

# **A Three Phase Seven Level Inverter for Grid Connected Photovoltaic System by Employing PID Controller**

S. Ragavan, Swaminathan<sup>1</sup>, R.Anand<sup>2</sup>, N. Ranganathan<sup>3</sup>

PG Scholar, Dept of EEE, Sri Krishna College of Technology, Coimbatore, Tamilnadu, India<sup>3</sup>

Assistant Professor, Dept of EEE, Sri Krishna College of Technology, Coimbatore, Tamilnadu, India<sup>2</sup>

PG Scholar, Dept of EEE, Sri Krishna College of Technology, Coimbatore, Tamilnadu, India<sup>3</sup>

**ABSTRACT:** This paper presents a three phase seven level photovoltaic (PV) inverter topology for grid connected PV systems with a novel Pulse Width Modulated(PWM) control scheme. Two reference signals identical to each other with an offset equivalent to the amplitude of the triangular carrier signal were used to generate PWM signals for the switches. A digital Proportional-Integral-Derivative (PID) current control algorithm is implemented in DSPTMS320F2812 to keep the current injected into the grid sinusoidal and to have high dynamic performance with rapidly changing atmospheric conditions. The inverter offers much less total harmonic distortion and can operate at near-unity power factor. The proposed system is verified through simulation and is implemented in a prototype. Experimental results are compared with the conventional three phase three level grid connected PWM inverter.

**KEYWORDS:** Grid connected Photovoltaic system, Three phases even level inverter, Maximum power point tracking system and Proportional-Integral-Derivative (PID) Controller.

## **1. INTRODUCTION**

The Demand for renewable energy has increased significantly over the years because of shortage of fossil fuels and green house effect. The definition of renewable energy includes any type of energy generated from natural resources that is infinite or constantly renewed. Examples of renewable energy include solar, wind, and hydropower. Renewable energy, due to its free availability and its clean and renewable character, ranks as the most promising renewable energy resources like Solar energy, Wind energy that could play a key role in solving the world wide energy crisis. Among various types of renewable energy sources, solar energy and wind energy have become very popular and demanding due to advance mentin power electronics techniques. Photovoltaic(PV) sources are used to day in many applications as they have the advantages of effective maintenance and pollution free. Solar electric energy demand has grown consistently by 20%to25% per annum over the past 20 years, which is mainly due to its decreasing costs and prices. This decline has been driven by the following factors.

- 1) An increasing efficiency of solar cells
- 2) Manufacturing technology improvements
- 3) Economies of scale

PV inverter, which is the heart of a PV system, is used to convert dc power obtained from PV modules in to ac power to be fed in to 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 threelevel PWM inverters. They offer improved output waveforms, smaller filter size and lower EMI, lower Total Harmonic Distortion(THD). The three common topologies for multilevel inverters are as follows:

- 1) Diode clamped(neutral clamped)

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

- 2) Capacitor clamped (flying capacitors)
- 3) Cascaded H-bridge inverter

In addition, several modulation and control strategies have been developed or adopted for multilevel inverters, including the following multilevel sinusoidal (PWM), multilevel selective harmonic elimination & Space Vector modulation. A typical three phase three-level inverter adopts full-bridge configuration by using approximate sinusoidal modulation technique as the power circuits. The output voltage then has the following three values: zero, positive (+V<sub>dc</sub>), and negative (-V<sub>dc</sub>) supply dc voltage (assuming that V<sub>dc</sub> is the supply voltage). The harmonic components of the output voltage are determined by the carrier frequency and switching functions. Therefore, their harmonic reduction is limited to a certain degree. To overcome this limitation, this paper presents a seven-level PWM inverter whose output voltage can be represented in the following seven levels: zero, +1/2V<sub>dc</sub>, V<sub>dc</sub>, -1/2V<sub>dc</sub> and -V<sub>dc</sub>. As the number of output level increases, the harmonic content can be reduced. This inverter topology uses two reference signals, instead of one reference signal, to generate PWM signals for the switches. Both the reference signals V<sub>ref1</sub> and V<sub>ref2</sub> are identical to each other, except for an offset value equivalent to the amplitude of the carrier signal V<sub>carrier</sub>, as shown in Fig.1.

