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COMPARATIVE STUDY OF PULSE WIDTH MODULATION CONTROL TECHNIQUES OF MATRIX CONVERTER

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Abstract- *The Matrix converter is a forced commutated Cyclo-converter with a variety of controlled semi conductor switches that interfaces straightforwardly the three phase source to the three phase load. The matrix converter is an immediate AC-AC Converter. In a matrix converter, the frequencies of output voltage harmonics are identified with the frequencies of input, output, and carrier signals, which are autonomous of each other. Pulse width modulation strategies have been created for Matrix converters (MCs) keeping in mind the end goal to enhance their execution. Some of the modulation techniques existing are Alesina-Venturi and Space vector Modulation Techniques. This paper presents control and Modulation procedures for Matrix converters (MCs). The motivation behind these strategies is to produce sinusoidal current on the input and output sides. These techniques are thought about thinking about hypothetical multifaceted nature and execution. Reenactment examines were completed in MATLAB Simulink to confirm the adequacy of the adjustment systems. The simulated results are analyzed and show that the THD is better for Near State SVPWM technique.*

1. INTRODUCTION

In various AC drive applications, it is appealing to use smaller voltage source converter to give sinusoidal output voltages with differing amplitude and frequency, while drawing sinusoidal information streams with unity power factor from the AC source, and having high direction data transfer capacity, high effectiveness, and commotion over the sound range. Starting late, Matrix converters (MC's) have ended up being dynamically engaging for these applications since they fulfill each one of the essentials, having the ability to supplant the routinely used Rectifier/Dc Link/Inverter structures. The need to fabricate the quality and the capability of the power supply and the power utilize, the three stage lattice converters transforms into a front line imperativeness converter and has ascended out of the early conventional essentialness change modules. The examination of the grid converter has been proceeding all through the past 25 years. The progress in the change of energy gadget (silicon) development and broad power fused circuits bolstered the excitement of research to explore an AC-AC grid converter as a lovely silicon-concentrated and beneficial way to deal with change over electric power for the going with: AC motor drives, uninterruptible power supplies, variable frequency generators, and responsive vitality controls. In any case, the power converter is up 'til now not utilized as a part of industry because of the inconveniences related with the sensible utilization related to bi-directional switch affirmation, zero current substitution issues, the diserse nature of the PWM control technique, the synchronization and the confirmation issues Matrix Converters (MC), allow organize AC/AC control change, with high efficiency and without DC imperativeness storing join, beside little ventilating channels to confine trading swells.

The nonappearance of huge DC associate electrolytic capacitors allows the diminishment of this power converter volume, weight and expenses, extending the power thickness and their reliability when diverged from standard Back to Back Voltage-Source Converter (VSC) structures with electrolytic capacitor banks. Plus, they allow bidirectional power stream and don't contribute in a general sense to the consonant degradation of the data ebbs and flows. Absence of enormous open portions in the structure of this all silicon made converter realizes lessened size and improved steady quality diverged from customary multistage AC/DC/AC recurrence converters. Thusly its unrivaled points of interest, for instance, sinusoidal yield voltage and information present, controllable information control factor, high resolute quality and furthermore a little and squeezed structure make it a sensible other alternative to back to back converters. Figure 1 demonstrates the three phase to three phase design of the Matrix converter. The network converter comprises of nine bidirectional switches which are orchestrated into 3 gatherings of three switches. Each gathering is associated with each output phase. It demonstrates that converter switches are exchanged on rotational premise. For this situation no two switches in a leg exchanged on all the while.

