \text{-------------- (16)}$$

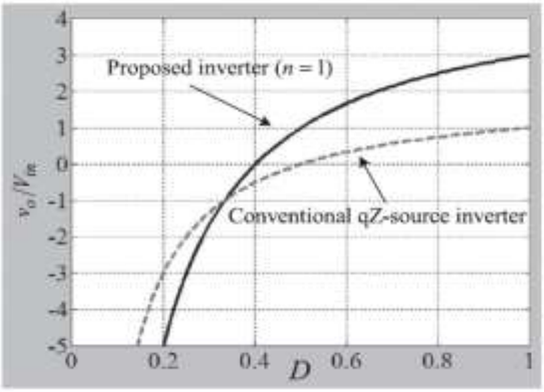


Fig. 5 Voltage gain comparison

In 2nd mode, expressed as follows

$$i_{L1} - i_{L2} = \frac{(2D-1)}{D} i_o \qquad \text{-------------------------- (17)}$$

B. Modulation Of Inverter

Presented inverter has similar modulation scheme as qZ-source inverter. Where the output voltage will define from (18), M-index of inverter derived below.

$$v_o = V_{in} \sin wt \qquad \text{---------------------------- (18)}$$

$$M = \frac{V_m}{V_{in}} \qquad \text{---------------------------- (19)}$$

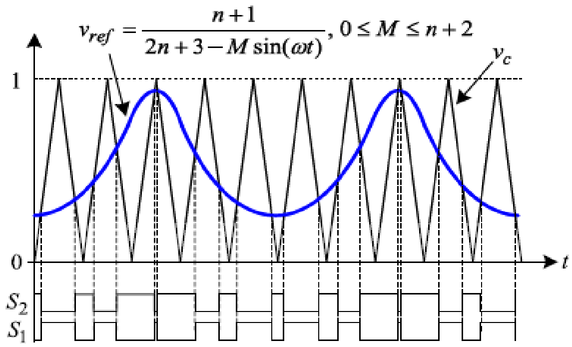


Fig. 6 Gate Signal Generation

(18) & (19) substitute in (10), then D will be

$$D = \frac{n+1}{2n+3-M\sin wt}, (0 \le M \le n+2) \text{ ------------ (20)}$$

III. FUZZY CONTROLER

There are two types of controllers and they are,

1. PI controller
2. PID controller

Fuzzy controller is easy to implement, but relatively hard to tune, compared to above mentioned controllers. Compared to other controllers like PI & PID, Fuzzy controller is more flexible because fuzzy have more parameters of input and output (types & membership functions parameters in the fuzzyfication and defuzzyfication) to shape their surface of control, these makes them useful in case of controlling non-linear systems. Fuzzy controller is easy to understand because of their rule basis, in case of small number of linguistic variables. Therefore, Fuzzy is suitable and better option.

And in the fuzzy written some rules for controlling output voltage they are

- If (input1 is a_1) then (output1 is 04) (1)
- If (input1 is a_2) then (output1 is 04) (1)
- If (input1 is a_3) then (output1 is 03) (1)
- If (input1 is a_4) then (output1 is 02) (1)
- If (input1 is a_5) then (output1 is 01) (1)
- If (input1 is a_6) then (output1 is 01) (1)
- If (input1 is a_7) then (output1 is 02) (1)
- If (input1 is a_8) then (output1 is 03) (1)
- If (input1 is a_9) then (output1 is 04) (1)

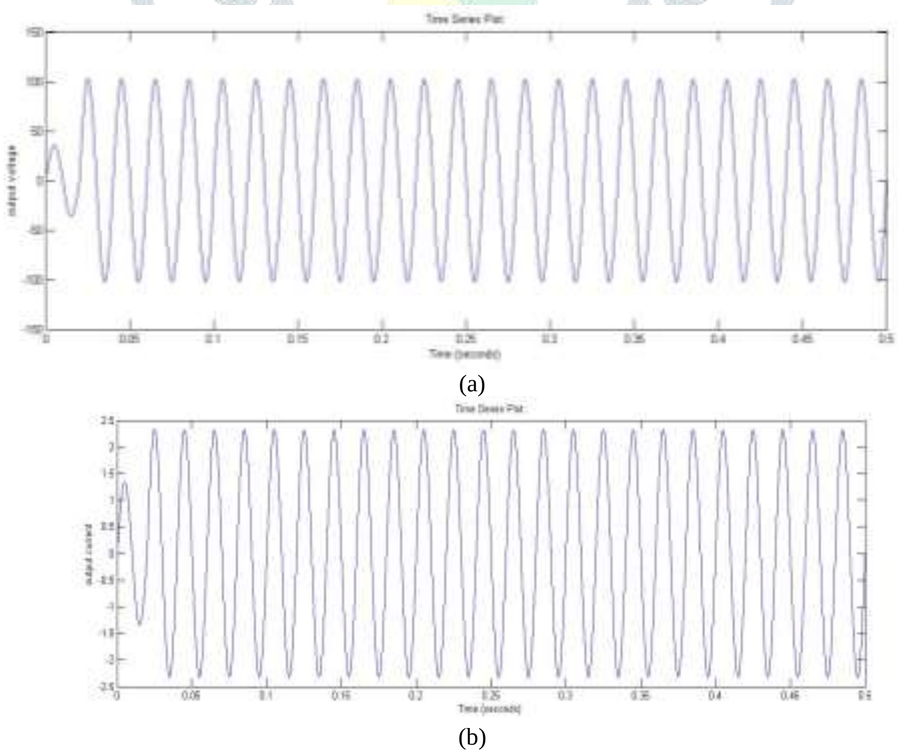
Where, $a_1, a_2, ..., a_9$ are the input membership functions
01, 02, ….., 09 are the output membership functions.

