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Simulation of High Efficiency Grid Connected THIPWM-Three Phase PV Inverter

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ABSTRACT

This paper presents a three phase DC-AC inverter for grid connected PV system using Third harmonic injection PWM (THIPWM) technique. The SPWM technique is easiest modulation scheme to understand but it requires complicated mathematical operation so third harmonic injection techniques for PWM (THIPWM) is employed to reduce the total harmonic distortion (THD) and to make the inverter suitable for grid connection, by synchronizing the inverter voltage with the grid voltage. The application of THIPWM to inverter increases for management of voltage and constancy in frequency of the system thereby increasing its overall efficiency.. MATLAB simulink model is developed to illustrate the proposed system. The inverter model complies with all IEEE 1547 standards varying a maximum of 5% under different testing conditions

Key words: Phase inverter, Third harmonic injection PWM, Grid connection

INTRODUCTION

Due to ever increasing world energy demand, more renewable grid connected systems are being developed. With development and utilization of an unstable DC voltage source recently, such as photovoltaic array, grid connected inverters are widely used as essential power electronic devices for a grid-connected system. The PV industry has a need of more sophisticated inverter design to enhance the functionality , reduce cost and suit to new proposed technologies [1,3] One of the major challenges in large scale development of these systems is the high harmonics pollution of the output currents of these systems. According to standard IEEE-1547, the total harmonics distortion of output grid connected current of inverter must be less than 5%, and each harmonic distortion must be less than 3% 4]. Power quality of grid connected inverter is an important factor especially in high power applications. The power quality is determined by the voltage quality, when the voltage is a controlled variable. If there is connection to an existing grid, then the voltage cannot be controlled. The power quality is then defined by the current quality. The grid-connected inverters are therefore, desired to have high power-quality, high efficiency, high reliability, low cost, and simple circuitry.

In the design procedure of the inverters for PV/grid systems, the DC voltage generated at the PV array, is converted to a suitable AC voltage. Also tracking the Maximum Power Point enables the maximization of the exploited energy. There is no single PWM method that is the best suited for all applications and for these reasons, the PWM techniques have been the subject of intensive research since 1970s [5,8]. With advances in solid-state power electronic devices and microprocessors, various pulse-width modulation (PWM) techniques have been developed for industrial applications. The SPWM technique is the easiest modulation scheme to understand and to implement in software or hardware but this technique is unable to fully utilize DC bus supply voltage available to the voltage source inverter. This drawback led to the development of THIPWM and SVPWM [9, 11]. THIPWM is a technique that adds the third order harmonic content to a sinusoidal reference signal there by increasing the utilization rate of the Dc bus voltage by 15.5%. The implementation of conventional SVPWM is especially difficult because it requires complicated mathematical operation. In the under modulation region, this algorithm provides 15.5% higher output voltages compared to the SPWM technique. Three phase voltage source PWM inverters have been widely used for DC to AC power conversion since they can produce outputs with variable voltage magnitude and variable frequency [12, 16]. This paper presents the modelling and simulation of a three phase THIPWM inverter for grid connected PV system.

LITERATURE REVIEW

There is a need of more sophisticated inverter design to enhance the functionality, reduce cost and suit to new proposed technologies for grid connected PV system due to its highly variable voltage output because of intermittent nature of available solar radiation. [3, 5]The problem of the under-utilization of the DC bus voltage led to the development of the third-harmonic-injection pulse-width modulation (THIPWM). In 1975, Buja developed this improved sinusoidal PWM technique, which added a third-order harmonic content into the sinusoidal reference signal leading to a 15.5% increase in the utilization rate of the DC bus voltage. Another method of increasing the output voltage is the space-vector PWM (SVPWM) technique. SVPWM was first introduced in the mid-1980s and was greatly advanced by Van Der Broeck in 1988. Compared to THIPWM, the two techniques have similar results but their methods of implementation are completely different. With the development of microprocessors, SVPWM has become one of the most important PWM methods for three-phase inverters. Many SVPWM schemes have been developed and extensively investigated in the literature. The goal in each modulation strategy is to lower the switching losses, maximize bus utilization, reduce harmonic content, and still achieve precise control. The SVPWM technique utilizes the DC bus voltage more efficiently and generates less harmonic distortion when compared with the SPWM technique. The maximum peak fundamental magnitude of the SVPWM technique is about 90.6% of the inverter capacity [7, 9].