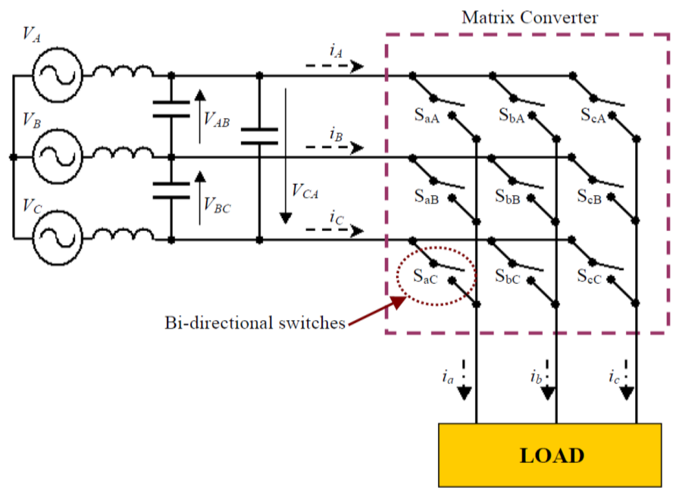

Figure 1. Three Phase Matrix Converter

2. MATRIX CONVERTER TOPOLOGIES

A Matrix converter in view of high frequency amalgamation control was presented in 1980.Since at that point, the converter turned into the focal point of consideration for serious research, and various examinations have been finished by various gatherings of scientists. The examinations that have been done yet generally focuses on the execution of the matrix converter switches, known as a four-quadrant switch or bidirectional switch and the various switching control methodology of the matrix converter topology are as shown in figure 2.These Matrix converter topologies utilize a bi-directional switch as the essential building piece of the converter, and apply a similar balance procedure approach in view of a high frequency waveform amalgamation method. In this way, it is critical to research the design of the bi-directional switch since there is no single module bi-directional switch accessible in the market. The arrangement of the bi-directional switch and the high frequency waveform combination procedure are examined before the matrix converter topologies.

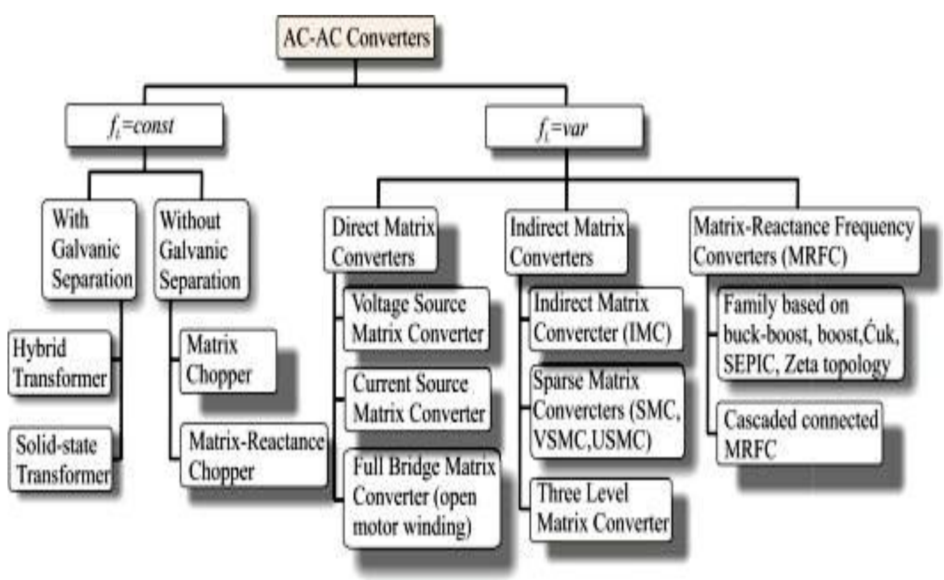

Figure 2. Types of Matrix Converters

The first topology is known as the conventional inverter based converter, which has intermediate reactive energy storage elements that act as a DC-bus link. The size of this topology is large because of the reactive elements needed to store the intermediate energy. The direct matrix converter is the second topology that consists of 9-bidirectional switches arranged in such a way so that any of the input line can be connected to the output line to give desired frequency and voltage as shown in figure 3. This topology is small in size, all-silicon converter, provides sinusoidal input and output current waveform, bidirectional energy flow and controllable input power factor regardless of the size or type of the load. All the above advantages are on the cost of complex control system.

The direct AC-AC matrix converter topology has a simple structure and many attractive features; but the complexity of its conventional PWM control strategy and the commutation problem prevent it from being used in industry. An alternative approach to overcome these failures is proposed. It is a two -stage converter topology known as an indirect matrix converter. This topology is similar to the conventional inverter-based converter topology without any reactive DC-link energy storage components for the intermediate imaginary DC-link bus.