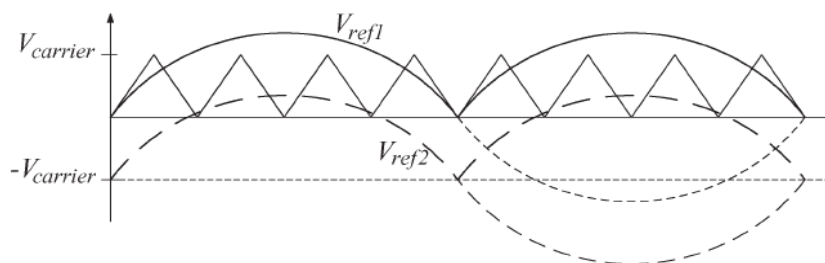


Fig.1 Carrier and reference signals

Because the inverter is used in a PV system, a PID current control scheme is employed to keep the output current sinusoidal and to have high dynamic performance under rapidly changing atmospheric conditions and to maintain the power factor at near unity. Simulation and experimental results are presented to validate the proposed inverter configuration.

### II. SEVEN LEVEL INVERTER TOPOLOGY AND PWM LAW

The proposed three phase seven level inverter topology is shown in Fig.2. The inverter adopts a full-bridge configuration with an auxiliary circuit. PV arrays are connected to the inverter via a dc-dc boost converter. Because the proposed inverter is used in a grid-connected PV system, utility grid is used instead of load. The dc-dc boost converter is used to step up inverter output voltage V<sub>in</sub> to be more than √2 of grid voltage V<sub>g</sub> to ensure power flow from the PV arrays in to the grid.

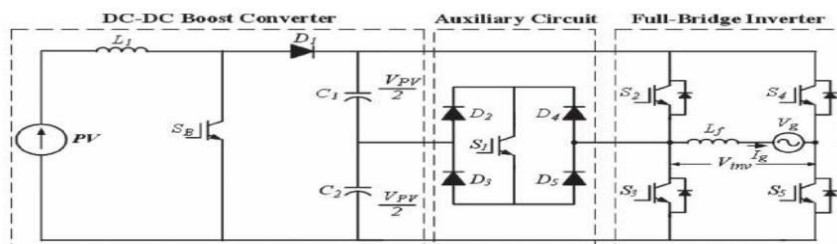


Fig.2 Three phase seven level inverter topology

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

A filtering inductance  $L_f$  is used to filter the current injected into the grid. The injected current must be sinusoidal with low harmonic distortion. In order to generate sinusoidal current, sinusoidal PWM is used because it is one of the most effective methods. Sinusoidal PWM is obtained by comparing a high frequency carrier with a low frequency sinusoid, which is the modulating or reference signal. The carrier has a constant period; therefore, the switches have constant switching frequency. The switching instant is determined from the crossing of the carrier and the modulating signal.

