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Simulation Study of CFSI Based Power Grid System

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ABSTRACT: This paper proposes a CFSI based power grid system. Inverters possess properties like high step-upcapabilities, high step-down capabilities andshoot-through immunity. The topologies like Z-source inverter (ZSI) andSwitched boost inverter (SBI) has low distortion ac inversion. The realization of ZSI is costlier than SBI as it requires two sets of passive filters. SBI has less component count since it has one LC pair less than ZSI but its gain is less than ZSI.This paper proposes the current-fed switched inverter (CFSI) based power grid system which combines the properties of ZSI and low passivecomponent count of SBI and the output is synchronized with the utility line. A MATLAB/Simulink model isdeveloped and is used to study the characteristics of CFSI based power grid system.

KEYWORDS:Z-source inverter (ZSI), switched boost inverter (SBI), current-fed dc/dc topology (CFT).

I.INTRODUCTION

Power inverters has various applications like electric motor speed control, induction heating, HVDC power transmission, power grid etc.The traditional VSI has limitation like its peak ac outputvoltage is slighter than the inputdc-link voltage and shoot-through in any of the inverter legs is not permitted, it will allows to flow short circuit current through the legs. Therefore,a dead-band is introduced between the switching signals ofcomplementary switches of the inverter legs, which, in turn,causes ac output distortion. Inverters with transformers are bulky andnoisy. Therefore, transformerless inverters are better choice for noise free output. Current Fed Switched Inverter (CFSI) is a topology which takes the advantage of topolgies ZSI and SBI. Z-source inverters employs a unique impedance network.ZSI couples theconverter main circuit to the power source. The Z-source concept can be applicable to ac-to-dc, ac-toac,dc-to-ac and dc-to-dc power conversion.Switched boost inverter is an another topology which have lesser passive component than ZSI. The X-shaped impedance network in ZSI is replacedby an active network in SBI. CFSI topology is made by combining the advantages of ZSI and SBI like better gain, good EMI noise immunity, less component count.

CFSI does not requires dead-band for switching signals since shoot-through state is an active state of CFSI. The output of CFSI is connected to the utility line through grid and transfer synchronously with the line. A grid based CFSI system can provide an alternate power generation like renewable sources like wind or solar power without batteries.

II.WORKING OF CFSI

The CFSI based system has complementary current-fed topology (CCFT). In order to get the CCFT topology from current fed topology (CFT), passive and controlled switches are interchanged. The CFSI topology is shown in figure 1. The CFSI can work in both buck and boost modes of operation. By controllingthe duty ratio D and the modulation index M of theinverter properly, buck and boost operations can be achieved. The input of the current-fed switched inverter is a switched voltage and it provides single stage dc-ac inversion. The CFSIis suitable for renewableapplications since it draws continuous input currentfrom the dc source. It does not demand forradical duty ratio operation to achievehigh voltage boost.CFSI operates in two modes which is non shoot-through mode and shoot-through mode. The shoot-through mode of CFSI is an active state. The high gain of the inverter is obtained due to insertion of shoot-through interval. No reverse voltage appears across the switch S as the emitter terminal is either connected to the ground when D_b is on or to thr negative terminal of the capacitor C_o when S is on.

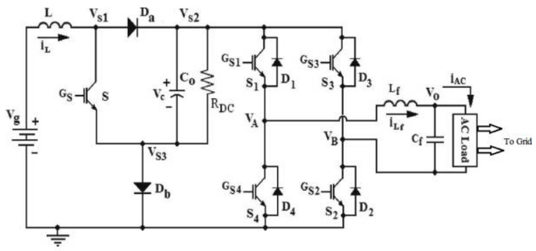

Fig. 1 CFSI topology connected to grid

III.MODES OF OPERATION

Mode 1 (Shoot-through interval): In shoot-through interval (D interval) the initial voltage of the capacitor $C_o$is equal to V_g, and theinitial inductor current is zero before the switching signals arestarted. In the shoot-through interval (D interval), switches Sand S_i(S_1-S_4 or S_3-S_2)are turned on, and diodes $D_a$and $D_b$become reversebiased as they are now in parallel with C_o. In this interval,source $V_g$and capacitor C_o charge inductor L together. The voltage across inductor and current through the capacitor during (1-D)T_s is given by,