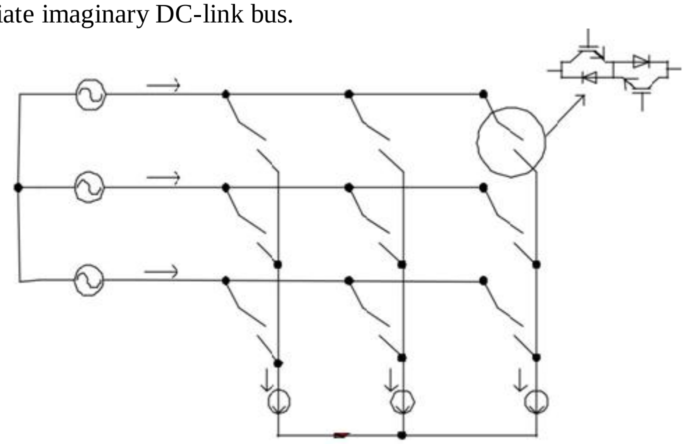

Figure 3. Three Phase Direct AC/AC Matrix Converter

All the desired features of the direct matrix converter topology, such as sinusoidal input current and sinusoidal output voltage, four -quadrant operation, unity power factor, no DC-storage elements are achieved by this indirect matrix converter topology. In addition, this topology simplifies the complexity of the conventional PWM control strategy, and overcome the commutation problems of the previous topology. Besides, commutation at zero input current is possible.

3. MODULATION CONTROL STRATEGIES

Because of advancements in solid state power devices PWM based converters are most widely used in drives.PWM inverters makes it possible to control both the frequency and magnitude of the voltage and current applied to drive the motor. The energy that a PWM converter delivers to a motor is controlled by PWM signals applied to the gates of the power switches. Different PWM techniques exist, that are Sinusoidal PWM, Hysteresis PWM and the relatively new Space-Vector PWM. These techniques are commonly used for the control of ac induction, Brushless Direct Current (BLDC) and Switched Reluctance (SR) motors. As a result, PWM converter powered motor drives offer better efficiency and higher performance compared to fixed frequency motor drives.

A matrix converter topology that has the same approach as the conventional inverter based converter without including any reactive energy storage as an intermediate DC-bus link is discussed. This topology is known as the Indirect SV PWM matrix converter. The indirect SVPWM matrix converter is divided into two portions, a rectifier side, and an inverter side. The rectifier side of the converter is directly connected to the input line side and converts the three-phase input into DC voltage. This DC voltage is supplied in to the inversion side of the converter, which produces the desired frequency range and voltage level for the load.

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The generation of PWM pulse requires reference sine wave and triangular wave. The reference sine wave is compared with the feedback from the output voltage, is amplified and integrated. This signal is then compared with a generated triangular wave. The rectangular wave is the result of this comparison. As the sine wave is reaching its peak, the pulses get wider. It is clearly visible that the duty cycle of the rectangular wave is varying according to the momentary value of the required output voltage. The result is that the effective value of the rectangular wave is the same as that of the output voltageThis pulse is used to switch ON or OFF the power switches. The width of the pulse or duty cycle can be varied by varying the frequency of the reference wave.

4. SPACE VECTOR MODULATION

The concept of space vector is derived from the rotating field of AC machine. In this technique the three phase quantities can be transformed into two phase quantities in a d-q frame. The d, q components are found by Park transform, where the total power, as well as the impedance, remains unchanged. The magnitude of each active vector (V1to V6) is 2/3 Vdc (dc bus voltage). SVPWM based converters supplies the AC machine with the desired phase voltages. The space vector modulation concept is used to calculate the duty cycle of the switches which is imperative implementation of digital control theory of PWM modulators. Space vector modulation is a PWM control algorithm for multi-phase AC generation, in which the reference signal is sampled regularly; after each sample, non-zero active switching vectors adjacent to the reference vector and one or more of the zero switching vectors are selected for the appropriate fraction of the sampling period in order to synthesize the reference signal as the average of the used vectors.The space vector pulse width modulation technique has the following advantages when compared to the conventional PWM technique.

- Its maximum output voltage is 15.5% greater,
- The number of switching required is about 30% less

The modulating signal is generated by injecting selected harmonics to the sine wave. This results in flat-topped waveform and reduces the amount of over modulation. It provides a higher fundamental amplitude and low distortion of the output voltage. The modulating signal is generally composed of fundamental plus harmonics.

The concept of space vector is derived from the rotating field of ac machine which is used for modulating the converter output voltage. In this modulation technique the three phase quantities can be transformed to their equivalent two phase quantity either in synchronously rotating frame (or) stationary d-q frame. From this two phase component, the reference vector magnitude can be found and used for modulating the converter output. SVM treats the sinusoidal voltage as a constant amplitude vector rotating at constant frequency. This technique approximates the reference voltage V_{ref} by a combination of the eight switching patterns (V_0 to V_7).The representation of rotating vector in complex plane is as shown in figure 4.

