

Implementation of Microcontroller Based PWM Scheme for PV Multilevel Inverter

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Abstract

This paper presents a single phase five 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 MICROCONTROLLER PIC16C7F88 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-unit power factor. The proposed system is verified through simulation and is implemented in a prototype. Experimental results are compared with the conventional single phase three level grid connected PWM inverter.

Keywords: Grid connected Photovoltaic system, Single phase five level inverter, Maximum power point tracking system and Proportional-Integral derivative (PID) Controller.

Introduction

The demand for renewable energy has increased significantly over the years because of shortage of fossil fuel and green house effect. The definition of renewable energy includes any type of energy generated from natural resources that is infinite or constantly renewed. An example of renewable energy includes 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 worldwide energy

crisis. 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 effective maintenance and pollution free. Solar electric energy demand has grown consistently by 20%to25% per annum over the past 20years, which is mainly due to its decreasing constant prices. This decline has been driven by the following factors.

- An increasing efficiency of solar cells.
- Manufacturing technology improvements.
- Economics of scale.

PV inverter, which 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 researcher sand manufacturers due to their advantages over conventional three level PWM inverters. They offer improved output Waveforms, smaller filter size and lower EMI, and lower Total Harmonic Distortion (THD) .The three common topologies for multilevel inverters are as follows:

- Diode clamped(neutral clamped)
- Capacitor clamped(flying capacitors)
- Cascaded H-bridge inverter

In addition, several modulation and control strategies have been developed or adopted for 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 ($-V_{dc}$)supply dc voltage(assuming that V_{dc} is the supply voltage).The harmonic component the output voltage are multilevel inverters including the following multilevel sinusoidal (PWM),multilevel selective harmonic elimination, & Space Vector modulation. A typical single 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 ($+V_{dc}$), and negative ($-V_{dc}$) supply dc voltage (assuming that V_{dc} 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 five-level PWM inverter whose output voltage can be represented in the following five levels: zero, $+1/2V_{dc}$, V_{dc} , $-1/2V_{dc}$ and $-V_{dc}$.As the number of output levels 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_{ref1} and V_{ref2} are identical to each

other, except for an offset value equivalent to the amplitude of the carrier signal $V_{carrier}$, as shown in Fig.1.

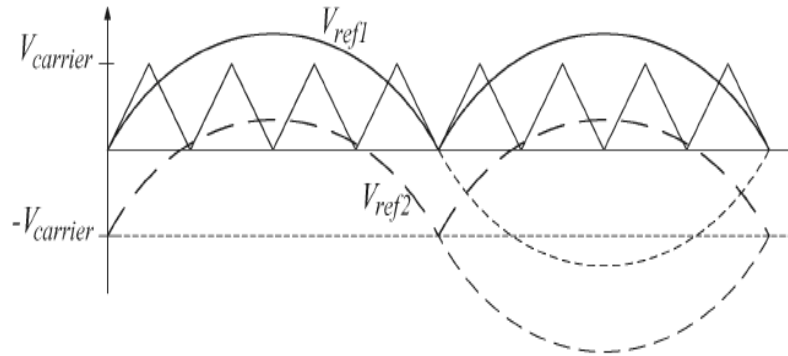


Figure 1: Carrier and reference signals

Five level Inverter topology and PWM law

The proposed single phase five 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_{in} to be more than $\sqrt{2}$ of grid voltage to ensure power flow from the PV arrays into the grid. A filtering inductance L is used to filter the current injected into the grid.