$$v_L = V_g + V_c$$

$$i_c = -I_L$$

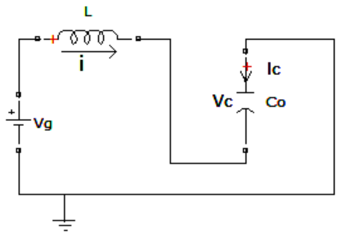

Fig. 2CFSI topology in shoot-through interval

Mode 2 (Non Shoot-through interval): In nonshoot-through interval (1-D interval), switches S and S_i(S_1-S_2 or S_4-S_3)areturned off, which forces diodes $D_a$and $D_b$to turn on, andthe inductor charges $C_o$and power are delivered to the ac loadthrough the inverter. Here, turning off switch $S_i$denotes thepower interval or zero interval of the inverter. The voltage across inductor and current through the capacitor during (1-D)T_s is given by,

$$v_L = V_g - V_c$$

$$i_c = I_L - I_i$$

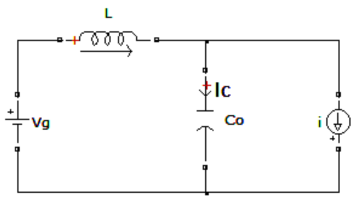

Fig. 3CFSI topology in non shoot-through interval

Turning on of both switches of an inverter leg is a valid state of CFSI, it has better EMI and noise immunity. The inverters are tied to the grid to feed into the electric power distribution system and they transfer synchronously with the

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line. High-quality modern grid connected inverter system has a fixed unity power factor. Reactive power supply to the grid is essential for keeping the voltage in limits during high production.

IV.SIMULATION AND RESULTS

The simulation result was done in MATLAB/Simulink.The simulink model of the current fed switched inverter (CFSI) is shown in figure 4. CFSI synchronize its frequency with that of the grid at 50Hz. Closed loop control is adopted for the CFSI based grid system. Modified PWM scheme is developed for the gating of switches in CFSI.

