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STUDY OF SVPWM BASED GRID CONNECTED INVERTER

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Abstract: A combined random carrier pulse width modulation principle in space vector pulse width to generate random pulse width modulation generation using an asymmetric frequency multicarrier called multicarrier random space vector pulse width modulation. The space vector pulse width modulation switching vectors with different frequency carrier are chosen with the aid of a random bi-nary bit generator. The multi carrier random space vector modulation generates the pulses with a randomized triangular carrier (1 to 4 kHz), while the conventional random pulse width modulation method contains a random pulse position with a fixed frequency triangular carrier. The four carrier signals with different frequencies of (1 to 4 kHz) are made to generate the randomness carrier. In order to merge these random carrier signals four 3x1 multiplexers are used, and finally, the MUX output is given to the 4x1 Multiplexer. The 8 bit pseudo random binary sequence as well as 16 bit pseudo random binary sequence generator are used to generate random 0 and 1 sequence which manipulate the random combination of four different carrier frequency signals. These voltage source inverter are needed in order to provide several advantages such as Harmonics elimination. The simulation study is performed through MATLAB/Simulink for a space vector pulse width modulation based Grid connected Inverter.

Keywords: pulse width modulation; random PWM; space vector PWM; voltage source PWM inverter; acoustic noise

1. INTRODUCTION

PWM-based Voltage Source Inverters (VSIs) are the driving force in industrial and commercial applications. Pulse-Width Modulation (PWM) is the core for control and has verified effective in driving present semiconductor power devices. Majority of power electronic circuits are controlled by PWM signals of various forms. Pulse Width Modulation is effective and commonly used as control method to generate analog signals from a digital device like a micro controller. In PWM technique, the energy is distributed through a series of pulses rather than a continuously varying analog signal. The average voltage can be controlled by varying the width of the positive pulse. Pulse Width Modulating signal can be generated using a Comparator. Modulating signal forms one of the input to the Comparator and the other input is fed with a non-sinusoidal wave or saw tooth wave. The Comparator compares the two signals and produces a PWM signal as its output waveform. Particularly, industrial drives benefit from the higher DC-link utilization, acoustic noise and vibration industrial standards. The Random Pulse Width Modulation (RPWM) is the best candidate for reducing the acoustic noises and is realized by randomly changing the slope of the carrier wave. However, the existing Random Pulse Width Modulation methods have less randomness and need complex digital circuitry. Therefore, a combination of Random Pulse Width Modulation principle in Space Vector Pulse Width Modulation (SVPWM) is introduced to generate Random Pulse Width Modulation generation. This project offers better DC link utilization, lower THD, switching loss, reduced acoustic noises and easier digital system implementation.PWM based ASDs are the driving force in industrial and commercial applications to meet ever growing demand for energy efficiency, feature rich functionalities and lower total cost of ownership. The harmonic voltage components from ASDs can produce a high pitch sound in the motor with mechanical resonance and vibration. Higher audible noise can cause lower acceptance particularly in buildings such as hospitals, schools, office complex, etc. The acoustic noise in ASD driven motor systems can be categorized in three parts: (a). Mechanical noise due to surface accidents, eccentricities, too accentuated or insufficient axial or radial displacement, shaft displacement, magnetics core vibration, cooling fans. Aero-dynamical noise constituted by air turbulences, siren effect and cavity resonance. These two noise types are practically independent from the electrical supply of the motor. Their frequencies in a Fourier analysis are typically below 2 kHz in developed applications. (c). Harmonics rich electromagnetic noise which is produced by excitations of each harmonic in the ASD output voltage spectrum to the motor it's driving. Pulse Width Modulation is a method of reducing the average power delivered by an electrical signal, by effectively chopping it up into discrete parts. The average value of voltage fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the

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higher the total power supplied the load. The random space vector pulse modulation strategy can weaken the harmonic spectrum peaks on or around the switching frequency and its multiple ones. The space vector modulation technique has been used in many kinds of fields, such as electric vehicle industrial control. Because of the basic principle of volt – second balance of pulse width modulation, the harmonic is inevitable besides the required fundamental. The harmonic brings out many problems, such as mechanical vibration, motor temperature increases, acoustic noise and electromagnetic radiation Pseudo random binary sequence are widely used in many application such as wireless communication and cryptography. Randomness of a sequence indicates the degree of difficulty of predicting next bit in that sequence whether it is physical or statistical analysis. MATLAB\ Simulink software tool for a three phase VSI and grid connected system. The simulation results show that the VSI and grid had comparable performance to the conventional MCRSVPWM; the power spectra of the current, voltage, dominant harmonic components were reduced as compared with the reported RPWM methods.

2. LITERATURE SURVEY

Huang, Y et al [1] Propose a novel hybrid random pulse-width modulation (HRPWM) technique based on the modified SVPWM for three-phase voltage source inverters (VSIs) to eliminate the PWM acoustic noise. Due to PWM technique and switching losses considerations, ear-piercing high frequency noise from motor is common. The proposed HRPWM technique is able to remove the high frequency unpleasant acoustic noise more effectively than conventional RPWM with lower switching losses and shorter random frequency range. In addition, the PWM harmonics in phase voltage and phase current are reduced significantly. The HRPWM method is simple to implement and does not employ additional circuits in drive system. Finally, the effectiveness of the proposed approach has been confirmed by detailed experimental results. In order to remove the 1st PWM frequency noise, the switching losses of modified SVPWM increase 33%.

Lee K et al [2] Quantitatively evaluate the performance characterization of five state-of-the-art random PWM modulation algorithms in industrial and commercial ASDs. Power spectrum theory is described for analysing the frequency components of RPWM signal. The additional comparative results taking into account of sampling effects, current ripple harmonics, influence of PWM modulation index, computation burden are evaluated. SVPWM is efficient overall with an exception of a high pitch audible noise. RZD-PWM solves the problem the best with low sampling error and CPU burden. RCDPWM has similar performance as RZD-PWM, but more costly in its implementation. SRP-PWM can maintain randomness better at higher PWM index, but it turns out more costly than RCD-PWM, this method is not recommended for adoption.

Y. Fang et al [3] Made the study on a PWM-fed electric powertrain. Firstly, the acoustic noise of electric powertrain is collected in a semi-anechoic chamber. Then two types of acoustic components of the electric powertrain, namely Harmonic order noise and switching noise, are distinguished through the analyses of supplied current from inverter and gear vibration. Furthermore, the relationship between subjective perception and spectral characteristics of the noise is discussed, based on which sensitivity is established. Subsequently, the contributions of acoustic components to psychoacoustic parameters are determined. After that, a sound quality model of the acoustic noise radiated by electric powertrain is established. The comparison between jury test and prediction shows that the established model can be used for sound quality evaluation of the electric powertrain. Finally, the influences of harmonic order noise and switching noise on subjective perception are discussed.

