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Design Of 7 & 9 Level Inverter & DC-DC Converter With Less Switches for Solar Power Utilities

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***Abstract*— In this paper a multi (seven and nine) level inverter and DC-DC converter with less number of switches for solar power utilities. The seven level inverter has six switches in the main circuit and one high frequency switch for switching at any time to generate seven level output and the nine level inverter has only seven switches. This reduces overall Total Harmonic Distortion, switching loss and improves the output power and efficiency. The control circuit in this paper is simple by balancing the voltage automatically. The necessary simulation results are explained in detail.**

***Keywords*—**DC-DC converter, multilevel inverter, solar power utilities and MATLAB/Simulink.

I. INTRODUCTION

Multilevel inverter has three types diode clamped [6-10], flying capacitor[11-13] and cascaded[14-18]. In dcmli and flying capacitor always used a capacitor to build several voltage steps and it is hard to control the voltage of these capacitors. The voltage in the output and power can be increase when the number of level increases. Increasing voltage level increases main switching device and decreases the harmonic content and also the filters used are reduced[20]. If the voltage level increases, the waveform has more free switching angles can be reselected for harmonic elimination. The switching losses can be avoided In the absence of pulse width modulation techniques. For a seven level inverter 12 switches in both diode clamped and flying capacitor types but in cascaded type only 8 switches are used[2]. The switching devices in the multilevel inverter do not encounter any voltage sharing problems. For this reason the multilevel inverter has more advantages such as good power quality, good electromagnetic compatibility, low switching losses and high voltage capability. Applications of the multilevel inverters are large motor drives and utility supplies.

II. PROPOSED CIRCUIT CONFIGURATION

The Fig 1. shows the configuration of proposed seven level inverter with DC-DC power converter.

The pv array is connected converter which converts the output power into two voltage sources which are supplied to the inverter and the converter is a boost converter that incorporates a transformer with the turns ratio of 2:1. The seven level inverter composed of capacitor and full bridge converter in cascade, the capacitor selection circuits gives the output of three level dc output and further the full bridge converter converts this three level dc output to seven level ac output.

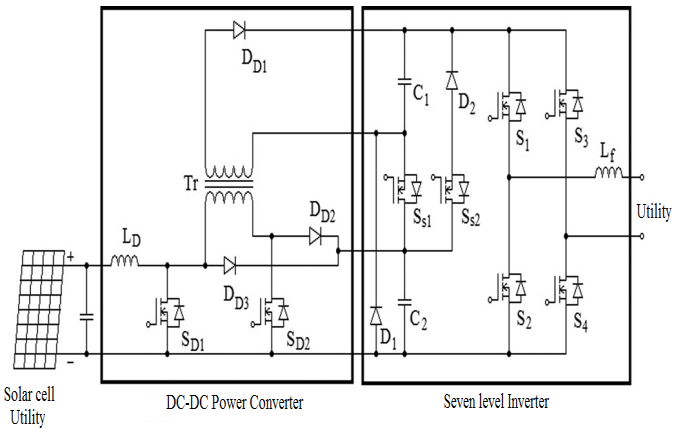

Fig 1. Proposed System

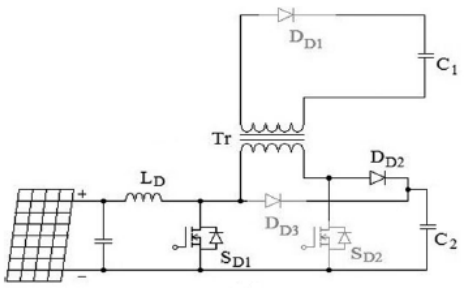

Fig 2a. When the Switch (S_{D1} is ON)

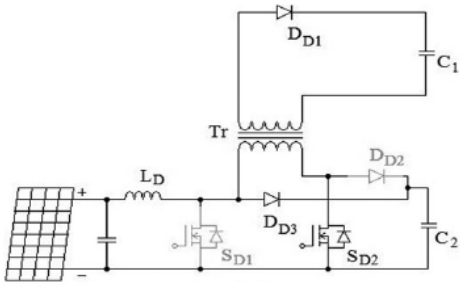

Fig 2b. When the Switch (S_{D1} is OFF)

The Fig 2a. consists of dc-dc power converter combines converter and a current fed converter.The boost converter and the current fed converter contains diode, inductor and a switch charges the capacitor C_2 and C_1.