This represents a 15.5% increase in the maximum voltage compared with conventional sinusoidal modulation. In 1991, Holtz proposed a classical over-modulation technique based on SVPWM, which divided the over-modulation range into two modes of operation and increased the utilization rate of the DC voltage to that of a six-step wave Holtz proposed this technique using switching time calculations in the over-modulation region of SVPWM. In 1998, Lee analyzed Holtz's over-modulation technique graphically, gave some approximate linear expressions between the modulation index and its own auxiliary parameter, and discussed the harmonic problem. He showed that this technique generated less harmonic distortion in the output voltages (or) the currents applied to the phases of an AC motor and provided more efficient use of the DC input voltage. Because of its superior performance characteristics, it found widespread application in recent years. Accordingly, many other researchers have explored various aspects of this technique in the literature. [11-12].Thus, THIPWM for grid connected PV inverter has been considered in this paper.

MODEL DETAILS

Six step modulation uses sequence of six switch pattern for three phase full bridge inverter to generate full cycle of three phase voltages. The inverter output voltage has the same frequency and amplitude with those of the grid voltage. The synchronization of the inverter output voltage with the grid voltage must be done in such a way that the two voltages are in Phase. The proposed system is designed to supply the three phase load and the grid as well. The simulation behaviour of three phase grid connected THIPWM PV inverter is studied which has the ability to feed a load of 10KW. This value of load has been chosen because it fits to the average energy value used from an ordinary household and in other professional buildings. We assume that the surface that the PV array will virtually cover is about 72m2.such a size can be accommodated and installed on a roof, as well as provide to the load the appropriate amount of energy.

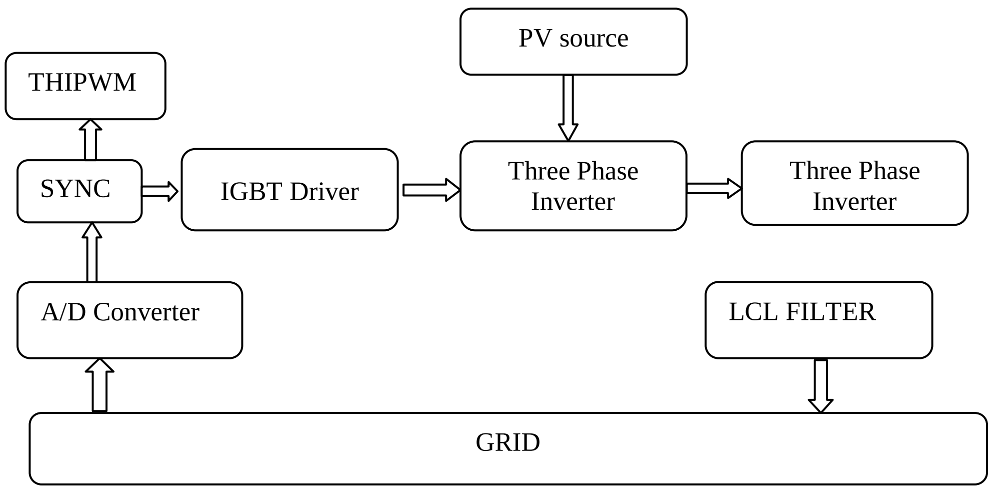

Fig. 1 Grid connected PV system

Third Harmonic Injection PWM is preferred in three-phase application, because third-harmonic component will not be introduced in three-phase systems. THIPWM is better in utilization of DC source. Among the modulation techniques used for three phase inverter, space vector modulation (SVM) extends the linear modulation range 15%

more compared with pure sine-wave (SPWM). This advantage can be achieved through injection of triplen harmonics to the sine-wave modulating signal, which result in third harmonic injection modulation or multiple harmonic injection modulation. As such, SVM and THIPWM offer the same advantages as compared with SPWM schemes. However, simple and direct implementation of THIPWM gives it advantage over the SVM, for the reason that no needs to track the operating sector or add a state machine for switch sequencing of THIPWM. In terms of harmonic distortion, high switching frequency THIPWM makes it appropriate for harmonic distortion elimination Injecting a third harmonic component to the fundamental component gives the following modulating waveforms for the three-phase voltages. The PV industry has the need of more sophisticated inverter design to enhance their functionality, reduce cost and suit to new proposed techniques using THIPWM.

$$Van = \frac{2}{\sqrt{3}}\left(sinwt + \frac{1}{6}\sin(3wt)\right)$$
$$Vbn = 2/\sqrt{3}\left(\sin\left(wt - \frac{2\pi}{3}\right) + \frac{1}{6}\sin(3wt)\right)$$
$$Vcn = 2/\sqrt{3}\left(\sin\left(wt + \frac{2\pi}{3}\right) + \frac{1}{6}\sin(3wt)\right) \quad (1)$$

The modulating signal is generated by injecting the third harmonic component to the 50 Hz fundamental component. Fig.2 shows the generation of THIPWM. It shows the reference Voltages (a,b,c), Triangular Waveforms (VT), and Output Voltage per phase (Vao;Vbo;Vco).