Huang Y et al [4] Propose a hybrid periodic carrier frequency modulation (HPCFM) technique based on the modified space vector pulse-width modulation (SVPWM) for two-level three-phase voltage source inverters to eliminate the PWM noise. Owing to PWM technique and switching losses considerations, ear-piercing high-frequency acoustic noise from motor is common. The proposed HPCFM technique is able to remove the high-frequency unpleasant acoustic noise more effectively than conventional PCFM with lower switching losses and shorter frequency range. In addition, the PWM harmonics in phase voltage and phase current are reduced significantly. Furthermore, the HPCFM method is simple to implement and does not employ additional circuits in drive system.

Y. Huang et al [5] propose a novel method for two-segment three-phase motor to eliminate the harmonics nearby PWM frequency. Due to PWM technique and switching losses considerations, ear-piercing high frequency electromagnetic noise in drive system is common. By using magnetically coupled inductors (MCIs) and interleaved technique, the proposed novel method is able to remove the high frequency harmonics located nearby the PWM frequency and other odd multiples in two-segment three-phase motor. With this method, the unpleasant acoustic noise could be removed when the PWM frequency is selected near 10 kHz. The size of MCIs mainly depends on the PWM frequency harmonic currents rather than the fundamental frequency currents. Thus, its size is very small.

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3. WORKING PRINCIPLE

The output voltage of converter is fed to the grid through a three phase VSI. In order to enhance the dc utilization and to reduce the acoustic noises, a PI controller based closed loop technique is employed. In this technique, a RPWM along with SVPWM is combined, so as to form a Multicarrier Random Space Vector Pulse Width Modulation (MCRSVPWM). The SVPWM switching vectors with different frequency carrier are chosen with the aid of a random bi-nary bit generator. The MCRSVPWM generates the pulses with a randomized triangular carrier. The proposed PWM is capable of eradicating the high-frequency unpleasant acoustic noise more effectually than conventional RPWM with a shorter random frequency range. The proposed method is used in power system shunt active power filters to improve the power quality. Also assists in reducing the acoustic noise and electromagnetic interference in VSI.

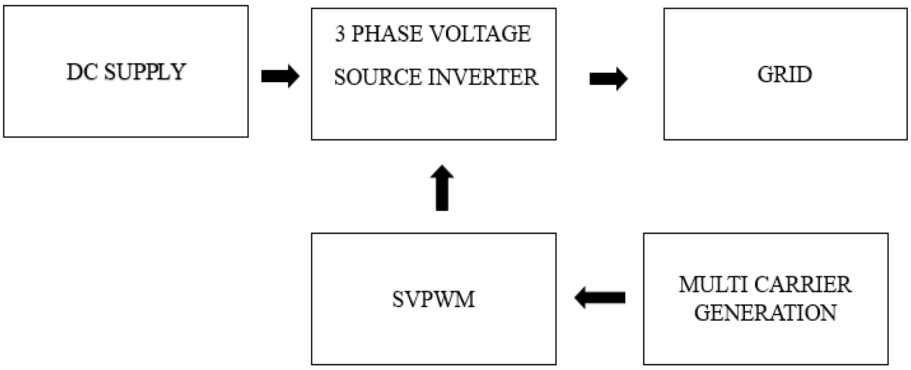

Figure 1 System under Investigation

3.1. Random Pulse Width Modulation

The important modification between standard PWM and random PWM methods is that the pulse width signal is no longer restricted to a few fundamental frequencies. The control relies on switching frequency (carrier frequency) and the modulated signal. The following section describes the RPWM generation for six switch voltage source inverters. where three legs and six switches are used to produce three-phase AC power. The VSI should generate the symmetry-less THD voltage and current. The reduction of THD is possible for spreading the harmonics spectra. The RPWM pulse arrangement. Here, the random carrier is achieved through a digital binary assignment process PRBS. In general, the RPWM processes triangular carrier waves (fixed frequency carrier), and multiplexer and shift register are used in the random carrier. The RPWM is realized by randomly changing the slope of the carrier wave. Generally, the prevailing RPWM can be grouped into three types

- Random Carrier Frequency Pulse Width Modulation (RCFPWM),
- Random Switching (RSPWM) And
- Random Pulse Position Pulse Width Modulation (RPPPWM).

3.2. Multicarrier Random Space Vector PWM

The RCPWM practice is basically related to conventional SPWM, the only variance being the usage of two different triangular carriers, which are the prerequisite frequency and 180-degree phase shifting on the carrier. RPWM targets the way of overwhelming the voltage and a current harmonic, which reduces the current ripple and torque ripple. For improving the inverter DC-link consumption performance, the RPWM is connected with SVPWM, which improves the SVPWM and RPWM quality on the VSI-connected drive. The Existing PWM generates the multiple carriers with a random pattern, and it is applied to SVD to generate the switching timing. The four carrier signals with different frequencies of 1 kHz, 2 kHz, 3 kHz, and 4 kHz (random values) are made to generate the randomness carrier. In order to merge these random carrier signals, four 3×1 multiplexers (MUX) are used, and finally, the MUX output is given to the 4×1 multiplexer. The 8-bit PRBS as well as 16-bit PRBS generator are used to generate random '0' and '1' sequence, which manipulate the random combination of four different carrier frequency signals. The randomness is present in the output in the sense that one element value in a sequence is not dependent on any other element sequence. Each carrier signal is selected through MUX and random binary sequence. The random sequence for 16-bit PRBS and 8-bit PRBS is developed through the pseudo method. Unlike conventional random sequences, the pseudo generator continues the random signal, and N elements later, the random signal repeats automatically and gives another set of random binary sequences in contrast to real random sequences, e.g. Radioactive decay and white noise. It is executed using the linear feedback type of shift registers for getting the same probability order of '1's and '0's. The PRBS bit generator is a lead–lag random bit trainer, which is designed by using shift register and XOR gates. Amore common form of LFSR is designed