The Fig 2b. is the operating circuit of the converter when S_{D1} OFF and S_{D2} ON, the capacitor C_1 is connected to the capacitor C_2 in parallel with transformer, the energy of the inductor and capacitor through diode $D_{D3}$and charge capacitor C_1through transformer, diode D_{D1} during the off state of switch S_{D1}. The boost converter is operated in the continuous conduction mode.

The voltage in capacitor C_2 is,

$$Vc_2 = Vs / (1-D)$$

The voltage in capacitor C_1 is,

$$Vc_1 = Vs / 2(1-D)$$

The operation is divided into positive cycle and negative cycle. For analysis, the switches used and diodes are ideal, capacitors C_1 and C_2 are constant and equal to and 2Vdc/3, output current solar power is sinusoidal and in phase with the voltage and in the positive half cycle of the utility the output current of seven level inverter is also positive.

The operation of multi(seven) level inverter in the positive half cycle further divided into four modes as shown in Fig3.

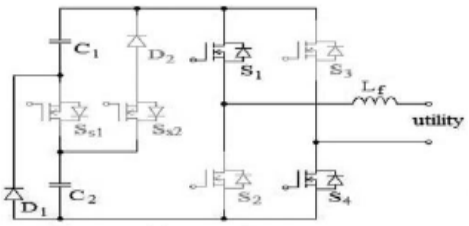

Fig 3a. In Positive half cycle (Mode 1)

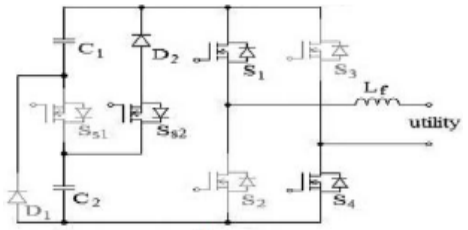

Fig 3b. In Positive half cycle (Mode 2)

Mode 1: S_{s1} and S_{s2} OFF, C_1 is discharged through D_1 and the output is Vdc/3. S_1 and S_4 ON, therefore the output voltage of seven level inverter is Vdc/3.

Mode 2: S_{s1} is OFF and S_{s2} ON, C_2 is discharged through S_{s2} and D_2 and the output is 2Vdc/3. S_1 and S_4 ON, therefore the output voltage of seven level inverter is 2Vdc/3.

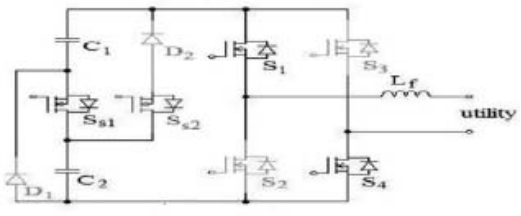

Fig 3c. In positive half cycle (Mode 3)

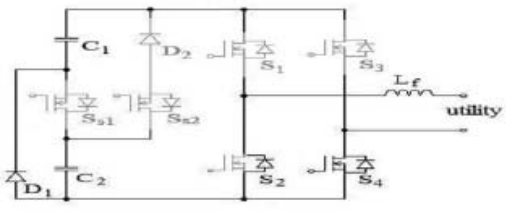

Fig 3d. In positive half cycle (Mode 4)

Mode 3: D_2 is reverse bias so S_{s1} is ON and S_{s2} may be ON or OFF because the state of S_{s2} cannot affect the current flow, C_1 and C_2 is discharged is series and the output is Vdc. S_1 and S_4 ON, therefore the output voltage of seven level inverter is Vdc.

Mode 4: S_{s1} and S_{s2} OFF, the output is Vdc/3. S_4 is ON, output current of the seven level inverter is positive and passes through the filter inductor forces the diode of S_2 to be switch ON for continuous conduction of the filter inductor current therefore the output voltage of seven level inverter is Zero.

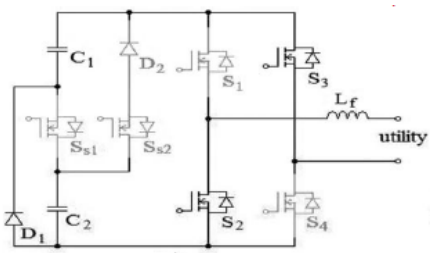

Fig 4a. In negative half cycle (Mode 5)

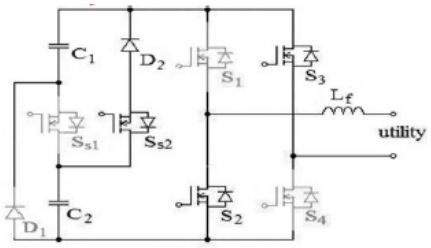

Fig 4b. In negative half cycle (Mode 6)

