Single phase Seven Level Inverter for Grid Connection

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Abstract: *This paper proposes a single-phase seven-level inverter for grid-connected photovoltaic systems, with a novel pulse width-modulated (PWM) control scheme. Three reference signals that are identical to each other with an offset that is equivalent to the amplitude of the triangular carrier signal were used to generate the PWM signals. The inverter is capable of producing seven levels of output-voltage levels (Vdc, 2Vdc/3, Vdc/3, 0,−Vdc,−2Vdc/3,−Vdc/3) from the dc supply voltage.*

Keywords: *Grid connected, modulation index, multilevel inverter, photovoltaic (PV) system, pulse width-modulated (PWM), total harmonic distortion (THD).*

I. Introduction

The demand for renewable energy has increased significantly over the years because of shortage of fossil fuels and greenhouse effect. Among various types of renewable energy sources, solar energy and wind energy have become very popular and demanding due to advancement in power electronics techniques. Photovoltaic (PV) sources are used today in many applications as they have the advantages of being maintenance and pollution free. Solar-electric-energy demand has grown consistently by 20%−25% per annum over the past 20 years, which is mainly due to the decreasing costs and prices. This decline has been driven by the following factors: 1) an increasing efficiency of solar cells; 2) manufacturing technology improvements; and 3) economies of scale [1]. PV inverter, which is the heart of a PV system, is used to convert dc power obtained from PV modules into ac power to be fed into the grid. Improving the output waveform of the inverter reduces its respective harmonic content and, hence, the size of the filter used and the level of electromagnetic interference (EMI) generated by switching operation of the inverter. In recent years, multilevel inverters have become more attractive for researchers and manufacturers due to their advantages over conventional three-level pulse width-modulated (PWM) inverters. They offer improved output waveforms, smaller filter size, lower EMI, lower total harmonic distortion (THD), and others. Various topologies for multilevel inverters have been proposed over the years. Common ones are diode-clamped, flying capacitor or multi cell, cascaded H-bridge, and modified H-bridge multilevel.This paper recounts the development of a novel modified H-bridge single-phase multilevel inverter that has two diode embedded bidirectional switches and a novel pulse width modulated (PWM) technique. The topology was applied to a grid-connected photovoltaic system with considerations for a maximum-power-point tracker (MPPT) and a current-control algorithm.

II. Principle of Operation of the Proposed Inveretr

The proposed single-phase seven-level inverter was developed from the five-level inverter in. It comprises a single-phase conventional H-bridge inverter, two bidirectional switches, and a capacitor voltage divider formed by C1, C2, and C3, as shown in Fig.1. The modified H-bridge topology is significantly advantageous over other topologies, i.e., less power switch, power diodes, and less capacitors for inverters of the same number of levels. Photovoltaic (PV) arrays were connected to the inverter via a dc–dc boost converter. The power generated by the inverter is to be delivered to the power network, so the utility grid, rather than a load, was used. The dc–dc boost converter was required because the PV arrays had a voltage that was lower than the grid voltage. High dc bus voltages are necessary to ensure that power flows from the PV arrays to the grid. A filtering inductance Lf was used to filter the current injected into the grid. Proper switching of the inverter can produce seven output-voltage levels (Vdc, 2Vdc/3, Vdc/3, 0,−Vdc,−2Vdc/3,−Vdc/3) from the dc supply voltage. Three reference signals Vref1, Vref2 and Vref3 will take turns to be compared with the carrier signal at a time.Fig.2 shows the carrier and reference signals. If Vref1 had exceeded the peak amplitude of Vcarrier, Vref2 was compared with Vcarrier until it had exceeded the peak amplitude of Vcarrier. Then, onward, Vref3 would take charge and would be compared with Vcarrier until it reached zero. Once Vref3 had reached zero, Vref2 would be compared until it reached zero. Then, onward, Vref1 would be compared with Vcarrier. Fig.3 shows the resulting switching pattern. Switches S1, S3, S5, and S6 would be switching at the rate of the carrier signal frequency, whereas S2 and S4 would operate at a frequency that was equivalent to the fundamental

frequency.Table5.1 illustrates the level of Vinv during S1–S5 switch on and off. Table I shows the output voltage according to the switches' On-Off condition. As Fig. 4 shows, the control system comprises a MPPT algorithm, a dc-bus voltage controller, reference-current generation, and a current controller. The two main tasks of the control system are maximization of the energy transferred from the PV arrays to the grid, and generation of a sinusoidal current with minimum harmonic distortion, also under the presence of grid voltage harmonics.