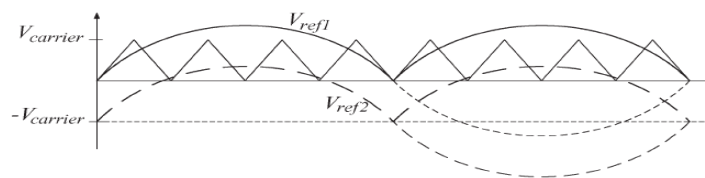


Fig.3 Carrier and reference signals for modulation index  $M=0$

### III. OPERATIONAL PRINCIPLE OF THE PROPOSED INVERTER

Because PV arrays are used as input voltage sources, the voltage produced by the arrays is known as  $V_{arrays}$ .  $V_{arrays}$  boosted by a dc-dc boost converter to exceed  $\sqrt{2}V_g$ . The voltage across the dc-bus capacitors is known as  $V_{pv}$ . The operational principle of the proposed inverter is to generate seven level output voltage, i.e.,  $0$ ,  $+V_{pv}/2$ ,  $+V_{pv}$ ,  $-V_{pv}/2$ , and  $-V_{pv}$ . Proper switching control of the auxiliary circuit can generate half level of PV. Supply voltage, i.e.,  $+V_{pv}/2$  and  $-V_{pv}/2$ . Two reference signals  $V_{ref1}$  and  $V_{ref2}$  will take turns to be compared with the carrier signal at a time. If  $V_{ref1}$  exceeds the peak amplitude of the carrier signal  $V_{carrier}$ ,  $V_{ref2}$  will be compared with the carrier signal until it reaches zero. At this point onward,  $V_{ref1}$  takes over the comparison process until it exceeds  $V_{carrier}$ .

### IV. CONTROL SYSTEM ALGORITHM AND IMPLEMENTATION

The feedback controller used in this application utilizes the PID algorithm. As shown in Fig., the current injected in to the grid, also known as grid current  $I_g$ , is sensed and fed back to a comparator which compares it with the reference current  $I_{ref}$ .  $I_{ref}$  is obtained by sensing the grid voltage and converting it to reference current and multiplying it with constant  $m$ . This is to ensure that  $I_g$  is in phase with grid voltage  $V_g$  and always at near-unity power factor. One of the problems in the PV generation systems is the amount of the electric power generated by solar arrays always changing with weather conditions, i.e., the intensity of the solar radiation.

A maximum power point tracking (MPPT) method or algorithm, which has quick-response characteristics and is able to make good use of the electric power generated in any weather, is needed to solve the a fore mentioned problem. Constant  $m$  is derived from the MPPT algorithm. The perturb and observe algorithm is used to extract maximum power from PV arrays and deliver it to the inverter. The instantaneous current error is fed to a PID controller. The integral term in the PID controller Improves the tracking by reducing the instantaneous error between the reference and the actual current. The resulting error signal  $u$  which forms  $V_{ref1}$  and  $V_{ref2}$  is compared with a triangular carrier signal and intersections are sought to produce PWM signals for the inverter switches.

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

**TABLE I: Inverter Output Voltage during S1-S5 Switch ON and OFF**

S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	S <sub>5</sub>	V <sub>in</sub>
ON	OFF	OFF	OFF	ON	+V <sub>pv</sub> /2
OFF	ON	OFF	OFF	ON	+V <sub>pv</sub>
OFF	OFF	OFF	ON	ON	0
ON	OFF	OFF	ON	OFF	-V <sub>pv</sub> /2
OFF	OFF	ON	ON	OFF	-V <sub>pv</sub>