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using a simple shift register getting feedback from two or more points or tapings available in the chain of registers. The PRPS working in the below example is from the output of the first (bit 0) and third D-flip-flop (bit 2) of the 3-bit shift register. All the third D-flip-flops of the 3-bit shift register are triggered by the same clock signal. The input for LFSR is produced by XOR using bit 0 and bit 2 from the shift register. The rest of the D-flip-flop outputs are used only for the data-shifting function. The pattern or the sequence of bits produced is the result of the combined action of output produced by XOR and the choice of inputs of XOR This creates an n-bit shift register with a constant clock of frequency fc generated with the help of a random carrier wave. The input for first D-flip flop is produced by the output of the XOR gate and is shifted in series to adjacent D-flip flops. The output of the XOR gate depends on the bits tapped from the D-flip flops and XOR operation. Random pulses are generated every fc clock signal. The possible number of outputs is determined by $K = 2n - 1$.The PRBS with a random variable needed to choose the PP is attained from the XOR gate output. The random selection of triangular carrier wave having discrete frequency is generated from a pseudo-random carrier method. The logic behind 8-bit and 16-bit PRBS .The output available from PRBS bits of the random bits generator is found as follows in Equations (3.1) and (3.2)

$$O_{PRBS-16bit} = B_{16} \oplus B_{14} \oplus B_{13} \oplus B_{11} \quad (3.1)$$

$$O_{PRBS-8bit} = B_8 \oplus B_6 \oplus B_5 \oplus B_4 \quad (3.2)$$

Where represents the output bit of the n-bit shift register and ⊕ represents the XOR operator. When the output of the 8-bit PRBS generator becomes zero as well as the output of 16-bit PRBS generator becomes zero, the carrier having 2 kHz frequency is chosen. When there is zero output of the 16-bit PRBS generator and unity output of the8-bit PRBS generator, a 3 kHz frequency carrier wave is chosen. When output of the 16-bitPRBS generator becomes one and that of the 8-bit PRBS generator becomes zero, a 4 kHz frequency carrier wave is chosen. When the output of the 16-bit PRBS generator becomes one and the output of the 8-bit PRBS generator becomes one, the carrier is determined to synthesize a random carrier wave. The random carrier wave generated is required for producing trigger gate pulses in VSI. The modulating signal is represented by three-phase reference signals. The Existing MCBRCPWM scheme waveforms.The randomness of the PWM signals is s result of both the different randomization of carrier frequency and the bits from PRBS. This feature makes for an incessant distribution of the power spectra when compared with just the random frequency carrier scheme or the conventional scheme.After creating a random signal, the multi-frequency random carrier signal is given to the SVPWM block. Here, the proposed SVPWM is alerted for adapting a random signal. The motor quantities (voltages and currents) can be given to the SVPWM reference generator, and these references are calculating the magnitude and phase angle of the SVD. In the SVPWM technique, the process of generating the pulse width command is reduced to a few simple equations. The basic idea behind SVPWM is the compensation of the required volt seconds by the use of discrete switching states and corresponding on-times (ta and tb) for switching. The 2-level inverter space vector diagram (SVD) and respective switching pulse. Every sector of the SVD remains an equilateral triangle with height; h (=3/2) is the height of a sector. The voltage vectors can be classified into two types: Large Vector (LV) and Zero Vector (ZV). Here, V1 to V6 vectors viz., {[100], [110], [010], [011], [001], and [101]} are active vectors and V0, V7 are zero vectors {(000), (111)}. The switching instants of SVPWM for six switch VSIs and switching cycles for sector-1. The on-time calculation for any of the six sectors (Di) (where i = 1, 2, 3, 4, 5 and 6) is the same, and hence, the function of sector 1 is considered for understanding the complete SVD. V*, the reference voltage, represents the rotating SVD form of three-phase voltage.The $\alpha - \beta$ plane projection of V* during any period lies in any one of the sector areas. For instance that V* lies in the first sector edged by vector V_1 andV_2. From timet_2, V* travels to t1 and the relationship with the time integral is given as

$$\int_{t_0}^{t_1} V^* = T_a V_1 + T_b V_1 \quad (3.3)$$

$$V^* T_S = V_1 T_a + V_1 T_b \quad (3.4)$$

$$V_{\alpha O}^* T_S = T_a + 0.5 T_b \quad (3.5)$$

$$V_{\beta O}^S T_S = h T_b \quad (3.6)$$

From the above two Equations (5) and (6), the time durations T_a and T_b can be Estimated.

$$T_b = T_S \left[\frac{V_{\beta O}^S}{h}\right] \quad (3.7)$$

Where $T_S = \left(1/f_S\right)$ is the sampling Period. Thus, the Ta equation is redefined as

$$T_S = T_a + T_b + T_o \quad (3.8)$$

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Therefore, the time spent by the zero-vector state is

$$T_o = T_S - T_a - T_b \tag{3.9}$$

3.3 Three Phase Inverter

An inverter is a power electronic device, used to change the power from one form to other like DC to AC at the necessary frequency & voltage o/p. The classification of this can be done based on the source of supply as well as related topology in the power circuit. So these are classified into two types (voltage source inverter) and CSI (current source inverter). The VSI type inverter has a DC voltage source with less impedance at the input terminals of an inverter. The CSI type inverter has a DC current source with high impedance.A three-phase inverter is used to change the DC voltage to three-phase AC supply. Generally, these are used in high power and variable frequency drive applications like HVDC power transmission. In a 3 phase, the power can be transmitted across the network with the help of three different currents which are out of phase with each other, whereas in single phase inverter, the power can transmit through a single phase. Generally, the three arms of this inverter will be delayed with 120 degrees angle to generate a 3 phase AC supply. The switches used in the inverter have 50% of ratio and switching can be occurred after every 60 degrees angle. The switches like S1, S2, S3, S4, S5, and S6 will complement each other. In this, three inverters with single-phase are placed across a similar DC source. The pole voltages within the three-phase inverter are equivalent to the pole voltages within the half-bridge inverter with a single phase.Inverter are basically used for the conversion of DC to AC supply. VSI drives used capacitive storage in their DC link, which stores and smooth the DC voltage of the inverter. It is very important to maintain or control the output voltage of inverter. The controlling of voltage can be done as:

- External control of inverter output voltage.
- Internal control in inverter

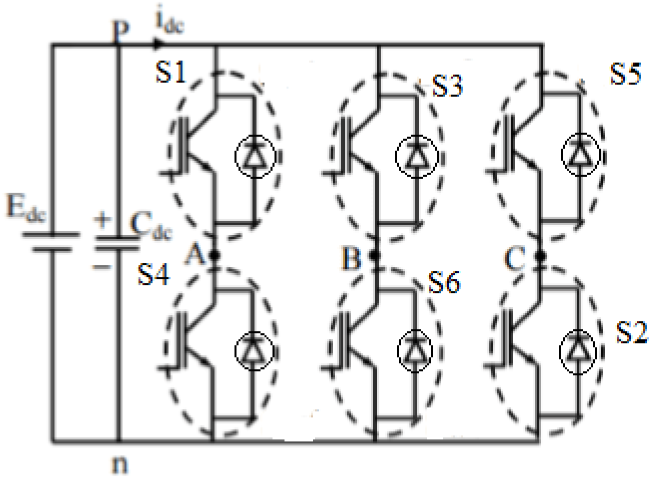

Figure 2 Circuit Diagram of Three phase Inverter

3.4 Space Vector Pulse Width Modulation

Space Vector Modulation (SVM) was originally developed as vector approach to Pulse Width Modulation (PWM) for three phase inverters. It is a more sophisticated technique for generating sine wave that provides a higher voltage to the motor with lower total harmonic distortion. The main aim of any modulation technique is to obtain variable output having a maximum fundamental component with minimum harmonics. Space Vector PWM (SVPWM) method is an advanced; computation intensive PWM method and possibly the best techniques for variable frequency drive application. Space vector pulse width modulation (SVPWM) is a technique used in the final step of field oriented control (FOC) to determine the pulse-width modulated signals for the inverter switches in order to generate the desired 3-phase voltages to the motor. The space vector pulse width modulation technique is frequently used in direct torque control drive and vector control drive. In addition to this when current control is exercised in rotating reference frame. The reference voltage generation is used in particularly for vector control drives. Space Vector Modulation (SVM) was originally developed as vector approach to Pulse Width Modulation (PWM) for three phase inverters. It is a more advanced technique for generating sine wave that provides a higher voltage to the motor with lower total harmonic distortion. The main aim of any modulation technique is to obtain variable output having a maximum fundamental component with minimum harmonics. The space-vector PWM technique is used to produce the switching control signals to be applied to the three-phase inverter. The SVPWM inverter is used to offer 15% increase in the dc link voltage utilization and low output harmonic distortions

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compared with the conventional sinusoidal PWM inverter. The control strategy of the SVPWM inverter is the voltage/frequency control method which is based on the space-vector modulation technique. The fundamental difference between SVPWM and SPWM is the existence of two additional zero voltage states V0 (000), and V7 (111). In addition to the six possible voltage vectors associated with the VSI, there are two zero voltage states associated with having all three of the positive pole switches on or all three of the negative pole switches on. This fact allows more output voltage since the third harmonic component exists. Thus, SVPWM is often considered as an eight state operation.

4. SIMULATION DIAGRAM

Figure 4 shows the Simulation circuit of Multi Carrier Space Vector Pulse Width Modulation Grid connnected inverter. The grid output voltage is 300 V and grid current is 5 amps The simulation model of the proposed MCRSVPWM is shown in Figure4. In this simulation, the major structure is with three main blocks: (1) reference signal generation, (2) random carrier generation, and (3) SVPWM pulse generation. After deciding the modulation index via a reference signal, the random carrier generation block will give the carrier signal to the SVPWM sampling and a holding block to compare the inverter pulses. The inverter is investigated with different RPPWM including the proposed MCRSVPWM. The VSI-connected conventional RPWM and RRPWM results captured and compared with the proposed MCRSVPWM schemes.