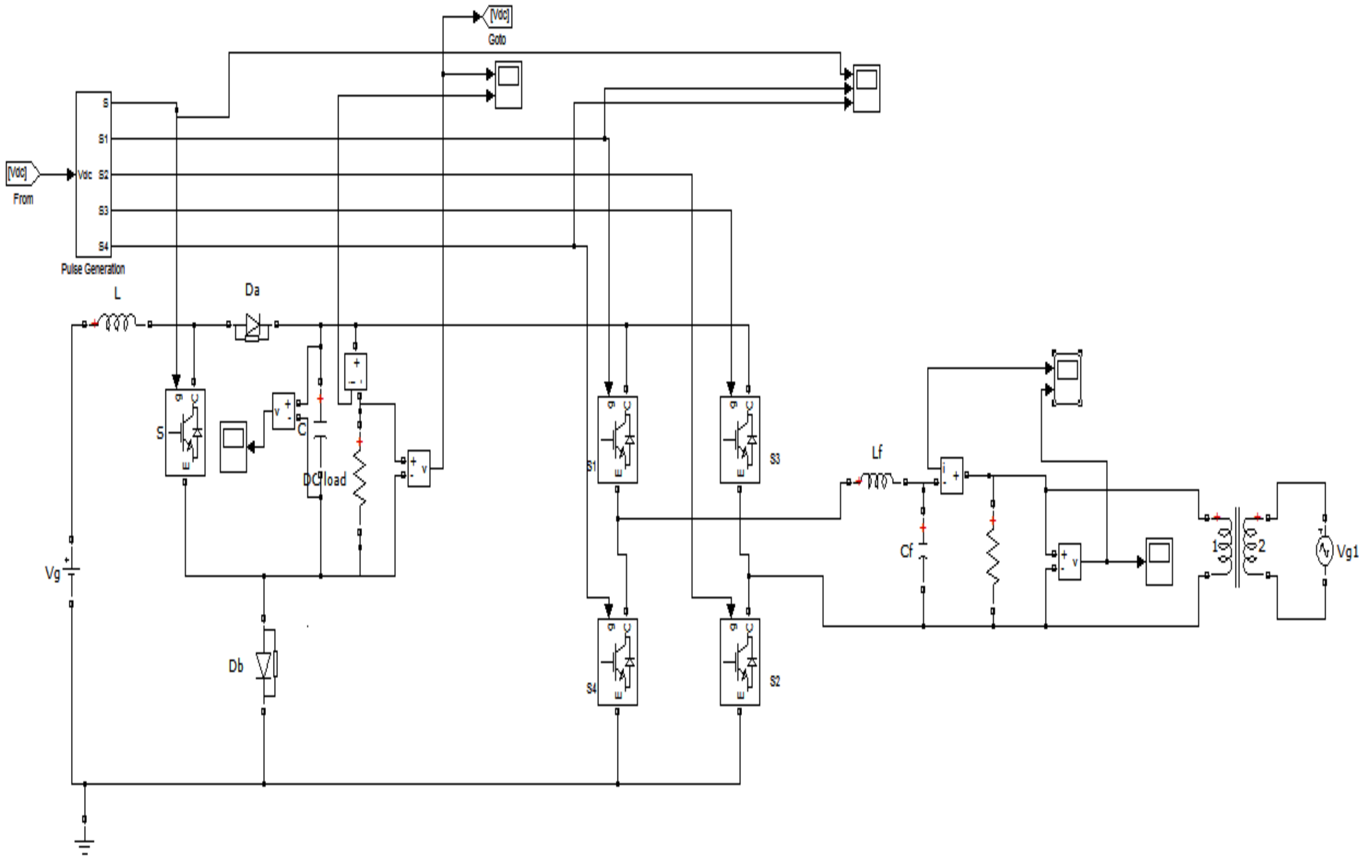

Fig. 4 Simulink model of CFSI based power grid system

The gate pulses are generated for switches S_1,S_2,S_3,S_4,andS are plotted in figure 5. Modified PWM control strategy is adopted for generation of gating pulses.