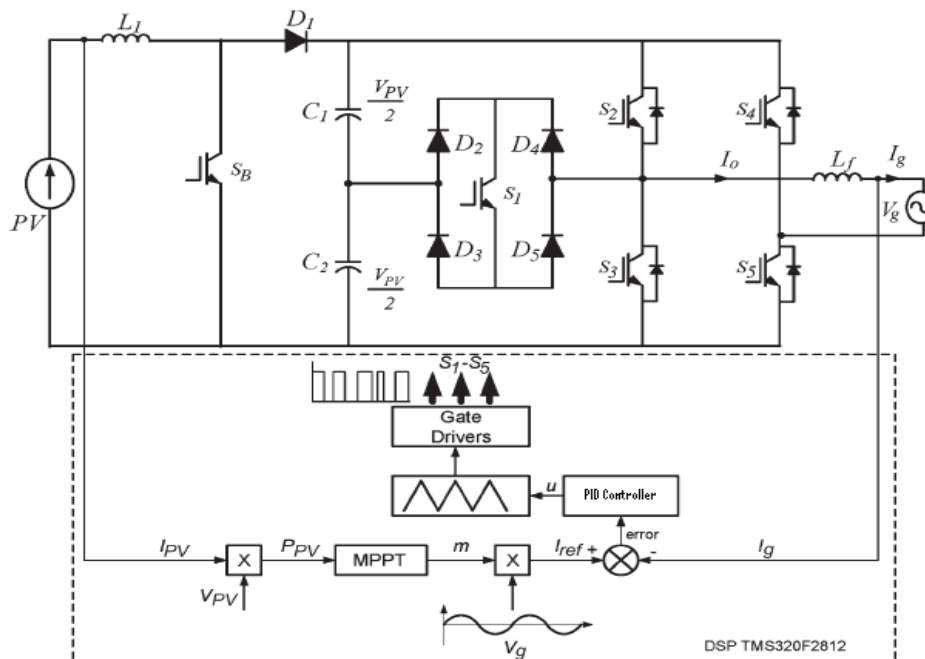


Fig.4 Seven level inverter with control algorithm implemented in DSPTMS 320F2812

Implementing this algorithm using a DSP requires one to transform it into the discrete time domain. Trapezoidal sum approximation is used to transform the integral term into the discrete time domain because it is the most straight forward technique. The proportional term is directly used without approximation. The Simulation result for seven level inverter for grid connected PV system is obtained and as shown in Fig.4, Fig.5 and Fig.6