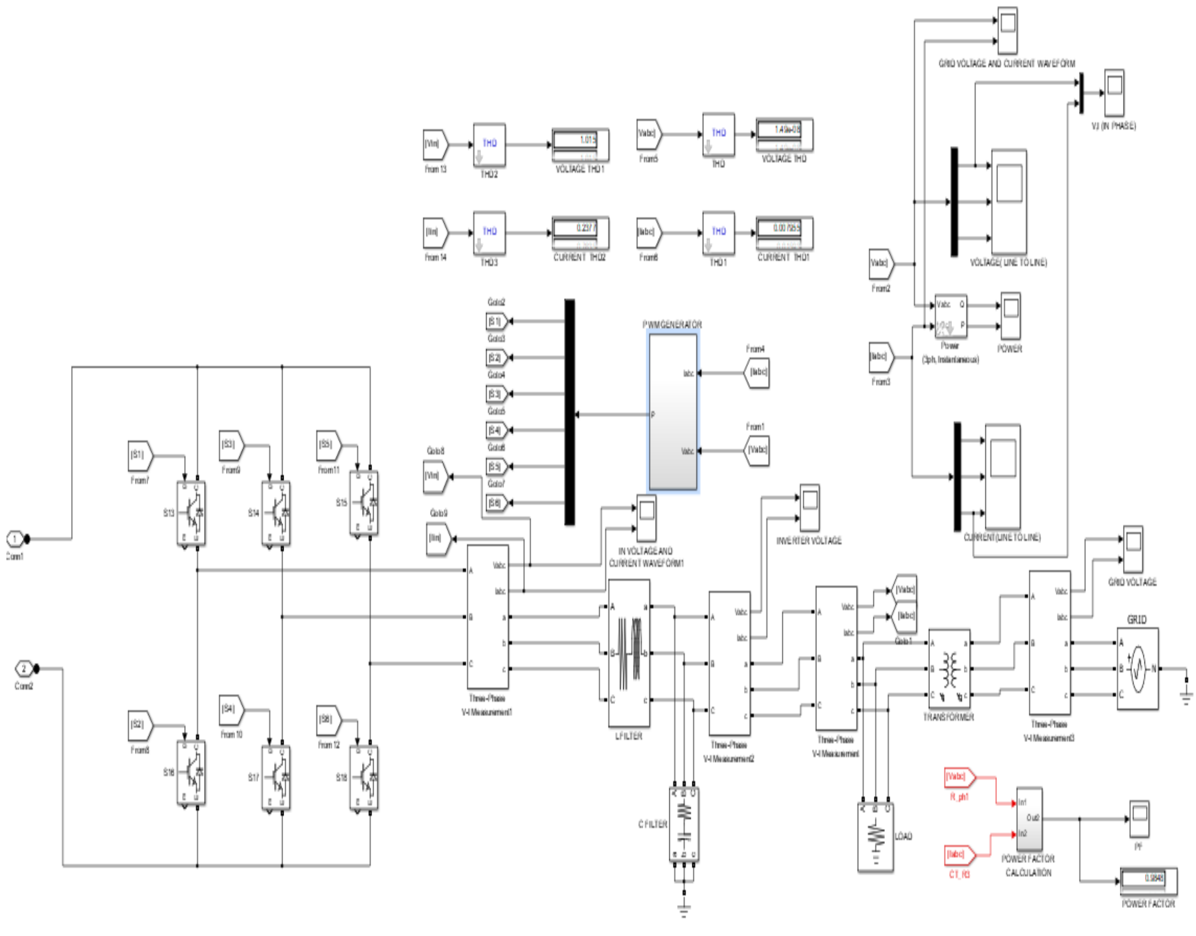

Figure 4. Mcrsvpwm Grid Connected Inverter Simulation Circuit

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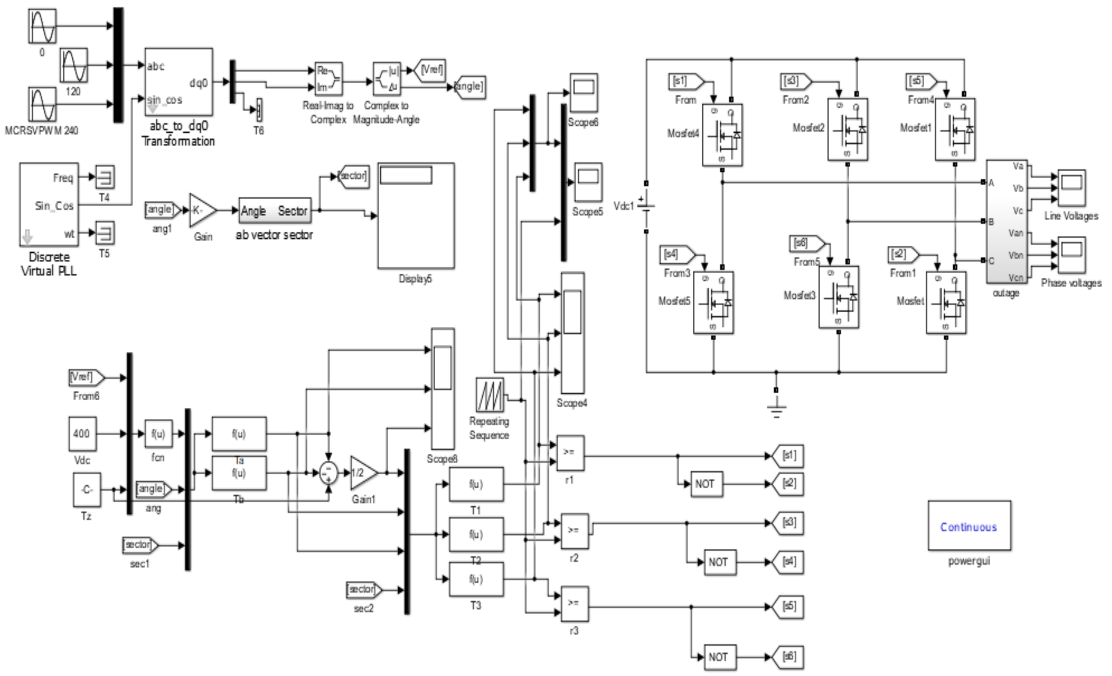

Figure 5. Simulation model of SVPWM based Inverter

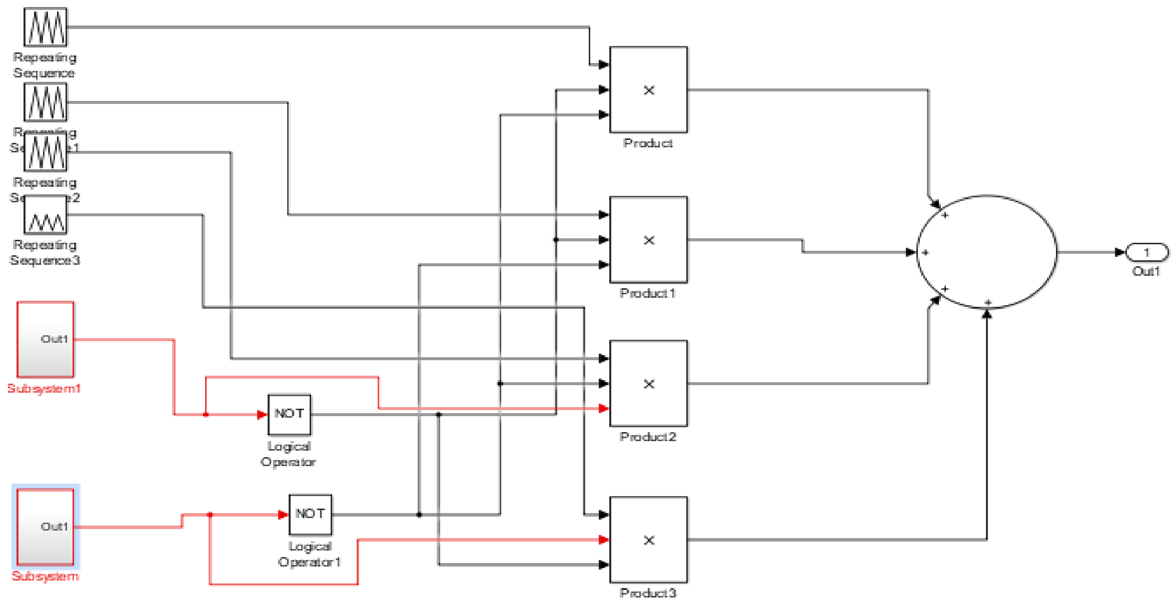

Figure 6. Simulation model of multi carrier generation

5. SIMULATION RESULTS

The inverter investigated with different RPPWM Including the proposed MCRSVPWM .the VSI connected conventional RPWM and RRPWM results are captured and compared with the proposed MCRSVPWM schemes. The switching frequency of RCPWM are 1KHz to 4KHz; through out the simulation, the DC- link voltage has been maintained as 200 V, the inverter operated in the range of the modulation index from 0.1. M_a to 0.9 M_a .When multiple frequency are fixed at the signal generator as 1KHz,2KHz,3Khz,4KHz, are analysis is taken these simulation.

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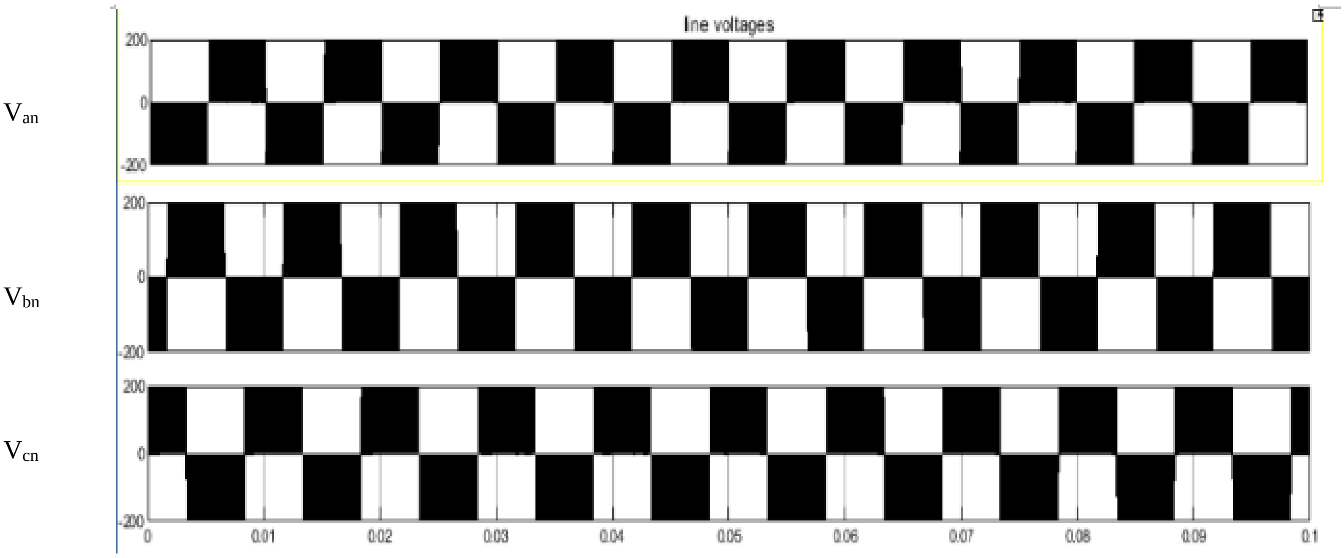