The rules are written by using parameter functions. The possibilities of the input and those are very low (25V to 50V), low (50V to 100V), medium (100V TO 110V), high (110V to 150V) and very high (above 150). On this basis the voltage is provided using fuzzy logic. The output parameters are taken on the basis of input parameter possibilities. If the fuzzy input is lower the fuzzy output must give high, if the fuzzy input is high than fuzzy out must give low. Thus other rules are written to obtain the medium and stable fuzzy output.

The need of using Fuzzy controller is to get a stable output voltage and compared to other controllers it is more efficient.

IV. RESULT

Electrical specification of the presented inverter is summarized in Table I. projected prototype is designed and tested. Small current limiting inductors required in the path $V_{in} - D_x(S_x) - L_{2-}C_x - S_1$
The presented inverter output voltage and current shown in fig. 7 when input voltage is 62V, M= 2.5 and output power is 280W. The leakage inductance is generating by coupling L_1 and L_2.



(a)

(b)

Fig.7 Waveforms of (a) Output Voltage and (b) output current

The waveform of the proposed inverter output voltage is given above in fig.7 (a). By connecting coupled inductors output voltage has been enhanced, to get safe and stable output a Fourier function is interconnected between output and fuzzy logic controller and where in the initially it is less than 40V it is because of the Fourier function. It is the function where the frequency is set in the range of 0Hz to 50Hz. In the initial output is less than 40V because of 0Hz in initial frequency so it requires the time to come in suitable range of voltage magnitude.

The output current waveform of proposed inverter is shown in fig.7 (b). at the initial stage of Fourier function current is less than 1.8A. In this function the frequency range is 0Hz to 50Hz so the current is 1.8A. Means because of 0Hz in initially it require some time to attain stable output current.

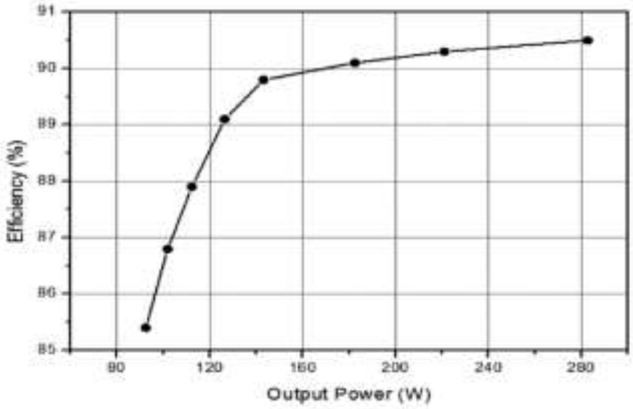


Fig. 8 Proposed Inverter Eficiency

Table I
Electrical specification of the presented inverter

Output power		280 W
Input voltage		62 Vdc
Output voltage		110 Vrms / 60 Hz
Switching frequency		20 kHz
IGBT (S_x, S_1, S_2)		FGH40N60
Coupled inductor	Core	EE7066
	Inductance (L_1, L_2)	60 uH
	Inductance (L_3, L_4)	240 uH
Capacitance (C_x, C_1)		100 uF
Capacitance (C_o)		4.4 uF

V. Conclusion

A single phase switched coupled inductor inverter is presented.. Voltage gain of presented inverter extended up to two by adding extra components C_x, S_x and coupled inductor. Gate signal generation in this presented inverter is very simple. Convertor volume is decreases by magnetic integration of all inductors. And also this inverter is same as single phase TSTS-ZSI and qZ-source, presented inverter has common ground between voltages of dc input and ac output.
The output of presented inverter is in continuous increasing form. It is unsafe for utility. Fuzzy is use to control the continuous varying voltage. And makes stable

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