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

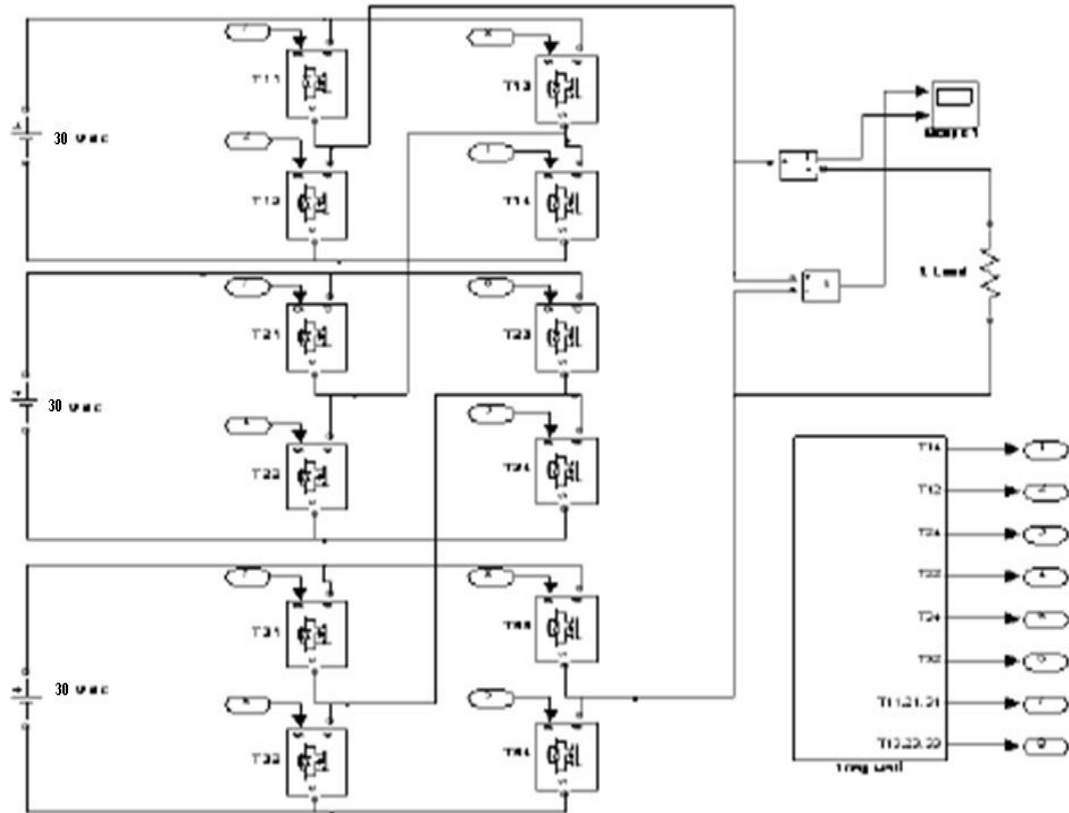


Fig.5 Simulink diagram for seven level inverter

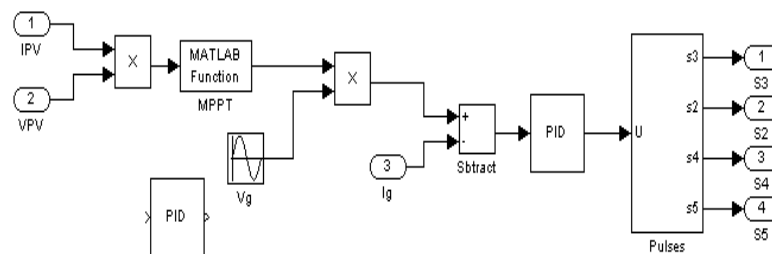


Fig.6 MPPT technology

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

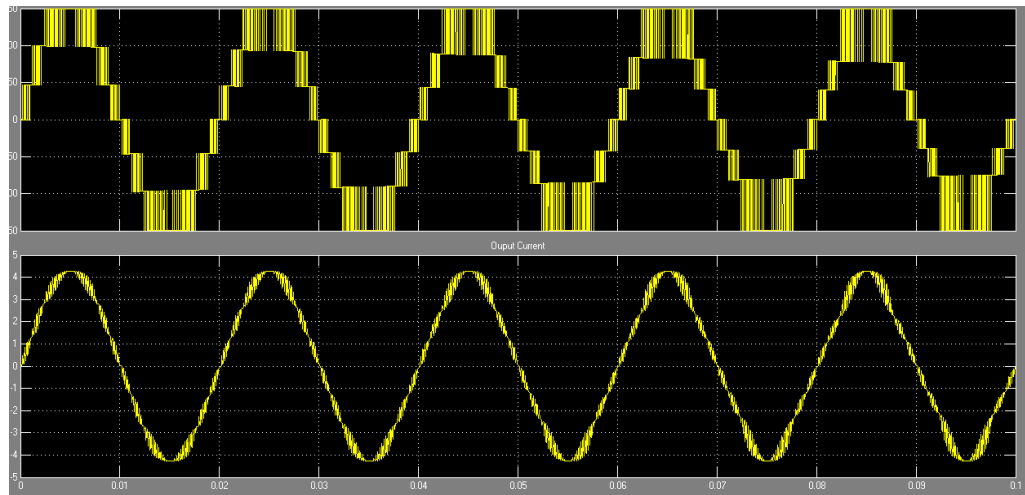


Fig.7 Simulation seven level output voltage and current for grid connected PV System.