Figure 7. Output for SVPWM Phase Voltage

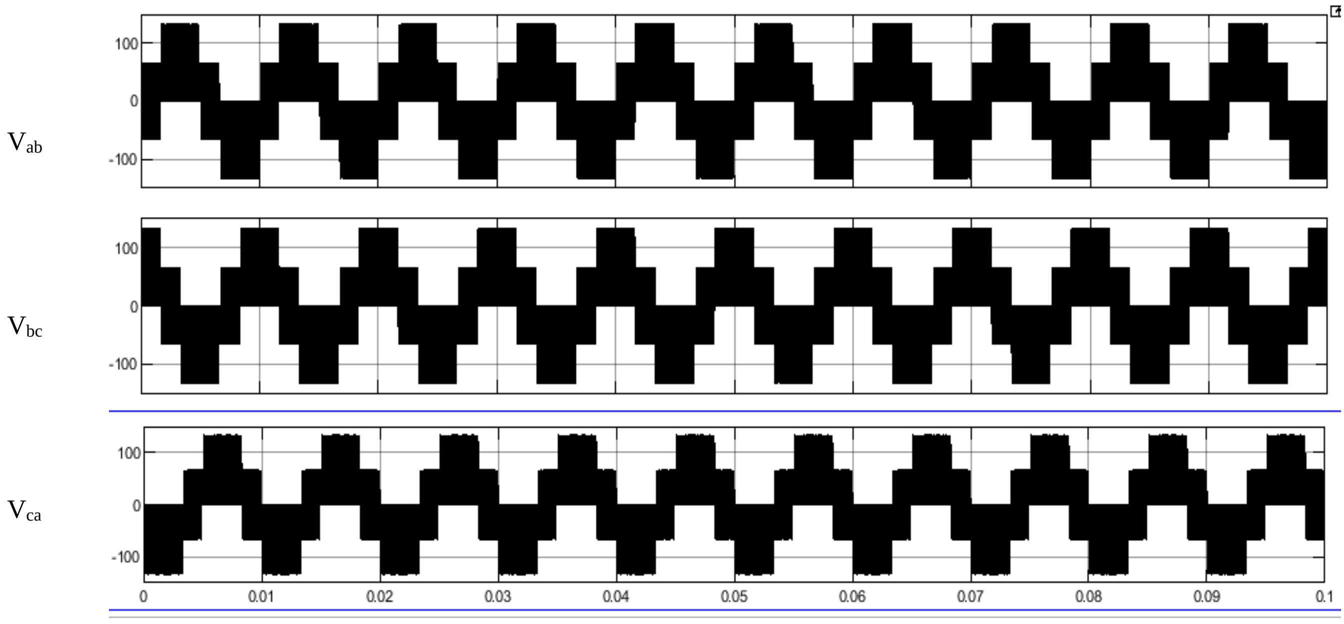

Figure 9. Output for SVPWM Line Voltage

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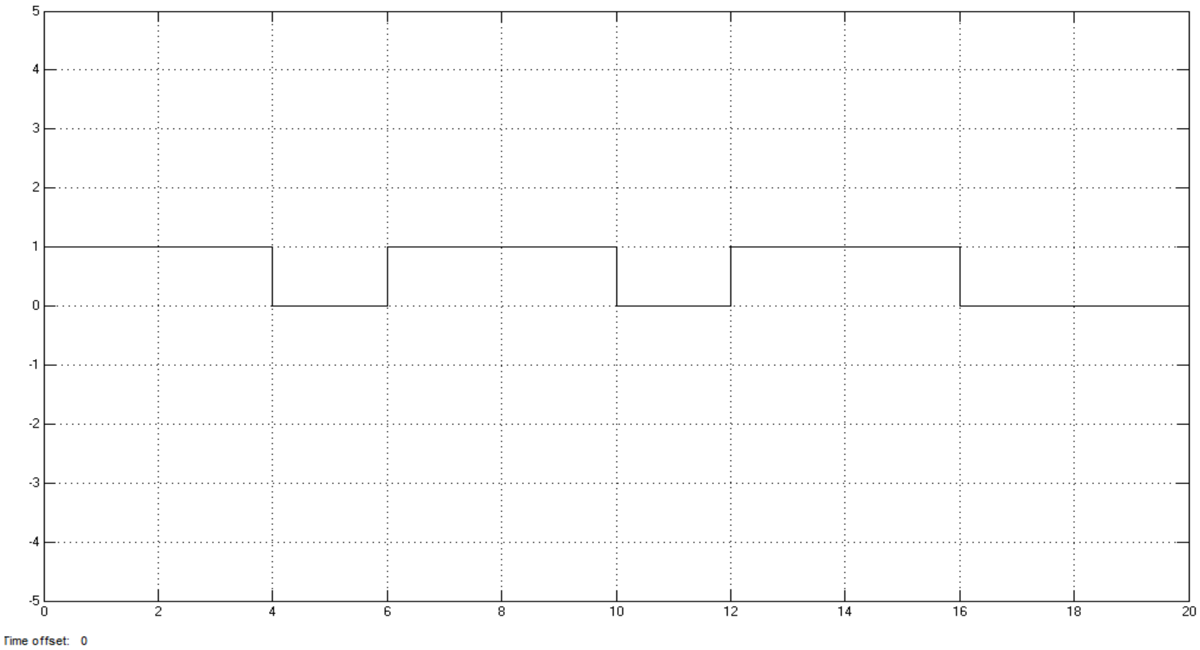