Using the modulator given in equation 1 will maintain the peak voltage equal to the dc voltage. Look-up table used to save the data of equation 1 which ultimately obtain threephase THIPWM for the three-phase inverter. The carrier signal shown in Fig. 2 used to be compared with the modulated signals to result in THIPWM. The THIPWM has been modelled as shown in Fig. 3 shows the THIPWM generation.

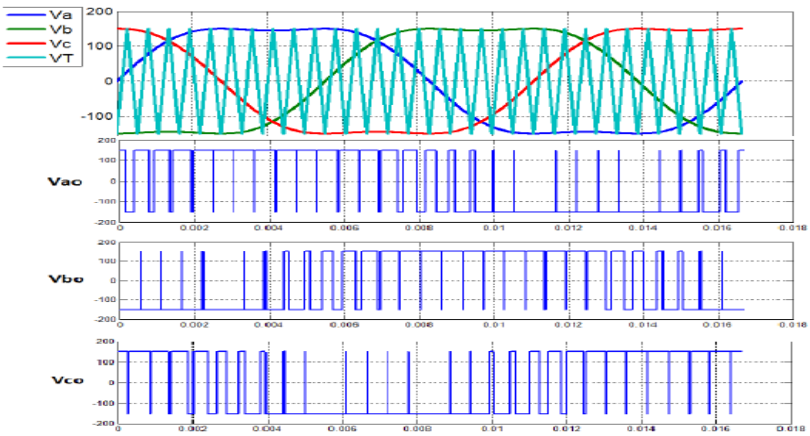

Fig. 2 Generation of THIPWM

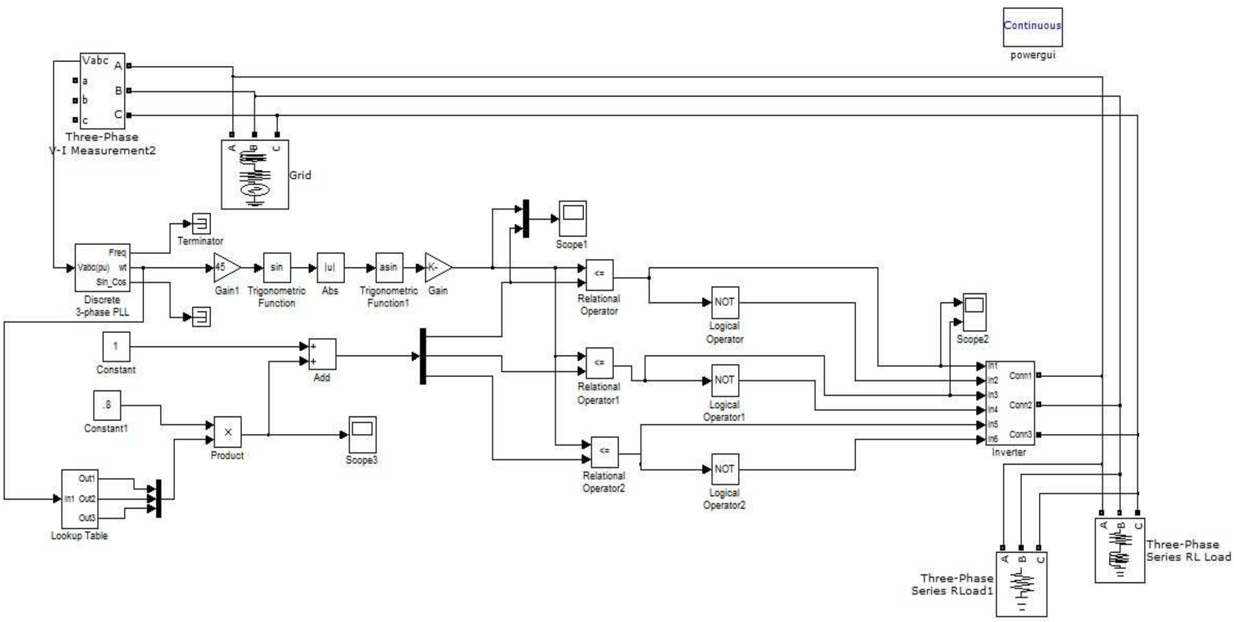

Fig. 3 Simulation of PV inverter

The inverter is the heart of the PV system and is the focus of all utility-interconnection codes and standards. A Solar inverter or PV inverter is a type of electrical inverter that is made to change the direct current (DC) electricity from a photovoltaic array into alternating current (AC) for use with home appliances and possibly a utility grid. Since the PV array is a dc source, an inverter is required to convert the dc power to normal ac power that is used in our homes and offices. To save energy they run only when the sun is up and should be located in cool locations away from direct sunlight. The PCU is a general term for all the equipment involved including the inverter and the interface with the PV (and battery system if used) and the utility grid. It is very important to point out that inverters are by design much safer than rotating generators.