The proposed inverter utilizes the perturb-and-observe (P&O) algorithm for its wide usage in MPPT owing to its simple structure and requirement of only a few measured parameters. It periodically perturbs (i.e., increment or decrement) the array terminal voltage and compares the PV output power with that of the previous perturbation cycle. If the power was increasing, the perturbation would continue in the same direction in the next cycle; otherwise, the direction would be reversed. This means that the array terminal voltage is perturbed every MPPT cycle; therefore, when the MPP is reached, the P&O algorithm will oscillate around it.The P&O algorithm was implemented in the dc–dc boost converter. The output of the MPPT is the duty-cycle function. As the dc-link voltage Vdc was controlled in the dc–ac seven level PWM inverter, the change of the duty cycle changes the voltage at the output of the PV panels. A PID controller was implemented to keep the output voltage of the dc–dc boost converter (Vdc) constant by comparing Vdc and Vdc ref and feeding the error into the PID controller, which subsequently tries to reduce the error. In this way, the Vdc can be maintained at a constant value and at more than √2 of Vgrid to inject power into the grid.

To deliver energy to the grid, the frequency and phase of the PV inverter must equal those of the grid; therefore, a grid synchronization method is needed. The sine lookup table that generates reference current must be brought into phase with the grid voltage (Vgrid). For this, the grid period and phase must be detected. A PI algorithm was used as the feedback current controller for the application. The current injected into the grid, also known as grid current Igrid, was sensed and fed back to a comparator that compared it with the reference current Igridref . Igridref is the result of the MPPT algorithm. The error from the comparison process of Igrid and Igridref was fed into the PI controller. The output of the PI controller, also known as Vref , goes through an anti windup process before being compared with the triangular wave to produce the switching signals for S1–S6. Eventually, Vref becomes Vref1; Vref2 and Vref3 can be derived from Vref1 by shifting the offset value, which was equivalent to the amplitude of the triangular wave.
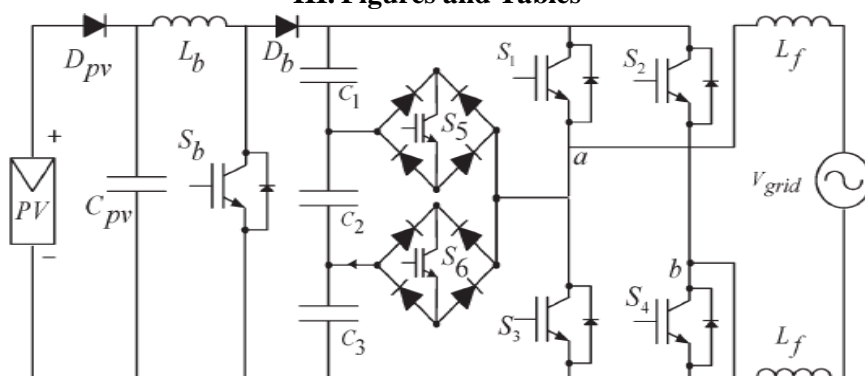
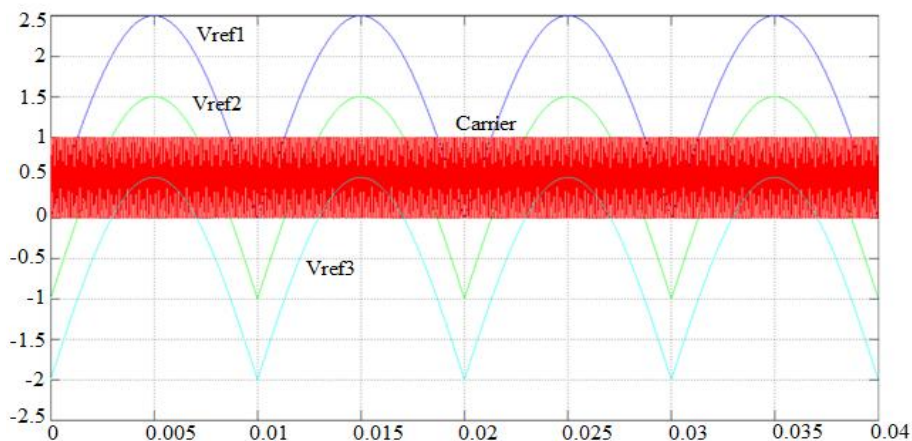## III. Figures and Tables