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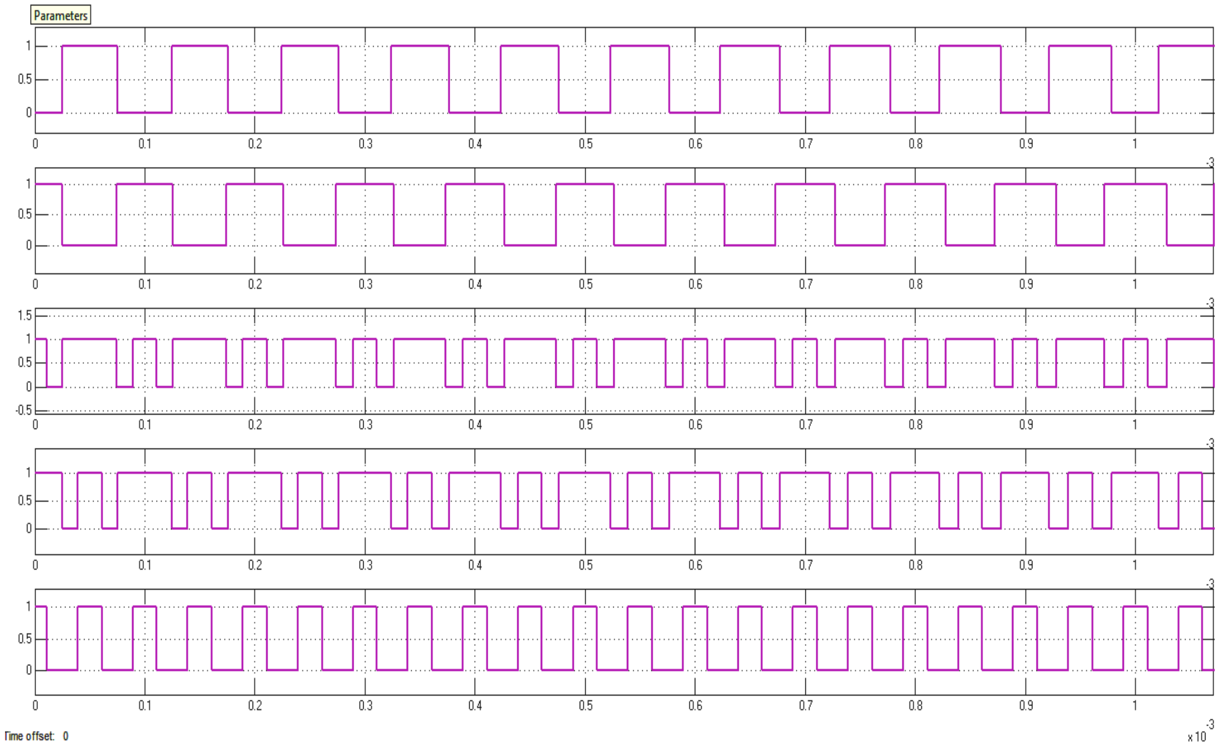

Fig. 5Gating pulses for switches S1, S2, S3, S4 and S respectively

Figure 6. shows the input dc voltage and dc link voltage of CFSI based grid system.

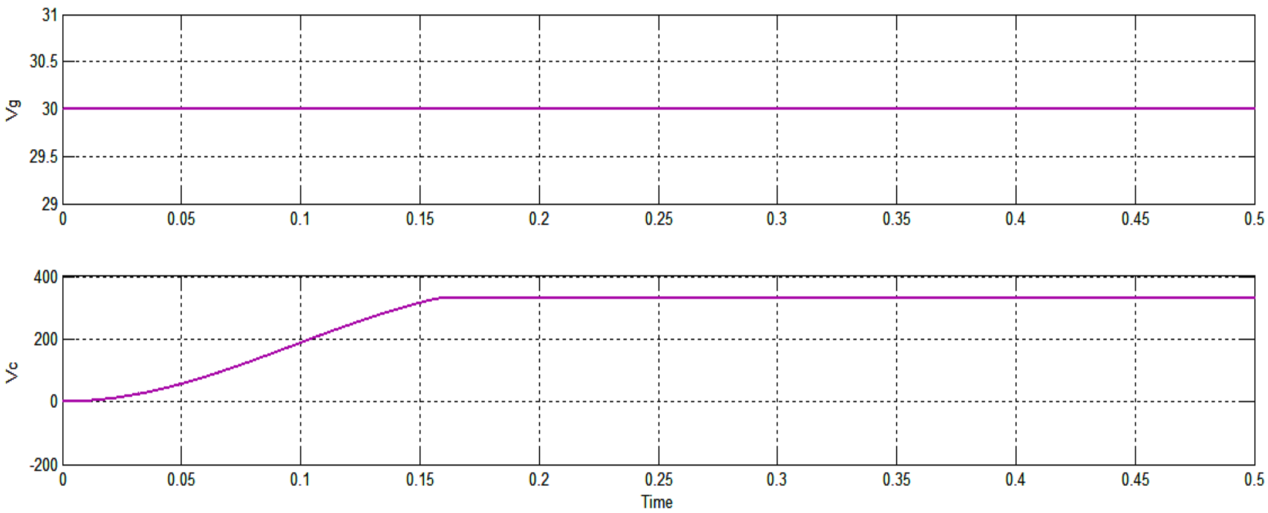

Fig. 6Input voltage and dc link voltage of CFSI

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The output voltage and current waveforms through the grid is shown in figure 7.