Figure 9. Output for Pesudo Random Binary Sequence 8 Bit RPWM

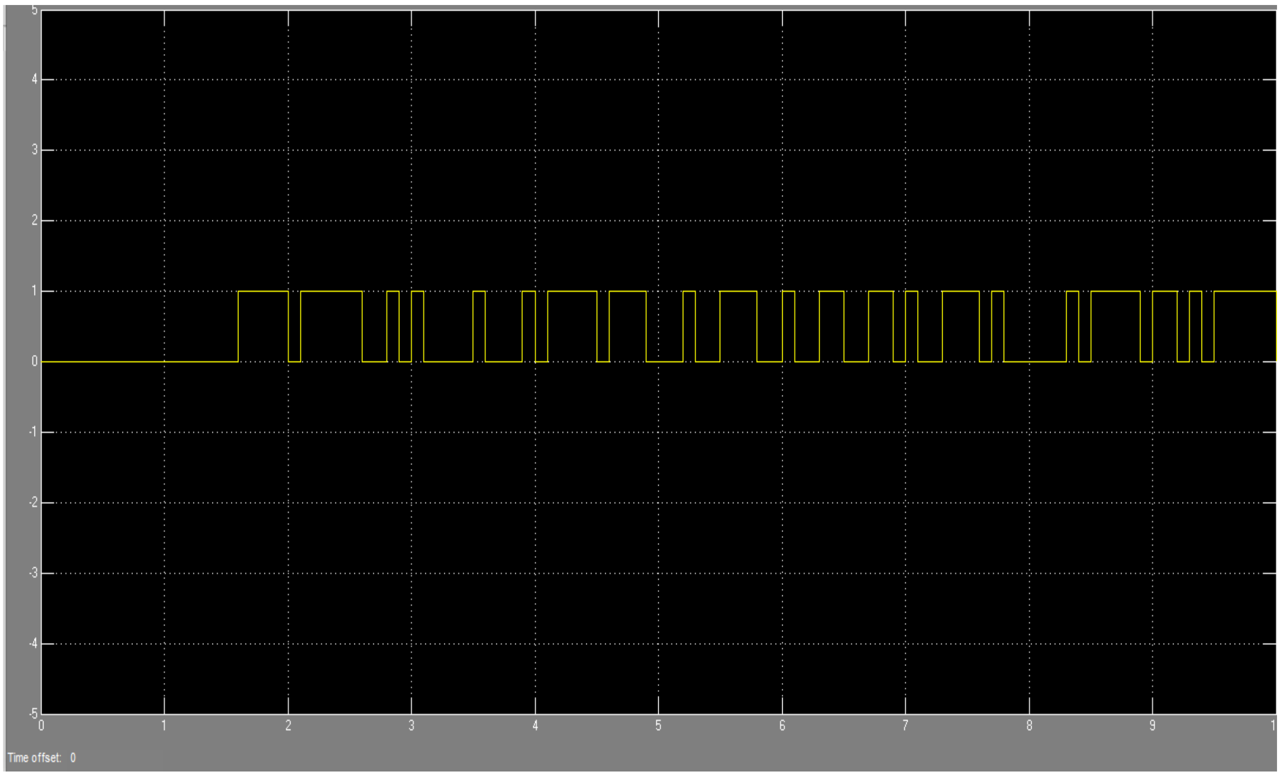

Figure 10. Output for Pesudo Random Binary Sequence 16 Bit RPWM

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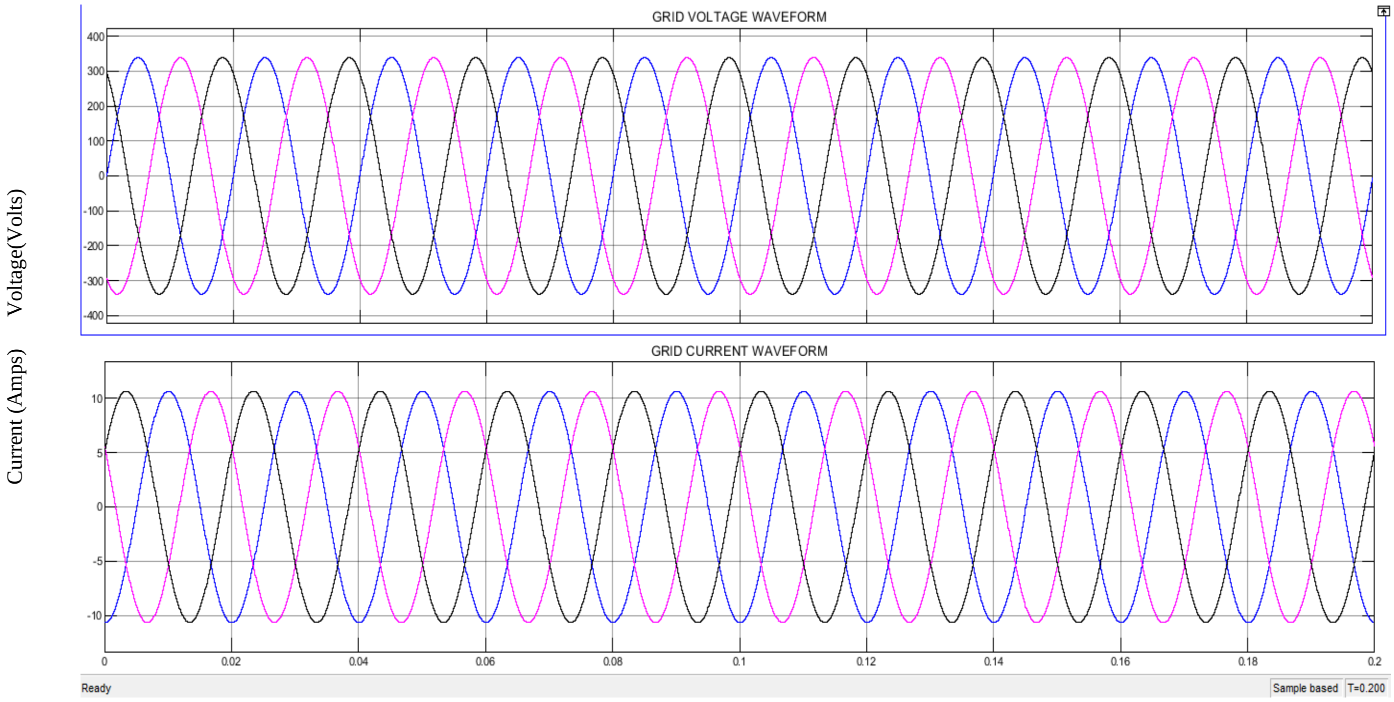

FIGURE 11. OUTPUT FOR GRID VOLTAGE AND CURRENT

Time(Sec)