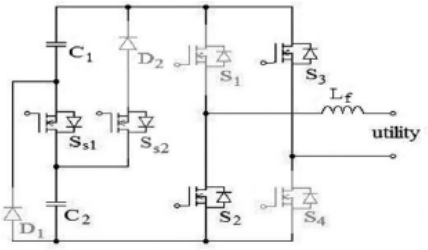

Fig 4c. In negative half cycle (Mode 7)

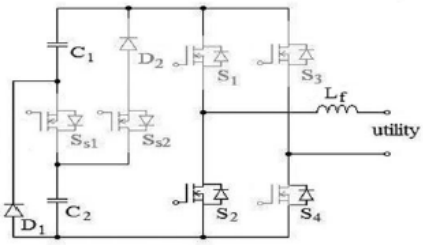

Fig 4d. In negative half cycle (Mode 8)

In the operation of the negative half cycle, the output current of the seven level inverter is negative. It can also be divided into four modes and it is shown in the Fig 4. Compared with positive cycle, in this cycle has the difference is Switch S_2 and S_3 ON during 5, 6, 7 modes and S2 may ON or OFF during mode 8 of negative half cycle. The output voltage of negative cycle in seven level inverter also has four levels -Vdc, -2Vdc/3, -Vdc/3 and 0.

TABLE I. STATES OF SWITCHES AND DEVICES OPERATING IN ALL MODES

V_O	S_1	S_2	S_3	S_4	S_{s1}	S_{s2}	C_1(VDC/3)	C_2(2VDC/3)
VDC/3	1	0	0	1	0	0	VDC/3	-
2VDC/3	1	0	0	1	0	1	-	2VDC/3
VDC	1	0	0	1	1	0	VDC/3	2VDC/3
0	0	0(D2ON)	0	1	0	0	-	-
-VDC/3	0	1	1	0	0	0	-VDC/3	-
-2VDC/3	0	1	1	0	0	1	-	-2VDC/3
-VDC	0	1	1	0	1	0	-VDC/3	-2VDC/3
0	0	1	0	0(D4ON)	0	0	-	-

III. SIMULATION CIRCUITS AND RESULTS

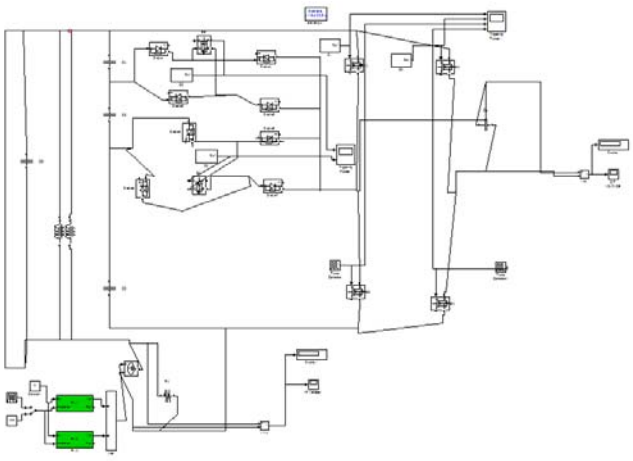

Fig 5a. MATLAB Seven level inverter simulation circuit

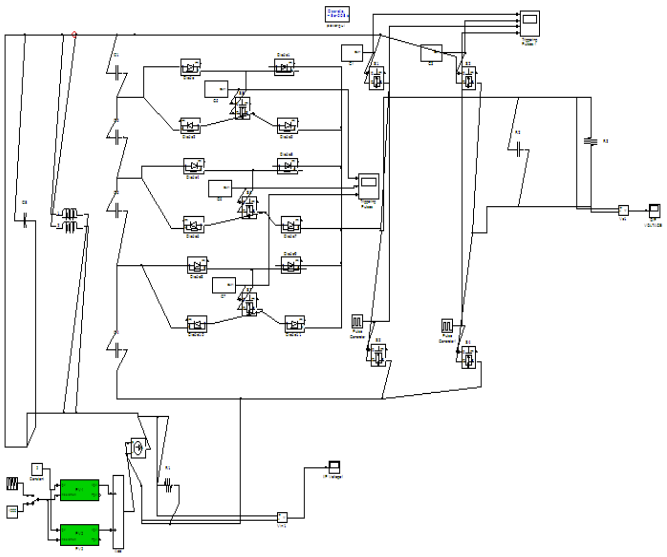

Fig 5b. MATLAB Nine level inverter simulation circuit

To analyze and verify the circuit operation and characteristics of the proposed system, MATLAB software is used for simulation. The Fig5a. shows the circuit diagram for multi(seven) level inverter consists of six switches and three balancing capacitors and Fig5b. shows the circuit diagram for multi(nine) level inverter consists of only seven switches and four balancing capacitors.