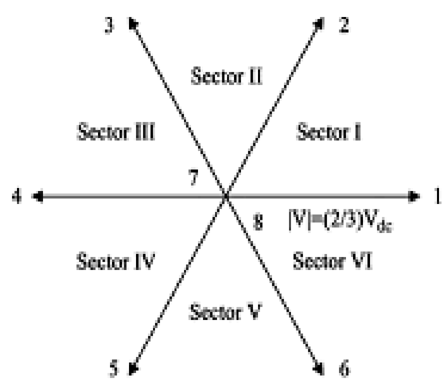


Figure 4. Representation of Rotating Vector in Complex Plan

5. NEAR STATE SPACE VECTOR MODULATION

The conventional SVPWM method utilizes the two adjacent voltage vectors (to the reference voltage vector) and the two zero-voltage vectors to program the PWM pulses.The NSPWM method utilizes a group of three-voltage vectors to match the output and reference volt-seconds. These three voltage vectors are selected such that the inverter voltage vector closest to reference voltage vector and its two neighbors (to the right and left) are utilized. Thus, in addition to the adjacent voltage vectors, a near-neighbor voltage vector is utilized. Hence, it is named “near state.” Note that the zero states are not utilized in NSPWM. The utilized voltage vectors are changed every 60◦ throughout the space. To apply the method, the space is divided into six segments. Defined with indexes, voltage vectors Vi−1, Vi, and Vi+1 are utilized for region Bi. For example, for the region between 30◦ and 90◦ (B2), the applied voltage vectors of NSPWM are V1, V2, and V3. Utilizing the near-state voltage vectors defined above, the complex variable volt-seconds balance equation and the PWM period equation for NSPWM can be written in a generalized form.The NSPWM is the widely used technique to reduce the common mode voltage variations at the output. CMV is defined as the potential of the star point of the load with respect to the centre of the DC bus. The NSPWM technique utilizes the three voltage vectors to obtain the output voltage which is equal to the reference voltage. This technique doesn't use any zero voltage vectors.

6. MODELING OF MATRIX CONVERTER

Implementation of the matrix converter is done using Matlab / Simulink tools. The different modulation techniques are used to provide the pulses for the matrix converter. The converter consists of nine modular H-bridge capacitor clamped switch cells, connected from each input phase to output phase as shown in figure 5. The ac supply is given to the H- bridge switch cell through the filter circuit. Each switch cell consists of four IGBTs and one capacitor. The gate pluses for the switches are given through the PWM pulse circuits.

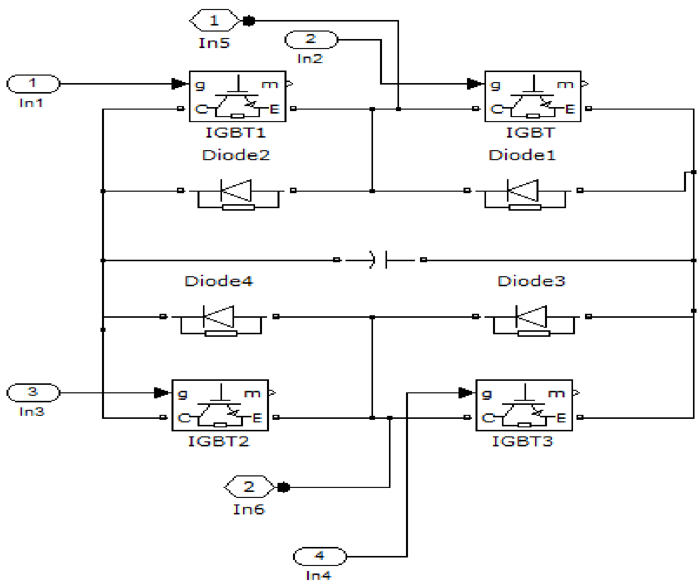


Figure 5. Simulink diagram of H-Bridge Switch Cell with Capacitor

Figure 6 -7 represents the matrix converter unit with PWM, and SVM modulation techniques respectively. The ac supply is given to the H- bridge switch cell through the filter circuit. Each switch cell consists of four IGBTs and one capacitor. The gate pluses for the switches are given through the PWM and SVM pulse circuits.

