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Experimental Study on 3-phase PWM Inverter for Grid Connected PV Generation System using SPWM technique

Preeti Sharma[1], Ms. Poonam Nandal[2]

[1]M. Tech. Student, Deptt. of EEE, CBS Group of Institutions, Jhajjar, Haryana
[2]Associate Professor, Deptt. of EEE, CBS Group of Institutions, Jhajjar, Haryana

ABSTRACT

Uninterruptible power supplies (UPSes) are used to provide backup power to critical loads, where even a temporary power failure causes large economic losses. The UPSes are used in applications like computer installations, process control in chemical plants, and general communication systems. The function of UPS is to provide a high quality sinusoidal voltage and for this it needs to be controlled. Conventional controllers cannot provide the exact sinusoidal output with the nonlinear loads. In this work we address the Design Simulation in Simulink, for a 3-phase grid connected system of a photovoltaic Inverter In order to analyze the output of the PV Array. This project proposes the Mat lab / Simulink implementation of the 1-phase and the 3-phase inverter and their characteristics. The open loop simulation results obtained from the 3-phase PWM inverter is compared with the 1-phase PWM inverter.

Keywords: Inverter, VSI, SPWM, Harmonics, UPS.

1. INTRODUCTION

To improve the performance multilevel inverter are preferred over two, three and five levels. This paper proposes a three phase two, three and five level inverter for grid connected (PV) system. The output current of the inverter can be adjusted according to the voltage of the photovoltaic (PV) array. This control scheme is based on SPWM topology. Multilevel inverter as compared to two, three and five level inverter has advantages like minimum harmonic distortion and can operate on several voltage level inverters. This paper explain the basic type of Multilevel Inverter such as diode clamped multilevel inverter (neutral point clamped), flywheel capacitor multilevel inverter (capacitor clamped), cascade multilevel inverter also the modulation and control technique like Pulse Width Modulation and the gate signal through modulation technique is given to MLI in such a way to reduce harmonics.

Multi-level inverters have gained much attention in the application areas of medium voltage and high power owing to their various advantages such lower common mode voltage, lower voltage stress on power switches, lower dv/dt ratio to supply lower harmonic contents in output voltage and current. Comparing two-level inverter topologies at the same power ratings, multi-level inverter also have the advantages that the harmonic components of line-to-line voltages fed to load are reduced owing to its switching frequencies Multi Level Inverter (MLI) plays an important role in the area of power electronics and it is widely used in industrial and renewable energy applications [4-6]. It is not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for high power application.

Three-phase sinewave 220V rms/60Hz, output voltage of three-phase inverter system is accomplished, whether the driving techniques of three-phase inverter system is sinusoidal pulsewidth modulation or space vector pulsewidth modulation. It is also added over/low voltage protection mechanism which includes hysteresis loop idea to increase the reliability of the three-phase inverter system. Finally, the inverter system with digital control is realized by digital signal processor (TMS320LF2407A) and auxiliary circuits. The output power of inverter is formed constant current to deliver energy for grid in grid-connected mode by current control scheme. The total harmonic distortion of inverter system is under 2.5% at any loading ratio in stand-along mode.

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TYPES OF PWM INVERTERS

The pulse width modulated (PWM) inverters are generally used for UPSes to maintain the output voltage as constant and regulates the output as sinusoidal shape in nature. The PWM type inverters are having an advantages of exclusion of lower order harmonics in the output voltage along with the control capabilities of output voltage, the harmonics in the inverter output are being eliminated by PWM technique, the filter circuit requirements are minimized. PWM techniques are characterized by constant amplitude pulses. The width of these pulses is modulated to control the inverter output voltage and for the reduction of harmonic content.

The Different PWM techniques are

- ✓ Single pulse modulation
- ✓ Multiple pulse modulation
- ✓ Sinusoidal pulse modulation.

The output voltage of single pulse width modulated inverter is of only one pulse located symmetrically. The width of the pulse is varied to control the inverter output voltage. The output voltage of single pulse width modulated inverter is quasi-square in nature and the harmonic content is more, which is not suitable for UPS applications.