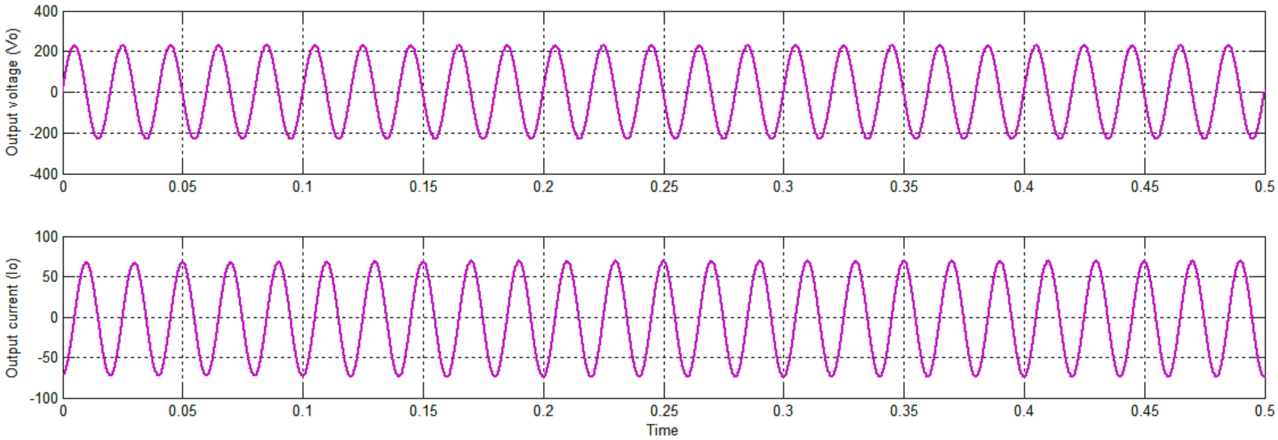

Fig. 7Output voltage and output current through the grid

VI. RESULTS AND DISCUSSION

In figure1, CFSI topology based grid connected system is shown. It comprises of 5 switches and gate pulses are given to the switches through pwm gate signal generation. In figure 4, represents the simulink model of CFSI based power grid system. In figure 7, the output voltage and output current through the grid is shown. CFSI model and grid is connected and synchronized. Iin figure 5, the gating pulses for switches S1, S2, S3, S4 and S respectively are plotted. They are generated through modified PWM technique and shoot through signals are generated through ORed of other gating signals.

V. DESIGN

The inductor current ripple is given by,

$$\Delta i_L = \frac{V_g + V_c}{L} DT_s$$

The capacitor voltage ripple is given by,

$$\Delta V_c = \frac{i_L}{C} DT_s$$

The input voltage, $V_g = 30V$
DC link voltage, $V_c = 350V$
Maximum duty ratio, $D_{max} = 0.46$
Switching time, $T_s = 52\mu s$

The output ac filter can be designed by keeping unity gain at 50Hz. The output inductor and capacitor value can be derived from the equation,

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$$\frac{diL_f}{dt} = -\frac{R_f}{L_f} iL_f + \frac{1}{L_f}(v_{AB} - v_o)$$

$$\frac{dv_o}{dt} = \frac{iL_f}{C_f} - \frac{v_o}{R_{AC} C_f}$$

Capacitor is designed for 0.15% ripple for 350V dc link voltage and inductor is designed for 50% peak to peak ripple rating.

VII.CONCLUSION

The simulation study of current fed-switched inverter based grid connected system is done. The output of CFSI is connected to the grid to interface with the utility line. The proposed inverter based grid system hasboth buck and boost capabilities. The CFSI topology has additional benefits such as reduced noise,and better EMI immunity.

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