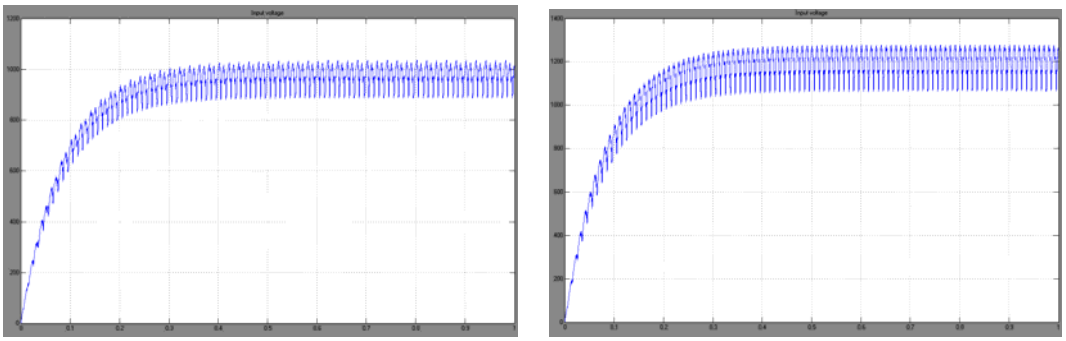

Fig 5c. Input Voltage of Seven level and Nine level Inverter

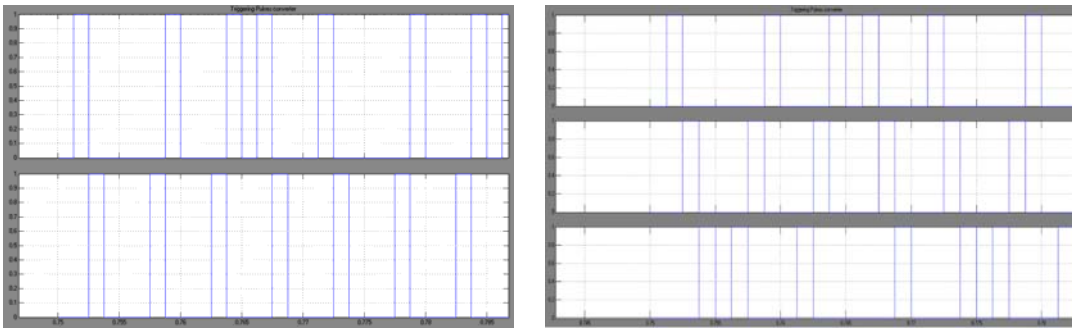

Fig 5d. Triggering pulses to the converter side of Seven level and Nine level Inverter