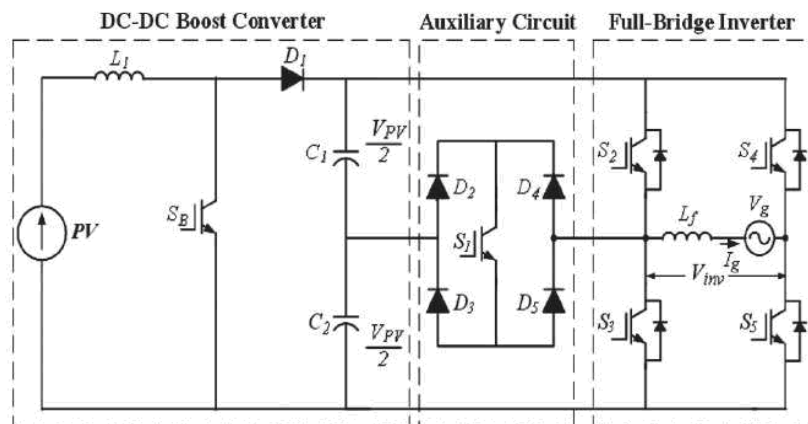


Figure 2: single phase five level inverter

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.

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 five 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 $V_{Carrier}$.

Table 1: Inverter Output Voltage during S1-S5 Switch ON and OFF

S_1	S_2	S_3	S_4	S_5	V_{inv}
ON	OFF	OFF	OFF	ON	$+V_{pv}/2$
OFF	ON	OFF	OFF	ON	$+V_{pv}$
OFF	OFF or (ON)	OFF or (ON)	ON or (OFF)	ON or (OFF)	0
ON	OFF	OFF	ON	OFF	$-V_{pv}/2$
OFF	OFF	ON	ON	OFF	$-V_{pv}$

Control system algorithm and implementation

The feedback controller used in this application utilizes the PID algorithm. As shown in Fig., the current injected into the grid, also known as grid current I_g , is sensed and fed back to a comparator which compares it with the current I_{ref} . I_{ref} is obtained by sensing the grid voltage and converting it to reference current and multiplying it with constant. 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 in density 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, it is needed to solve the a fore mentioned problem. Constant is derived from the MPPT algorithm. The

perturb and observe algorithm is used to extract maximum power from PV arrays

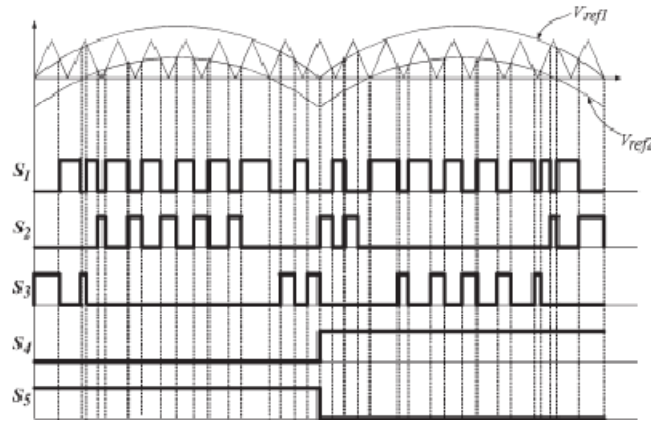


Figure 3: Switching pattern of five level inverter

and deliver it to the inverter. The instantaneous current error is fed to a PID controller. The integral terminal the PID controller improves the tracking by reducing the instantaneous error between the reference and the actual current. The resulting error signal 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

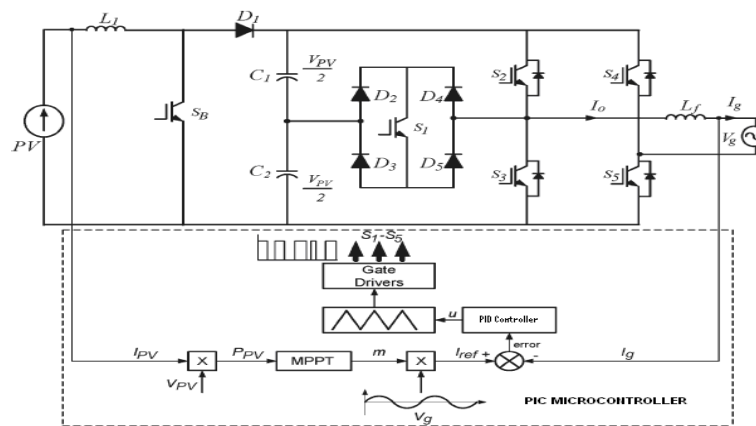


Figure 4: Five level inverter with control algorithm implemented in Microcontroller

Implementing this algorithm using PIC16C7F88 requires one to transform it into the discrete time domain. Trapezoidal sum approximation is used to transform the integral terminal to the discrete time domain because it is the most straight forward technique. The proportional term is directly used without approximation.