Fig.1 Proposed Inverter Topology
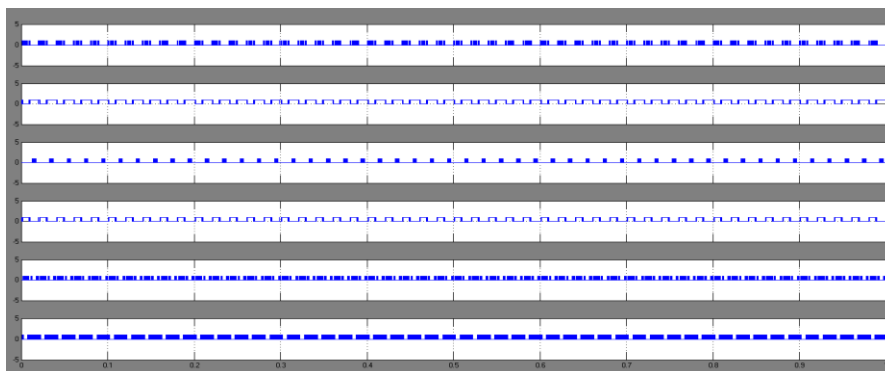

Fig.2 Reference and Carrier signals
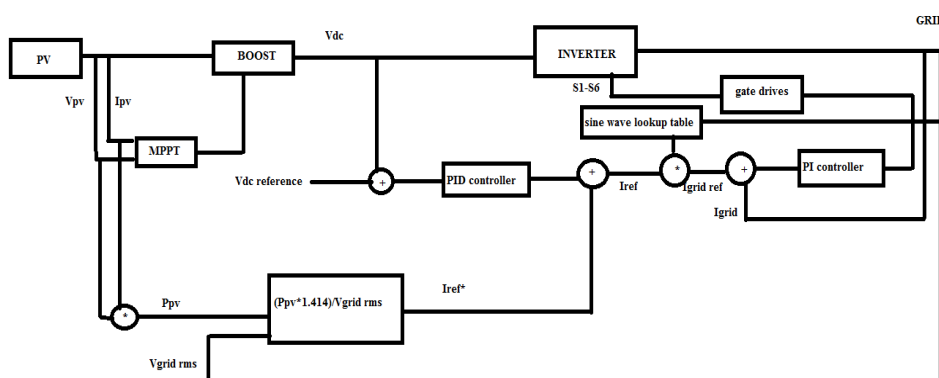
Fig.3 Switching Pattern
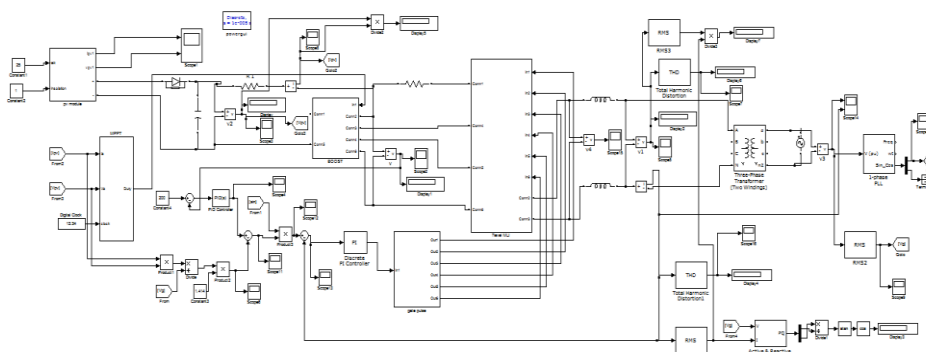