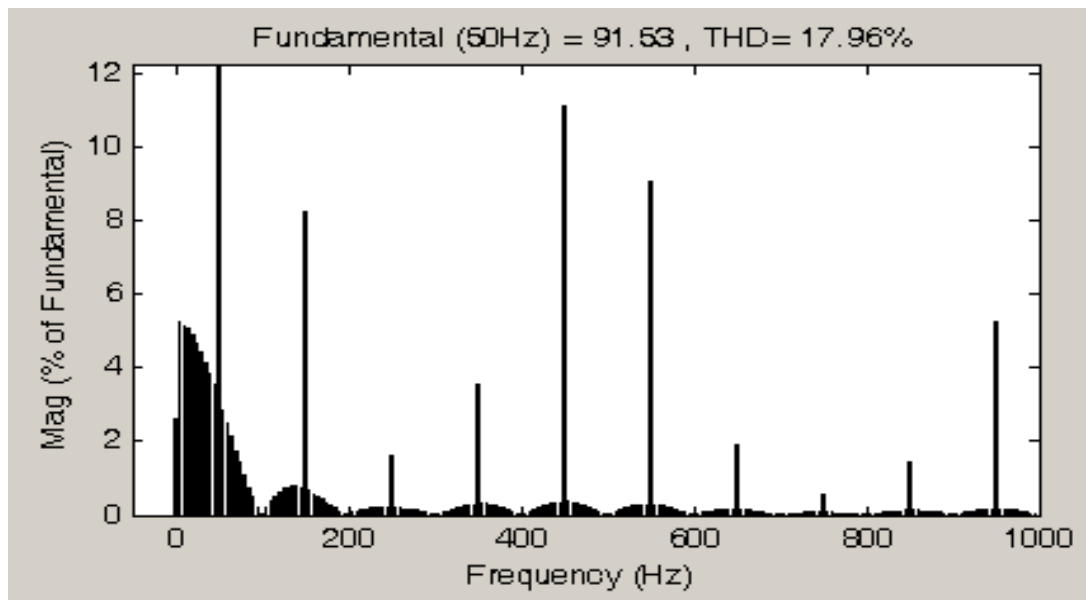


Fig.8 Simulink FFT output

## V. CONCLUSION

This paper presented a three phase multilevel inverter for PV application. It utilizes two reference signals and a carrier signal to generate PWM switching signals. The circuit topology, modulation law, and operational principle of the proposed inverter were analyzed in detail. A digital PI current control algorithm is implemented in DSPTMS320F2812 to optimize the performance of the inverter. Experimental results indicate that the THD of the seven level inverter is much lesser than that of the conventional three level inverter. Furthermore; both the grid voltage and the grid current are in phase at near-unity power.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

The proposed seven level diode clamped multilevel inverter has several promising advantages for the use of a three-phase stand-alone photovoltaic system. First, it can convert power from several relatively low dc voltage sources to a higher ac voltage by itself (without transformers or high frequency switching). Second, it increases output voltage levels without any transformer that reduce the losses and weight of the overall system. Third, in case of a seven level multi level inverter operating as a motor drive, it does not require an output filter because high order harmonics are effectively filtered off, owing to the reactance of the induction motor load; therefore, it can produce a high quality output voltage wave with a good harmonic characteristic. Finally, it reduces stresses on power switching devices, resulting in low audio and Radio Frequency (RF) noise and Electromagnetic Interference (EMI), and fewer Electromagnetic Compatibility (EMC) problems, since multilevel inverter operates with a low switching frequency and voltage switching is done for relatively lower voltage levels

## REFERENCES

- [1]. R.Thaila, V.Dhinesh, C.V.Venkatesan and S.Saravanan, "Design of Full-Bridge Resonant AC- Link Boost Converter Using Solar Energy System", International Journal on Engineering Science and Technology, Vol.2, No.5, pp.856-860, 2012 (Impact factor 0.356).
- [2]. A.Sasipriya, V.Dhinesh, T.Malathi, and S.Saravanan, "Design of a Boost-Buck Converter Fed PMDC Motor" International Journal on Engineering Science and Technology, Vol.3, No.4, 2013. (Impact factor 0.356).
- [3]. R.Satheesh Kumar, D. Kanimozhi, S. Saravanan, "An Efficient Control Scheme for Wind Farm Using Back to Back Converter," International Journal of Engineering Research & Technology (IJERT), Vol. 2, No.9, pp.3282-3289, 2013. (Impact factor 1.76).
- [4]. D.Kanimozhi, S. Saravanan, R.Satheesh Kumar, "Analysis of Doubly Fed Induction Generator Connected Matrix Converter in Wind Farm," International Journal of Engineering Research & Technology (IJERT), Vol. 2, No.11, pp.3981-3988, 2013
- [5]. T.Premkumar, P. Vijayakumar, V. Dhinesh and S.Saravanan, "Harmonic reduction using cascaded multilevel inverter fed induction motor drive" International Journal of Advanced and Innovative Research, Vol. 3, No.11, pp.274-278, 2014.
- [6] J. Pou, R. Pindado, and D. Boroyevich, "Voltage-balance limits in fourlevel Diode-clamped converters with passive front end," *IEEE Trans. Ind.Electron.*, vol. 52, no. 1, pp. 190-196, Feb. 2005.