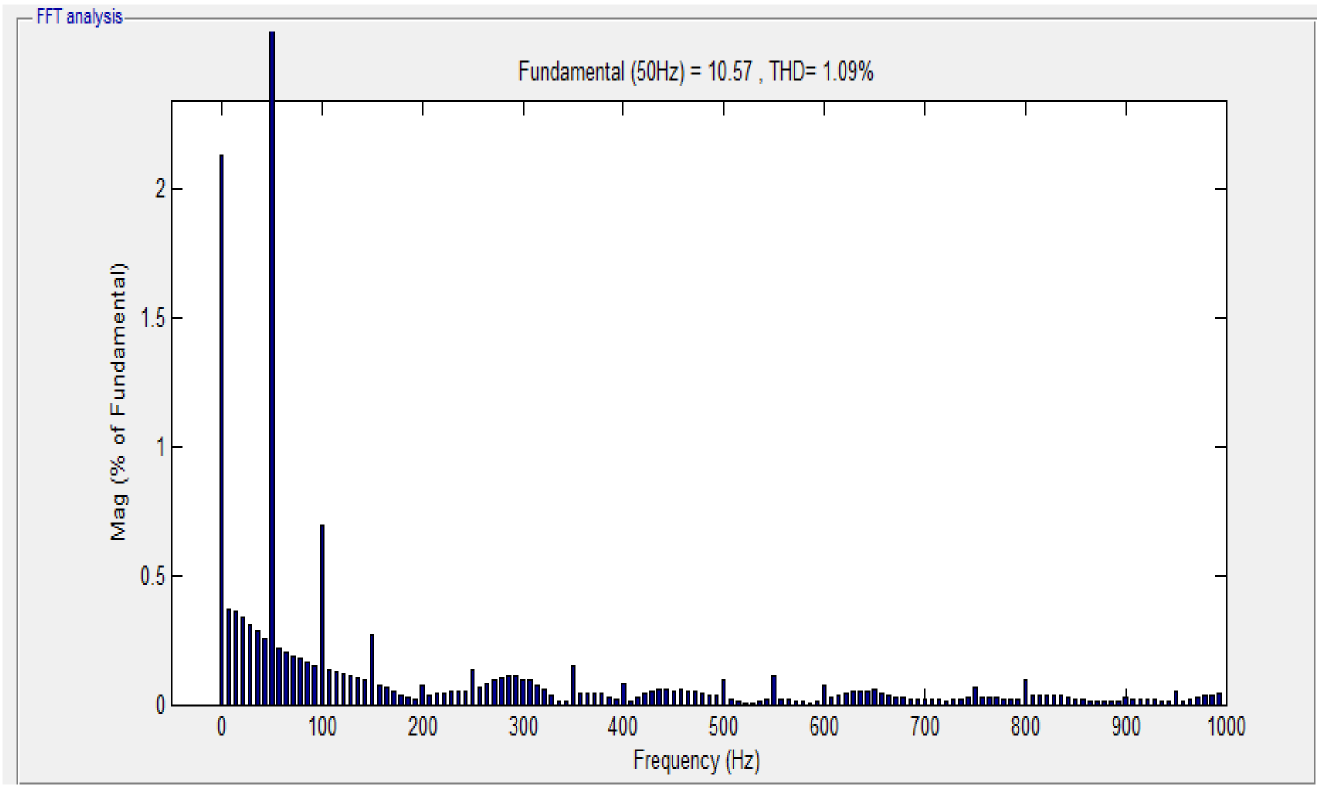

Figure 12. Current THD Analysis of Grid Connected Inverter

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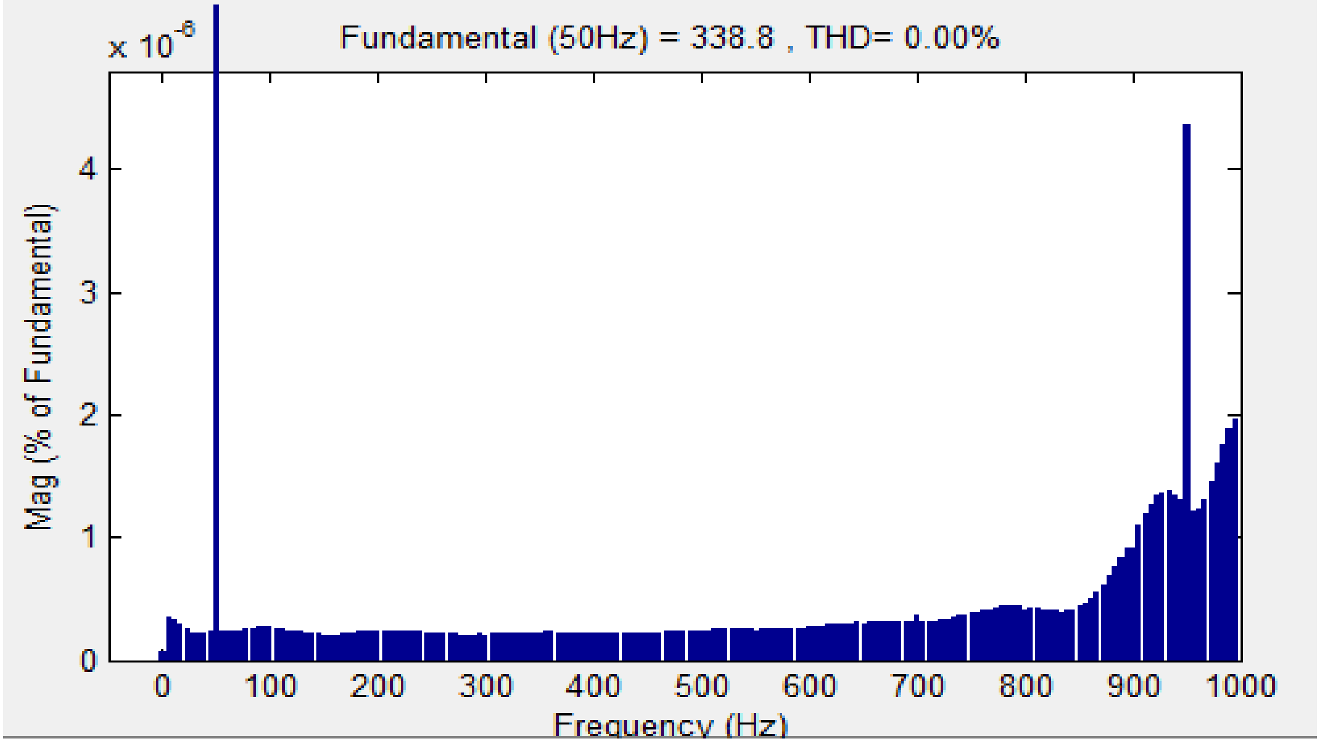

Figure 12. Voltage THD Analysis of Grid Connected Inverter

6. CONCLUSION

In this Project, a multicarrier random space vector PWM is presented for a grid connected system. A multicarrier random space vector PWM was presented for a three-phase two-level six switch voltage source inverter-fed induction motor. The multiple carrier-based random methods improve the randomness, which helps spread the harmonics around the spectra. The SVPWM agrees with multicarrier (different fixed frequencies as carrier waves), which are chosen with the aid of a random binary bit generator. The proposed MCRSVPWM generated pulses with a randomized triangular carrier (1 to 4 kHz), while the conventional RPWM method contains the random pulse position with a fixed frequency triangular carrier. The FPGA-based two PRBS bit (8 bit and 16 bit) generators are used to generate the random binary for getting random carriers for the pulse generations. The simulation study is performed through MATLAB/Simulink for a SVPWM based Grid connected Inverter. The MCRSVPWM is confirming the superiority of their reduction of THD and better DC-link utilizations. The MCRSVPWM can be used in grid to reduced the Harmonic analysis. The random PWM is able to reduce the THD.

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