Simulation

The proposed system can be practically implemented in a pv system simulation were performed by using MATLAB SIMULINK it also helpful conform the PWM switching strategy which is can be implemented in a PIC 16C7F88It consists of two reference signals and a triangular carrier signal reference signals are compared with the triangular carrier signal to produce PWM switching signals for switches S1–S5 Note that one leg of the inverter is operating at a high witching rate equivalent to the frequency of the carrier signal ,whereas the other leg is operating at the rate of fundamental frequency The switch at the auxiliary circuit S1 also operates at the rate of the carrier signal.

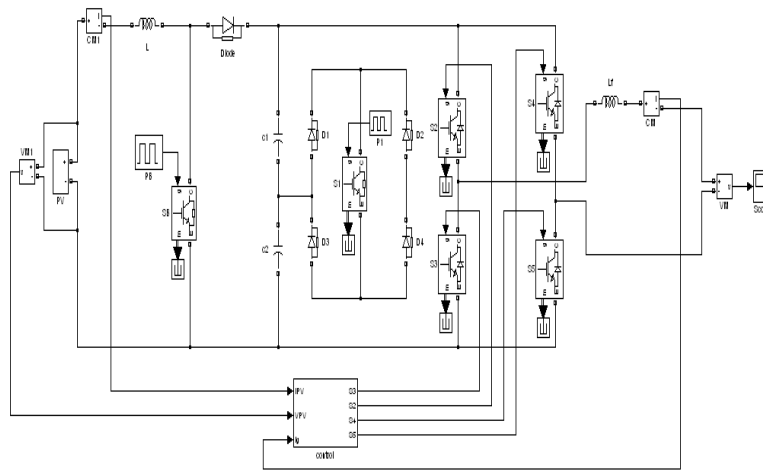


Figure 5: Simulink diagram for five level inverter

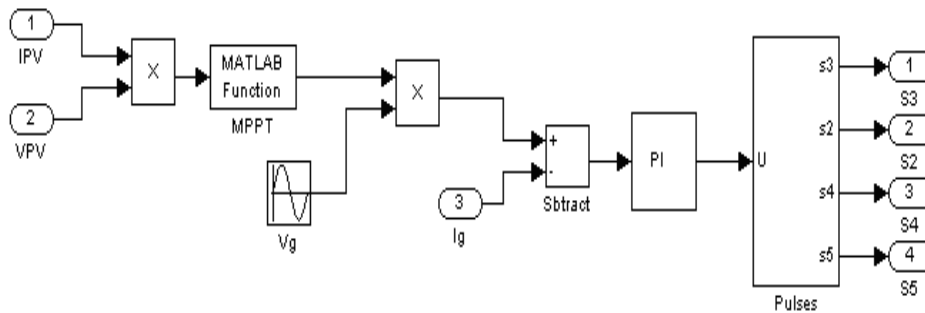


Figure 6: MPPT Technology

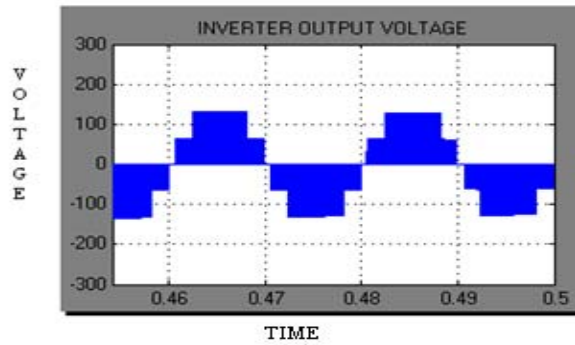


Figure 7: output voltage

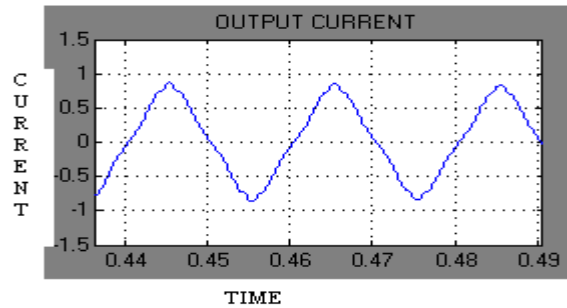


Figure 8: output current

Conclusion

This paper presented a single 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 PID current control algorithm is implemented in MICROCONTROLLER to optimize the performance of the inverter. Experimental results indicate that the THD of the five 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. The proposed five 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 five level multilevel 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.

Reference

- [1] J.M.Carrasco, L.G.Franquelo, J.T.Bialasiewicz, E.Galvan, R.C.PortilloGuisado, M.A.M.Prats, J.I.Leon, and N.Moreno-Alfonso, "Power electronic Systems for the grid integration of renewable energy sources: A survey," *IEEE Trans. Ind. Electron.*, vol.53,no.4,pp.1002–1016,Aug. 2006.