A standard three-phase inverter is shown below which is made in MATLAB consisting of six controlled switches such as IGBT. In this converter, the line currents can be shaped to be sinusoidal at a unity power factor, as well as the output ac voltage can be regulated at a desired value. The inverter is connected to the grid through three LC filters. THIPWM employed to make full use of the input voltage with minimum harmonic distortion in the output voltage and current.

Different methods to extract phase angle have been developed and presented in many papers up to now [8-11] PLL techniques causes one signal to track another one. It keeps an output signal synchronized with a reference input signal in frequency and phase. In three phase grid connected system PLL can be implemented using the d-q transformation and with a proper design of loop filter.

Look up used to save the third harmonic component waveform which ultimately obtain three phase THIPWM for the three-phase inverter. The carrier signal shown in the above Fig. used to be compared with the modulated signals to result in THIPWM. The THIPWM has been modelled as shown in Fig. 5. Fig. 6 shows the THIPWM generation.

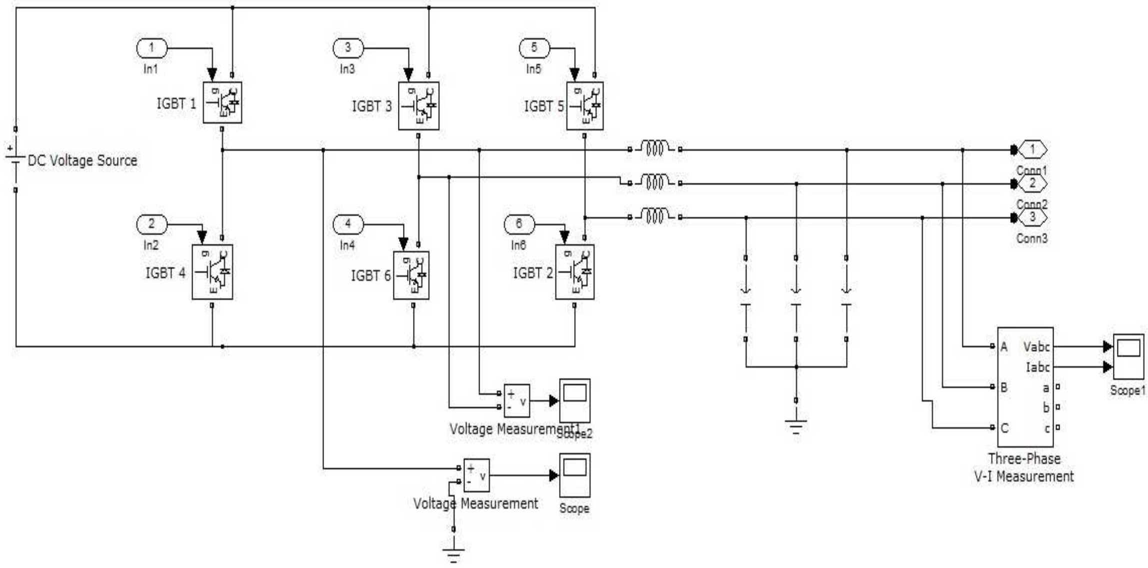

Fig. 4 Simulation circuit of carrier signal generator

SIMULAION RESULTS

The SIMULINK TOOL BOX results are being given to verify the operation on the THIPWM three phase inverter.