The extension of single pulse width modulation is called as multiple pulse width modulation .In this type of pulse width modulation uses several pulses of equal widths per half cycle.

The multiple pulses of equal widths are generated by comparing the carrier triangular wave with a reference DC signal. The width of the pulses is modulated by increasing or decreasing the amplitude of reference signal. The fundamental component of inverter output voltage is very low, and the amplitudes of higher order harmonics will be increased with decrease in amplitudes of lower order harmonics. The output voltage of the multiple pulse width modulated inverter is having very low magnitude and high filter requirements are essential. The Power circuit of the IGBT inverter for single phase application is shown in figure 1.

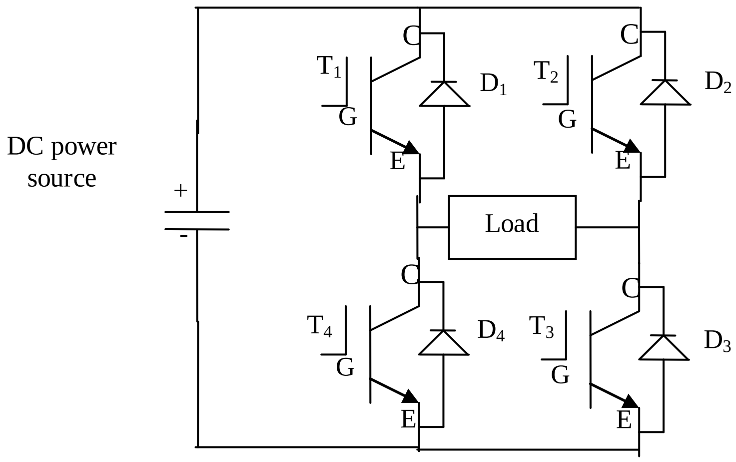

Fig.1: Power circuit of Single phase full bridge IGBT inverter

In sinusoidal pulse width modulation switching technique a high frequency triangular carrier wave E_c is compared with a sinusoidal reference wave E_r of the desired frequency. The intersection of E_c and E_r waves determine the switching instants as shown in figure 2 and commutation of modulated pulse. When sinusoidal wave has higher magnitude than the triangular, the pulse is generated. The ratio of Er/Ec is called the modulation index and it controls the harmonic content of the output voltage waveform. **A**m. P_m indicates the switching instant and duration of the pulse for which it conducts. The magnitude of fundamental component of output voltage is proportional to modulation index.

The choice of a particular PWM technique depends upon the permissible harmonic content in the inverter output voltage. For UPS inverter application the total harmonic distortion should be within 5%.So sinusoidal pulse width modulation is effective. The output voltage is not purely sinusoidal in nature with open loop control of SPWM UPS inverter. The closed loop controller is required for UPS inverter to regulate the output voltage with sinusoidal shaping.

