Simulation studies of PV fed Line Frequency Commutated 5-Level Inverter

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Abstract**—** Power electronic converters are essential for harnessing the abundantly available solar energy. Power from the photovoltaic array can be fed to the ac load or utility grid through inverter which is capable of producing an ac voltage with less harmonics. A multilevel inverter is generally employed for this purpose at the cost of extra switches and control complexity. In this paper, a system is proposed to obtain a multilevel output by introducing a simple auxiliary circuit between the photovoltaic array and the line frequency commutated inverter. Simulation studies of the proposed system have been carried out using MATLAB/Simulink software and the results are presented in this paper.

Keywords*- Photovoltaic array; Multilevel inverter*

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I. INTRODUCTION

The demand for electricity is increasing with the modern living and the fossil fuels are exhausting drastically in this decade. Hence, the researchers gained their attention towards the renewable energy sources such as wind and solar energy. The advancements in power electronic components and their control technologies accelerated the research in photovoltaic array utilities in the power generation [1-3].

The time varying dc power generated from the photovoltaic (PV) array cannot be supplied directly to the ac load/grid. Hence, there is a need for intermediate power electronic converter to convert the dc voltage into a suitable ac voltage with the reduced harmonics to supply the load [4-5]. In order to reduce the harmonics, the ac voltage can be generated as a stepped waveform using multilevel inverters. Multilevel inverters have better electromagnetic compatibility, less total harmonic distortion (THD) in the output voltage, less voltage stress across the switches [6-8]. But they have more number of switches and passive components and the count increases as the level of output voltage increases.

Considering the above factors, a system is proposed which converts the conventional H-bridge inverter into a multilevel inverter with the help of an auxiliary circuit introduced between PV array and H-bridge inverter [9]. The inherent feature of the proposed system has the benefit of increasing the number of levels in the output voltage by simply extending the auxiliary circuit without altering the H-bridge inverter configuration.

II. DESCRIPTION OF PROPOSED SYSTEM

Block diagram of the proposed system is shown in fig. 1 which consists of a PV array and a line frequency commutated five level inverter driving an ac load. An auxiliary circuit and an H-bridge inverter is used for developing the five level inverter. PV array voltage is first converted into a stepped dc voltage by means of an auxiliary circuit and then the stepped dc is converted into a multilevel ac output through H-bridge inverter. The working principle of the proposed system is explained in this section.

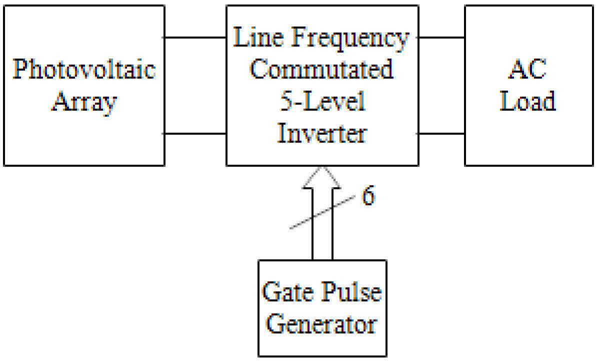

Figure 1. Block diagram of the proposed system

The schematic diagram of the proposed system is shown in fig. 2. The auxiliary circuit operates in four different modes providing a three level stepped dc voltage from a constant dc voltage.