Fig.4 Control system Model

Fig.5 Simulink Model of the Proposed Seven Level Inverter

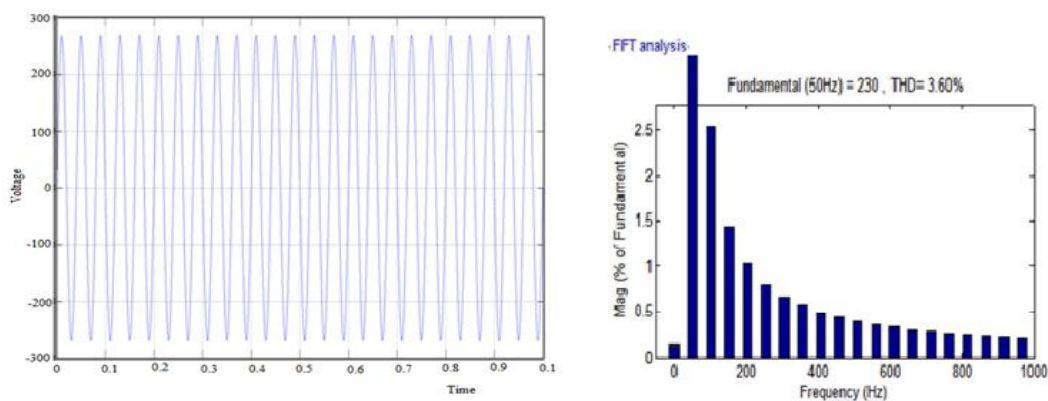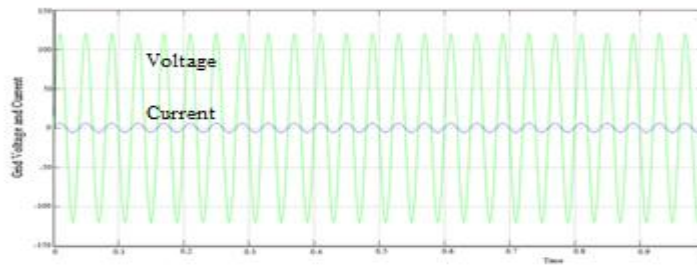**Fig.6** Inverter Output Voltage (M>0.66) and FFT Analysis
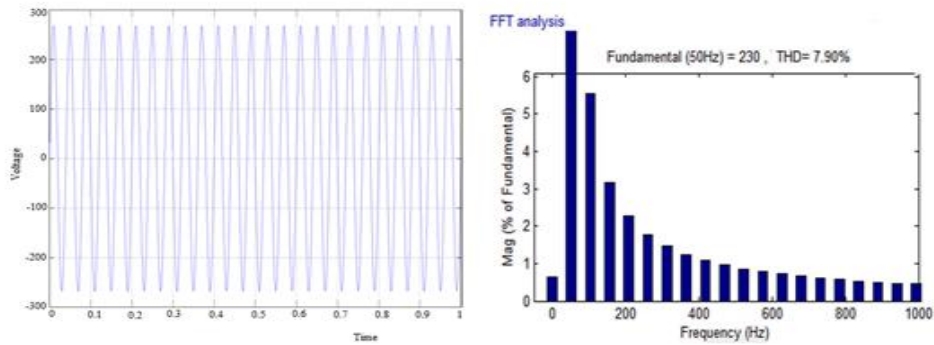
Fig.7 Grid Voltage and Current
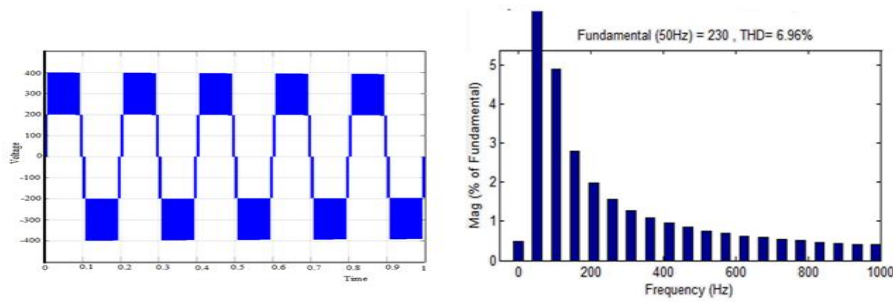