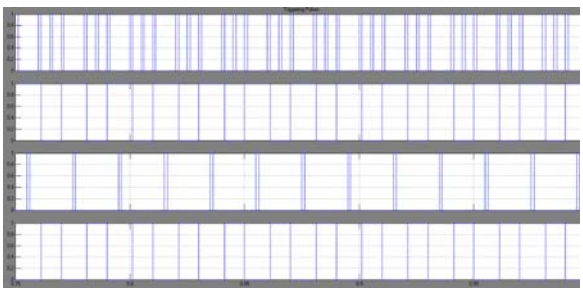

Fig 5e. Triggering pulses to the inverter side of Seven & Nine level Inverter

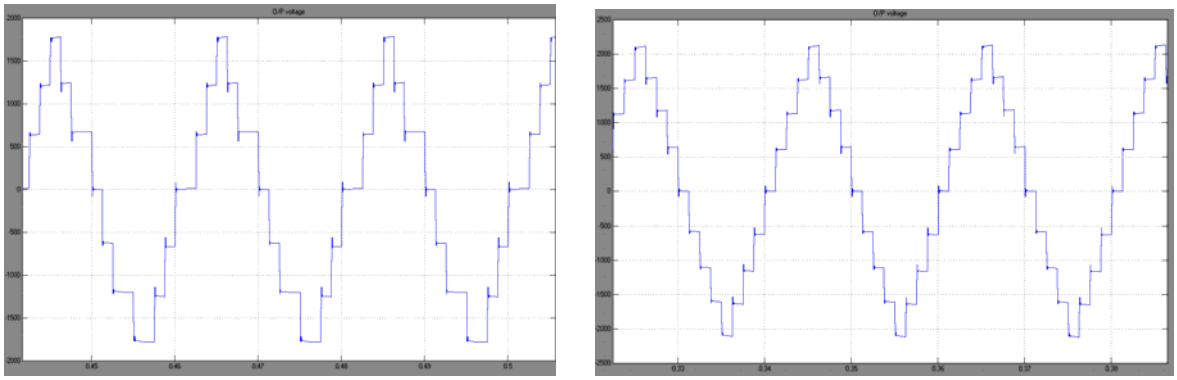

Fig 5f. Output voltage of Seven level and Nine level Inverter

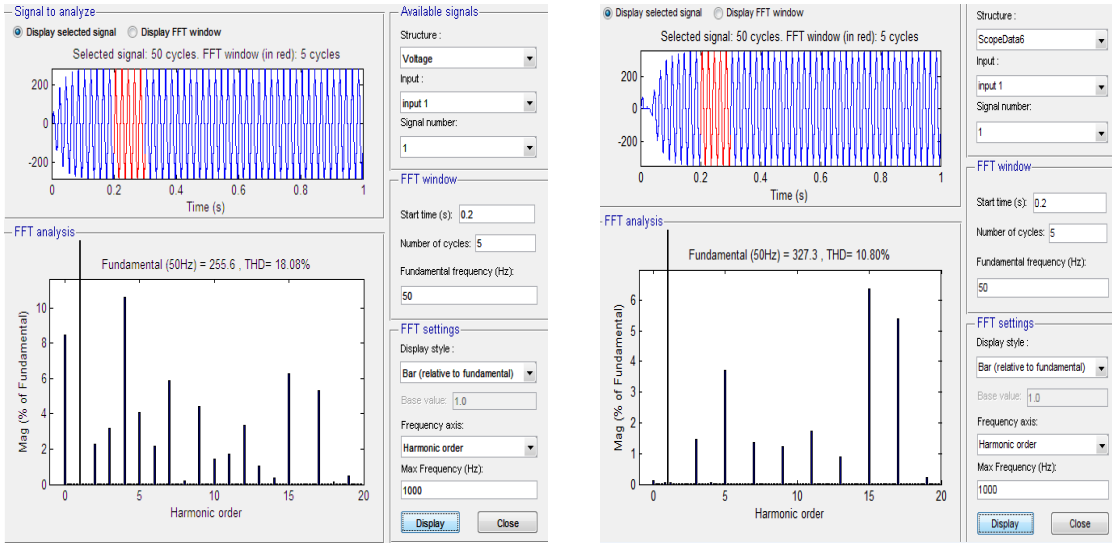

Fig 5g. THD Analysis of Seven level and Nine level Inverter

The Fig5c shows the input voltage given to the seven level and nine level inverter which is from the closed loop compared with the irradiance level in solar power and the inverter output.

The Fig5d. shows the triggering pulses given to the converter side generated by the pulse generator in the period of 20ms and different phase delay for each switches.

The Fig5e. is the triggering pulses to the inverter side generated by the pulse generator in the period of 20ms and different phase delay in each leg of the inverter switches to operate and to give the output. The Fig5f. shows the output voltage of seven level and nine level inverter.

The Fig5g. shows the FFT analysis of single phase seven level and nine level inverter where the Total Harmonic Distortion in Seven level Inverter is 18.08% and Nine level inverter is 10.80%.

TABLE II. COMPARISION OF THD IN MULTILEVEL INVERTER

PHASE	MULTILEVEL INVERTER	LEVEL	THD
SINGLE	CASCADED H-BRIDGE	SINGLE	18.79%
SINGLE	CASCADED H-BRIDGE	SEVEN	18.08%
SINGLE	CASCADED H-BRIDGE	NINE	10.80%

IV. CONCLUSION

In this paper a pv generation system to convert the solar power output dc into ac output that is fed to the utility. It has less number of switches when the level increases. The seven and nine level inverter contains six switches and seven switches to generate the output of stepped ac sinusoidal waveform. The proposed inverter has minimum number of automatic voltage balancing capacitors. Simulation results shows the output of multi(seven and nine) level output voltage and the output current is in phase with voltage and also the THD reduces by increasing the number of level.

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