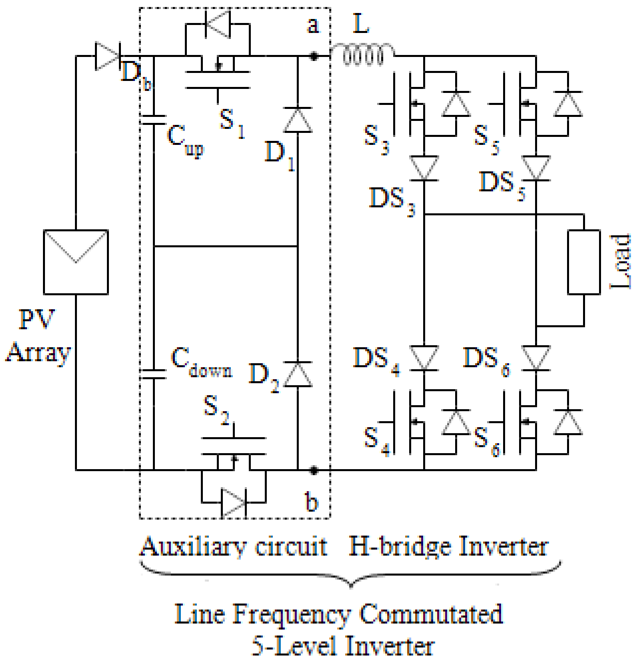

Figure 2. Schematic diagram of the proposed system

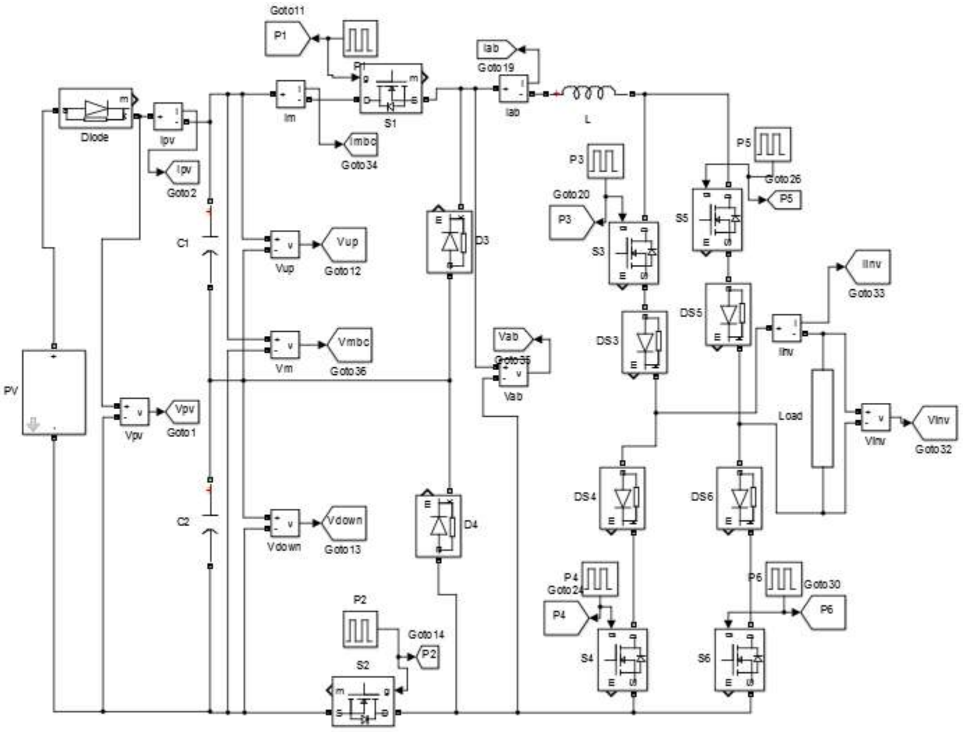

Figure 3. Simulation model of the proposed system

In mode 1, switch S_1 is ON and switch S_2 is OFF leading the voltage across the upper capacitor C_{up} as input to the H-bridge inverter. In mode 2, both the switches of auxiliary circuit are ON making the voltage across the upper capacitor, C_{up} and lower capacitor, C_{down} together to appear at the input terminals of the H-bridge inverter. In mode 3, switch S_2 is ON and S_1 is OFF and the lower capacitor, C_{down} voltage is fed to the H-bridge inverter. In mode 4, both the auxiliary switches are open and zero level is produced in the stepped dc voltage.

Since, a stepped dc input is given to the H-bridge inverter, a multilevel ac output is obtained at the load terminals. When the switches S_3 and S_6 are ON, multilevel positive ac voltage is produced at the output of the inverter and when switches S_4 and S_5 are ON, multilevel negative ac output voltage is generated.

For obtaining the multilevel ac output, the gate pulse generator produces the gate pulses of switching frequency 100 Hz and 50 Hz for the auxiliary circuit and H-bridge inverter respectively. In the auxiliary circuit, the gate pulse of switch S_2 is phase shifted by 90^0 from that of switch S_1 for generating the stepped dc voltage. Square wave pulse width modulation (PWM) technique is used for generating the gate pulses of the H-bridge inverter.

III. SIMULATION STUDIES AND RESULTS

Simulation model of the proposed system is developed in MATLAB/ Simulink software as shown in fig. 3. PV array is modeled using the independent and controlled current sources, arithmetic blocks and measurement blocks available in the Simulink library. Using the power electronic components in the Power System Blockset, schematic of the auxiliary circuit and H-bridge inverter is developed. The developed model is simulated and the results are furnished in this section.

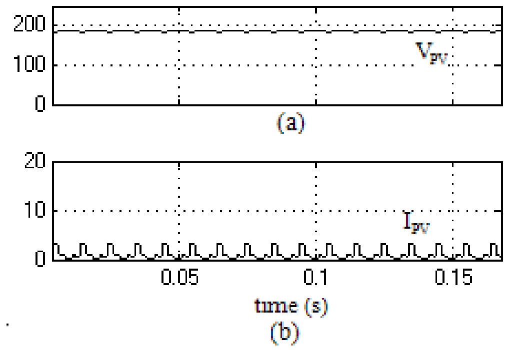

Figure 4. Waveforms of PV array (a) voltage and (b) current

Waveforms of the PV array voltage, V_{PV} of 186 V and PV array current, I_{PV} of 1.1 A is shown in fig. 4.This PV array voltage is distributed equally among the two capacitors C_{up} and C_{down} as shown in fig. 5.