Fig.8 Output Voltage (0.33≤M≤0.66) and THD Analysis

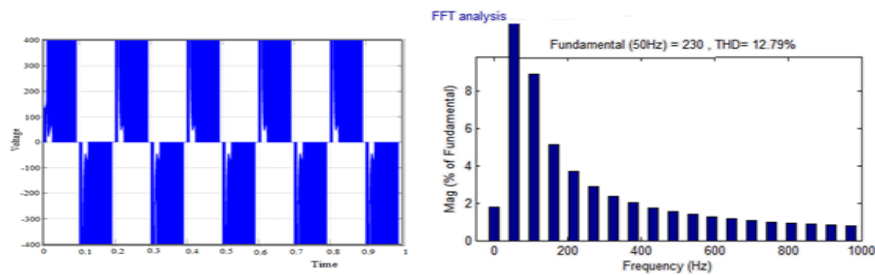**Fig.9** Output Voltage (M<0.33) and THD Analysis

Fig.10 Output Voltage and THD analysis of Five Level Inverter

IV. Conclusion

Multilevel inverters offer improved output waveforms and lower THD. This paper has presented a novel PWM switching scheme for the proposed multilevel inverter. It utilizes three reference signals and a triangular carrier signal to generate PWM switching signals. The behavior of the proposed multilevel inverter was analysed in detail. By controlling the modulation index, the desired number of levels of the inverter's output voltage can be achieved. The less THD in the seven-level inverter compared with that in the five- and three-level inverters is an attractive solution for grid-connected PV inverters.

References

Journal Papers:

[1]   J. Selvaraj and N. A. Rahim, "Multilevel inverter for grid-connectedPV system employing digital PI controller," (IEEE Trans. Ind. Electron.,vol. 56, no. 1, pp. 149–158, Jan. 2009.)

[2]   Nasrudin A. Rahim, Senior Member, IEEE, KrismadinataChaniago, Student Member, IEEE, and JeyrajSelvaraj "Single-Phase Seven-Level Grid-Connected Inverter for Photovoltaic System".(June 2011)

[3]   KinalKachhiya, MakarandLokhande, "MATLAB/Simulink Model of Solar PV Module andMPPT Algorithm" (National Conference on Recent Trends in Engineering & Technology.13-14 May 2011)

[4]   Sung-Jun Park, Member, IEEE, Feel-Soon Kang, Member, IEEE, Man Hyung Lee, Senior Member, IEEE, and Cheul-U Kim, Member, IEEE " A New Single-Phase Five-Level PWM Inverter Employing a Deadbeat Control Scheme". IEEE Transactionson Power Electronics, VOL. 18, NO. 3, MAY 2003

[5]   José Rodríguez, Senior Member, IEEE, Jih-Sheng Lai, Senior Member, IEEE, and Fang ZhengPeng, Senior Member, IEEE, "Multilevel Inverters: A Survey of Topologies, Controls, and Applications". IEEE Transactionson Industrial Electronics, VOL. 49, NO. 4, AUGUST 2002

[6]   C.Vijayalakshmi, R.Latha , "Implementation of New Single Phase Multilevel Inverterfor PV Power Conditioning System". International Journalof Advanced Scientific Researchand Technology Issue 2, Volume 2 (APRIL 2012) ISSN: 2249-9954

[7]   K.SuryaSuresh andM.Vishnu Prasad, " PV Cell Based Five Level Inverter Using Multicarrier PWM". (International Journal of Modern Engineering Research (IJMER) Vol.1, Issue.2, pp-545-551 ISSN: 2249-6645)

[8]   TrishanEsram, Student Member, IEEE, and Patrick L. Chapman, Senior Member, IEEE , "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques".(IEEE Transactions on Energy Conversion, VOL. 22, NO. 2, JUNE 2007)