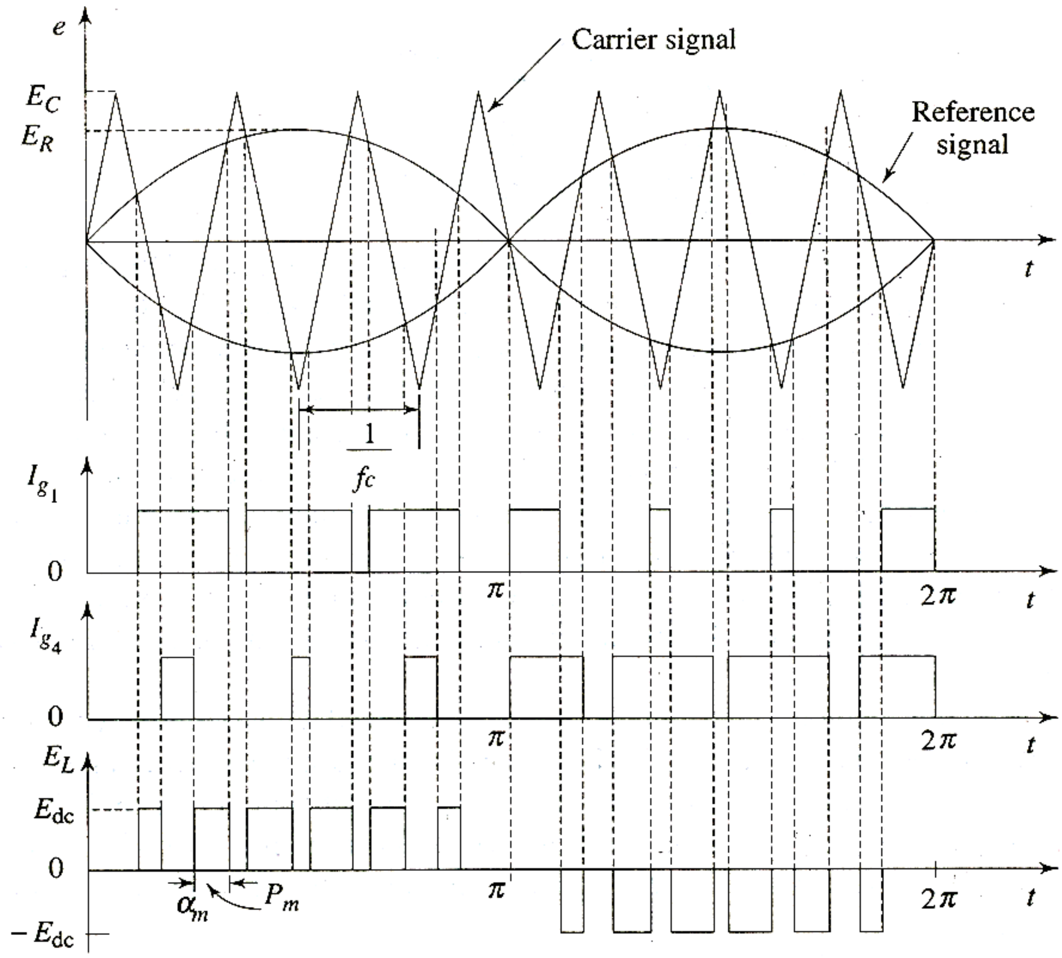

Fig. 2: Switching and modulation of pulses

Whereas, methods applied in the latter approach still impose mapping topology: two by two, mapping table and Super Peer. This requires a strong hypothesis to the administrator which has to respect and follow this topology. Hence, the scope of [10] work, proposing a method that can be adapted to any topology type. [10] presents a resource discovery method taking into account not only the semantic heterogeneity of data sources but also peer dynamicity to query execution. However, to illustrate the discovery mechanism established, the user query used is an SQL query related to relational models. These models are distinguished by their highly structured static schema. However, today, in big data area and with grid environment, imposing such strong hypothesis is a blocking constraint [11]. For these reasons, we deal, in this work, with resource discovery in grid environment allowing the use of NoSQL (Not Only SQL) queries.

CLOSED LOOP CONTROL OF UPS INVERTER WITH PI CONTROLLER

Linear modeling of UPS inverter is used to obtain the transfer function, so that the PI controller parameter values can be easily tuned for a give step input to yield better stability conditions. Because the switching frequency (20 kHz) is usually several orders higher than the fundamental frequency of the AC output, the dynamics of the PWM inverter can be ignored such that the PWM inverter is modeled as a proportional block with a gain K equal to Vdc/Vc.

V_{dc} is the voltage of DC source and Vc is the peak voltage of triangular carrier waveform. A multiple feedback loop control scheme is employed in order to have better steady state stability and to achieve good dynamic response. The two loops are outer voltage loop and inner current loop.

The inner current loop provides an inherent peak current limit in the power circuit; in addition, since the capacitor current represents the change of load voltage, the control scheme is capable of predicting near future variations in the load voltage and thus providing a good dynamic response. Furthermore the outer voltage loop regulates the load voltage and produces a stiff ac voltage supply and ensures a sinusoidal load voltage within the acceptable total harmonic distortion (THD).