- [2] V.G.Agelidis, D.M.Baker, W.B.Lawrance, and C.V.Nayar, "A multilevel PWM inverter topology for photovoltaic applications," in *Proc.IEEEISIE*, Guimarães, Portugal, 1997, pp.589–594.
- [3] S.kouro,J.Rebolledo, andJ.Rodriguez,"Reducedswitching-frequencymodulation algorithm for high-power multilevel inverters," *IEEE Trans. Ind.Electron.*, vol. 54, no. 5, pp.2894–2901,Oct.2007.
- [4] S.J.Park, F.S.Kang, M.H.Lee, and C.U.Kim, "A new single-phase five level PWM inverter employing a dead beat control scheme," *IEEE Trans. PowerElectron.*, vol.18, no.18, pp.831–843, May2003.
- [5] L.M.TolbertandT.G.Habetler,"Novel multilevel inverter carrier-based PWM method," *IEEE Trans. Ind. Appl.*,vol.35,no.5,pp.1098–1107,Sep./Oct.999.
- [6] D.-W.Kang, B.-K.Lee, J.-H.Jeon, T.-J.Kim, and D.-S. Hyun, "A symmetric carrier technique of CRPWM for voltage balance method of flying capacitor multilevel inverter," *IEEE Trans.Ind.Electron.*, vol. 52, no. 3,pp. 879–888, Jun. 2005.
- [7] B.-R.Linand C.-H. Huang, "Implementation of a three-phase capacitor clamped active power filter under unbalanced condition," *IEEE Trans.Ind.Electron.*, vol. 53, no. 5, pp. 1621–1630, Oct. 2006.
- [8] M. Marchesoni, M. Mazzucchelli, and S. Tenconi, "A non conventional power converter for plasma stabilization," in *Proc. IEEE Trans.Ind.Electron. Conf.*, 1988, pp. 122–129
- [9] J. Rodriguez, P. Hammond, J. Pontt, R. Musalem, P. Lezana, and S. Escobar, "Operation of a medium-voltage drive under faulty conditions," *IEEE Trans.Ind.Electron.*, vol. 52, no. 4, pp. 1080–1085, Aug. 2005.
- [10] X. Kou, K. Corzine, and M. Wielebski, "Over distention operation of cascaded multilevel inverters," *IEEE Trans. Ind. Appl.*, vol. 42, no. 3,pp. 817–824, May/Jun. 2006.