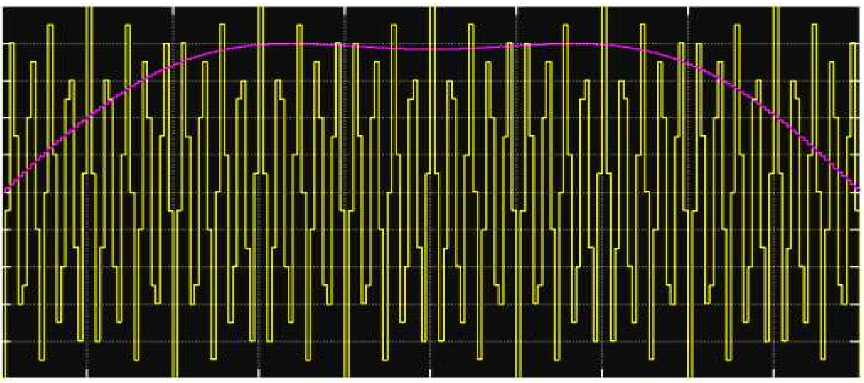

Fig. 5 Gate Signal for 1st and 3rd IGBT

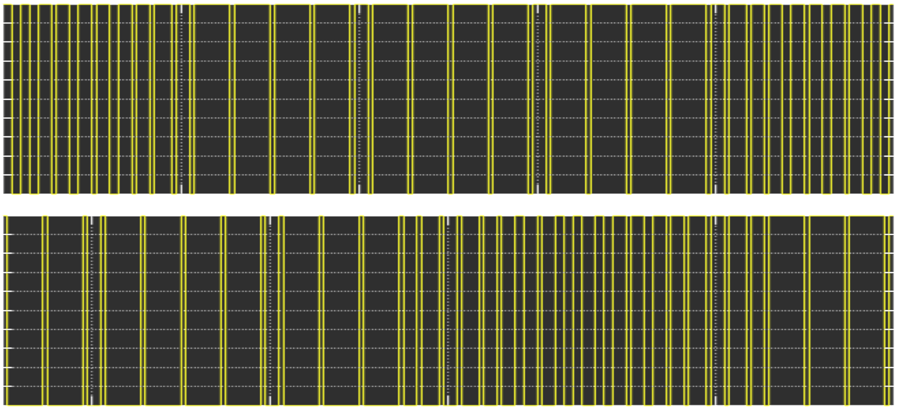

Fig.6 Inverter voltage waveform without Filter (Line to Line)

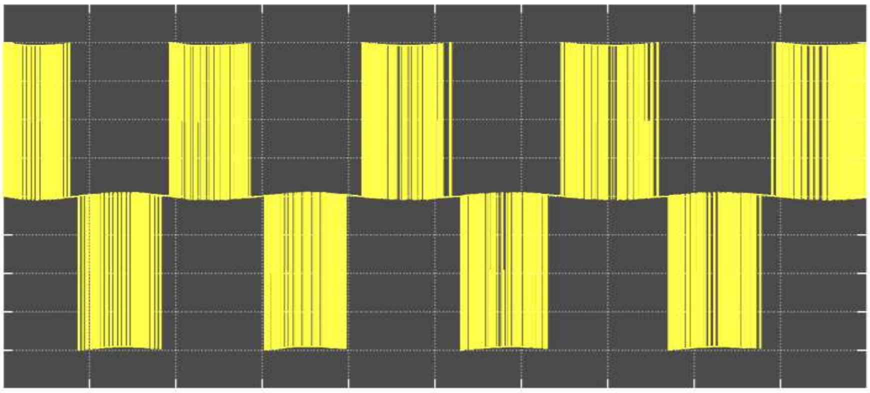

Fig. 7 Inverter voltage waveform (Line to Neutral)