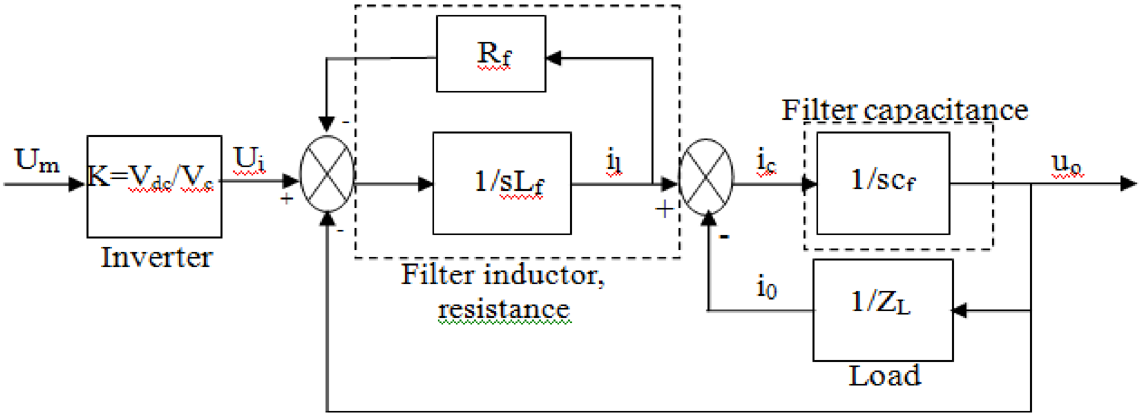

Fig. 3: Linear model of UPS inverter

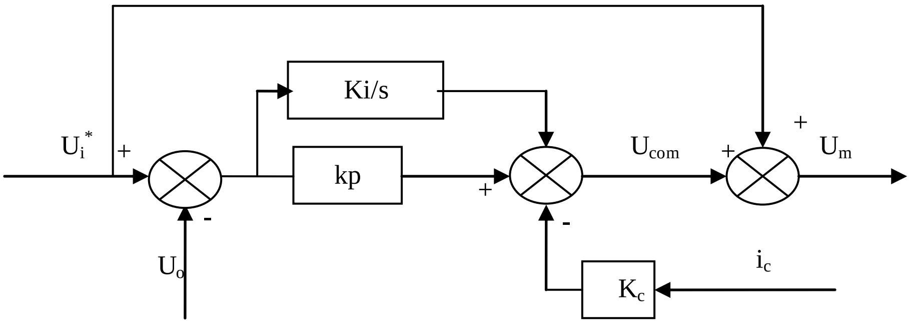

Fig. 4: Analogue PI controller

SIMULATION RESULTS & DISCUSSIONS

Artificial neural network controller based UPS inverter

The Matlab/Simulink implementation of closed loop control of UPS inverter with artificial neural network controller is shown in figure 2. The neural network specifications are given in the table 1 & 2.

The output voltage and output current waveforms with neural network controller is shown in figure 3. From the simulation results it is observed that total harmonic distortion of the output voltage is 1.76%.

The figure 4 shows the neural network controller based UPS inverter output voltage and current with load changes from no-load to full-load. It is observed that the dynamic response of the system is improved compared to the conventional PI controller.

Table 1: Specification of UPS inverter

Switching frequency, f_s	20KHz
DC source voltage, V_{dc}	48v
Rated output voltage	25v(rms)
Rated output current	5A(rms)
Rated output impedance	5 Ω
Filter inductance, L_f	250µH
Inductor resistance, R_f	0.2 Ω
Filter capacitance, C_f	30µF

Table 2: Neural network training parameters

Load Resistance	5 Ω
Sampling frequency	1KHz
Total number of cycles for which Samples had taken	3
Hidden layer transfer function	Logsig
Output layer transfer function	Purelin
Structure of the network	5-3-1
Type of network	Feed forward