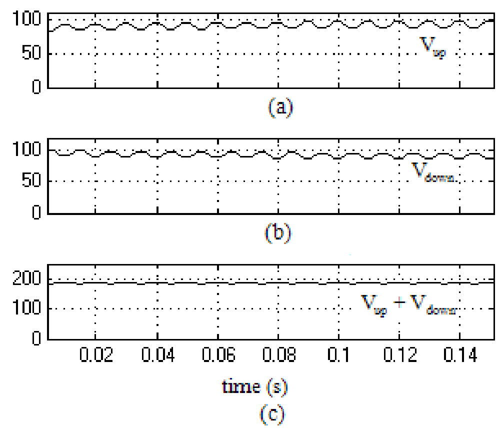

Figure 5. Waveforms of (a)Voltage across upper capacitor, V_{up} (b) Voltage across lower capacitor, V_{down} and (c) total capacitor voltage, V_{up}+V_{down}

Fig.6. depicts the waveforms of the total input voltage to the auxiliary circuit and stepped dc output voltage along with the generated gate pulses.

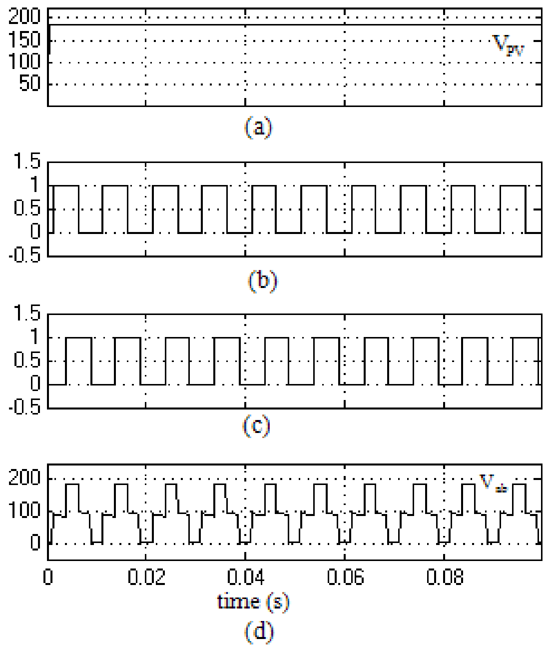

Figure 6. Waveforms of (a) auxiliary circuit input voltage, (b) gate pulses to the switches,S_1 (c) gate pulses to the switches, S_2 and (d) stepped dc output voltage

The stepped dc voltage is converted into a five level ac voltage by the H-bridge inverter as shown in fig. 7. The generated gate pulses of H-bridge inverter are also shown in fig. 7.

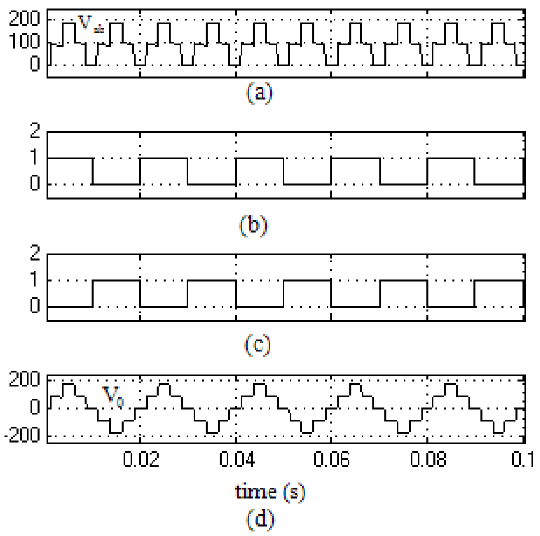

Figure 7. Waveforms of H-bridge inverter input volatge, switching pulses and the five level output volatge

From the simulation results, it is inferred that the PV array voltage can be converted into a five level ac voltage using the proposed circuit configuration with simple control techniques.

IV. CONCLUSION

A line frequency commutated five level inverter for PV systems is presented in this paper which is capable of generating a multilevel ac output voltage with reduced harmonics. Auxiliary circuit can be extended to increase the number of levels in the output retaining the H-bridge inverter circuit. The entire system is modeled and simulated in the MATLAB/Simulink software. From the simulation results, it was found that the multilevel ac output voltage can be obtained using the simple circuit configuration presented in this paper.

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