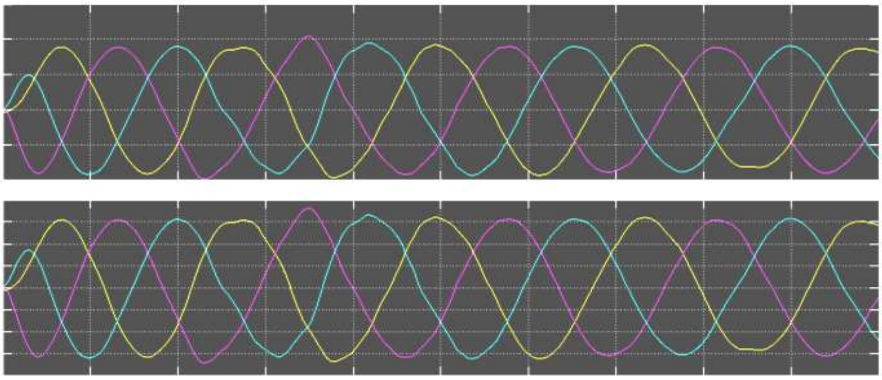

Fig. 8 Voltage and Current Waveform

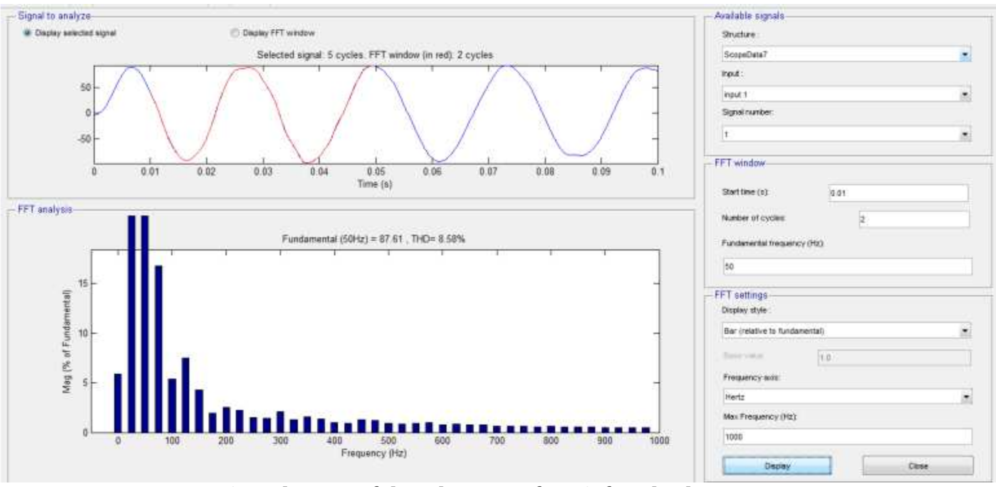

Fig.9 The THD of the voltage waveform is found to be 8.58%.

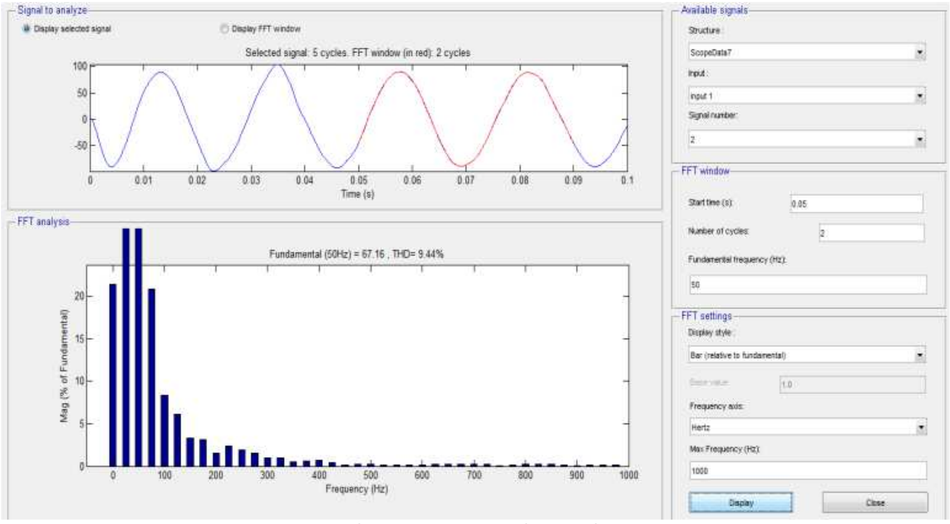

Fig.10 The THD of the current waveform is found to be 9.44%

CONCLUSION

This paper presents a high efficiency three phase DC-AC inverter for grid connected PV system using Third harmonic injection PWM (THIPWM) technique. Third harmonic injection pulse width modulation (THIPWM) technique with a modulation index 0.8 has been developed. Switching frequency is used to reduce the size of the LC filter and the complexity of the inverter. The inverter performance found to be satisfactory in terms of current and voltage total harmonic distortion (THD) injected to the grid.

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