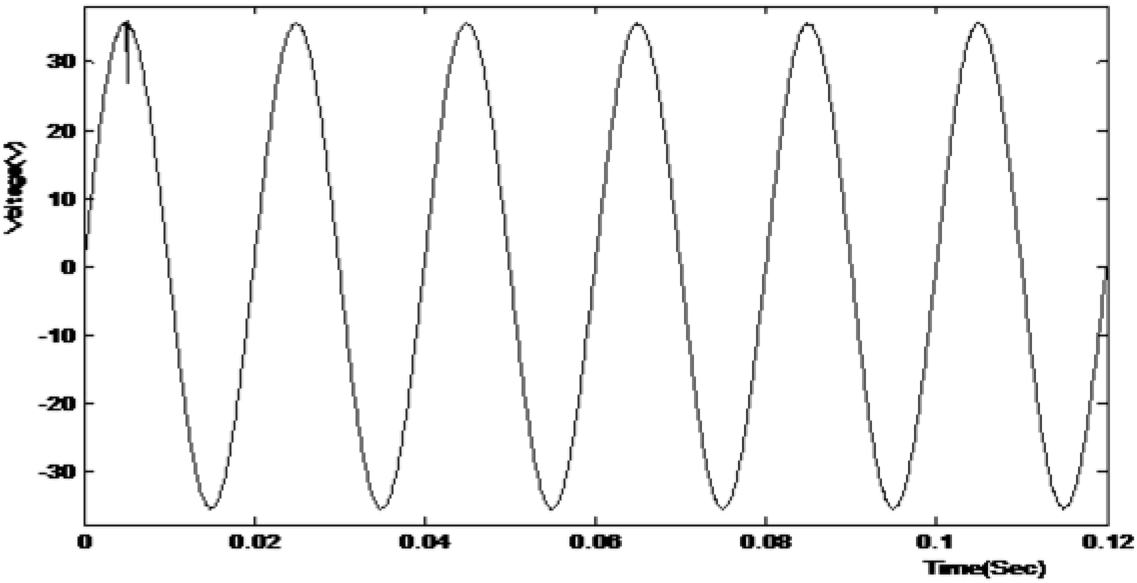

Fig.5 (a) Inverter output voltage with change in load from no-load to full load with PI controller

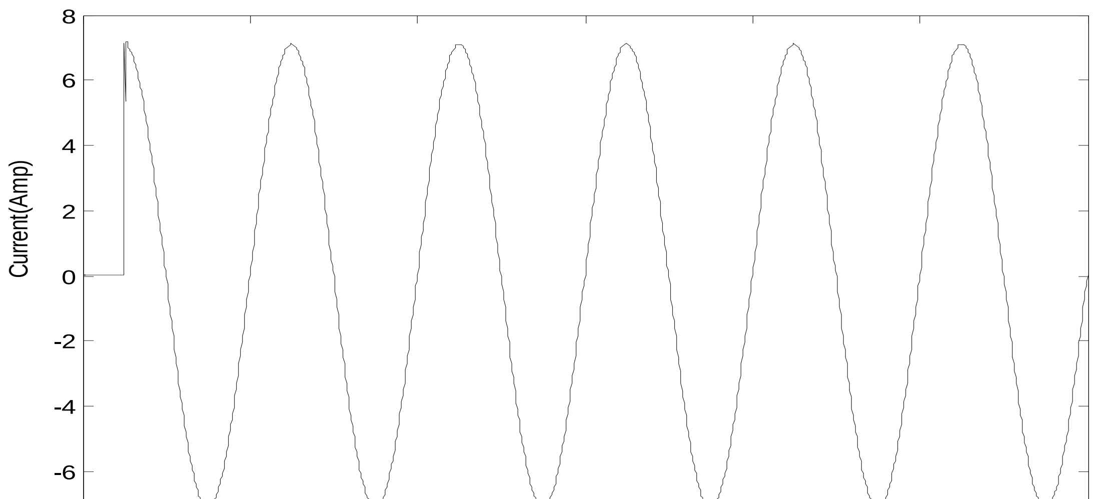

Fig. 5 (b) Inverter output current with change in load from lo-load to full load with PI controller

CONCLUSION

In this paper, the design and implementation of UPS inverter system with conventional PI controller and artificial neural network controller are developed using Matlab/Simulink toolbox. The open loop and closed loop simulation results of the UPS inverter system with conventional PI controller and artificial neural network controller are obtained. From the simulation results it is observed that the artificial neural network controller based UPS inverter system gives better performance compared to the conventional PI controller based UPS inverter system. The THD for neural network controller is less compared to PI controller.

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