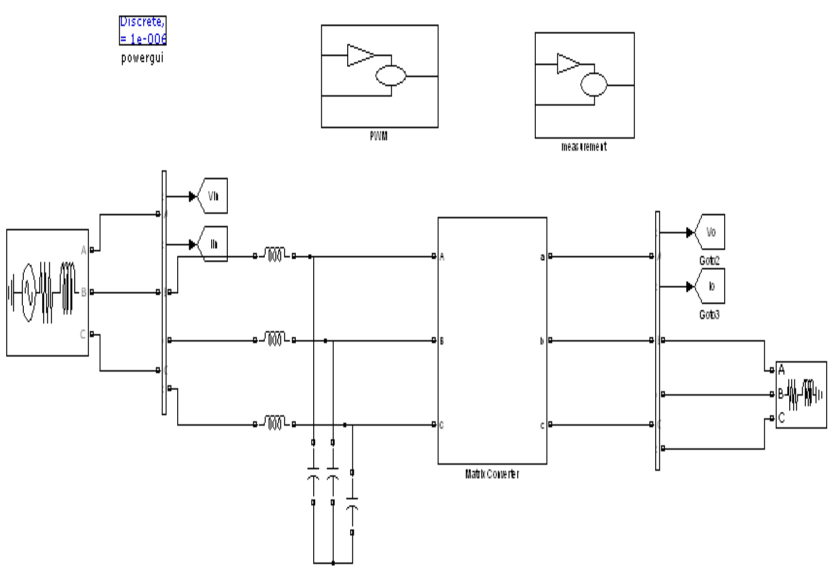


Figure 6. Simulink model of Matrix Converter Employing PWM Technique

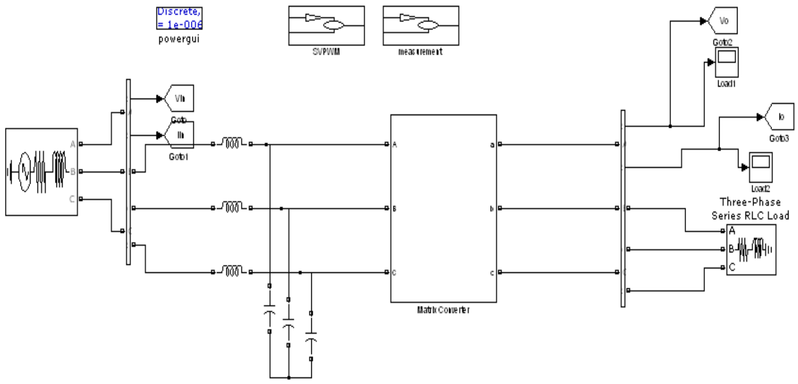


Figure 7. Simulink model of Matrix Converter Employing SVPWM Technique

7. SIMULATION RESULTS AND DISCUSSION

The proposed control algorithm is tested with an ideal nine-switch three phases to three phase matrix converter feeding a RL load. For this purpose, digital simulations are carried out using Matlab / Simulink software. The simulation parameters are set as; the supply frequency = 50Hz, the input voltage = 480 V, the input current = 27 A, the switching frequency = 2 kHz, resistance =20 Ω, inductance =310 mH.

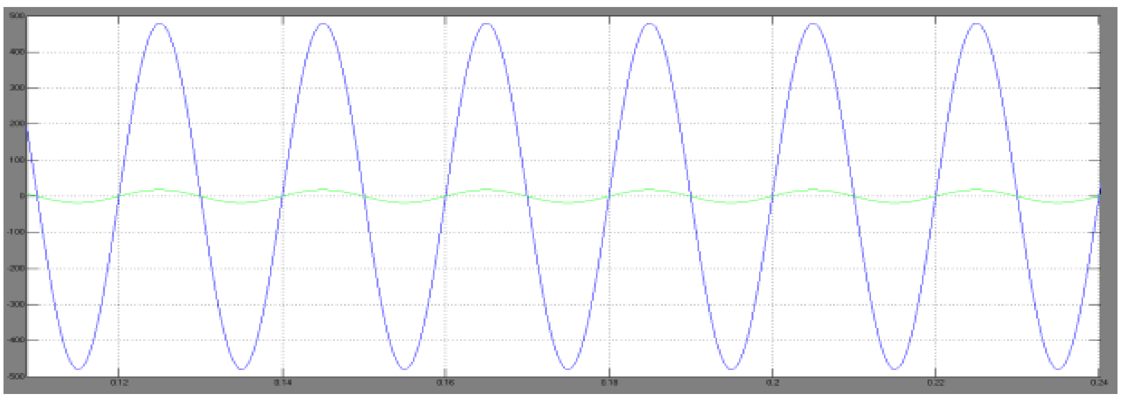


Figure 8.Input Voltage and Current Waveforms in Steady State Condition for PWM

Figure 8 shows the input voltage and current waveform given to the matrix converter. The input voltage and current is same for the modulation techniques.

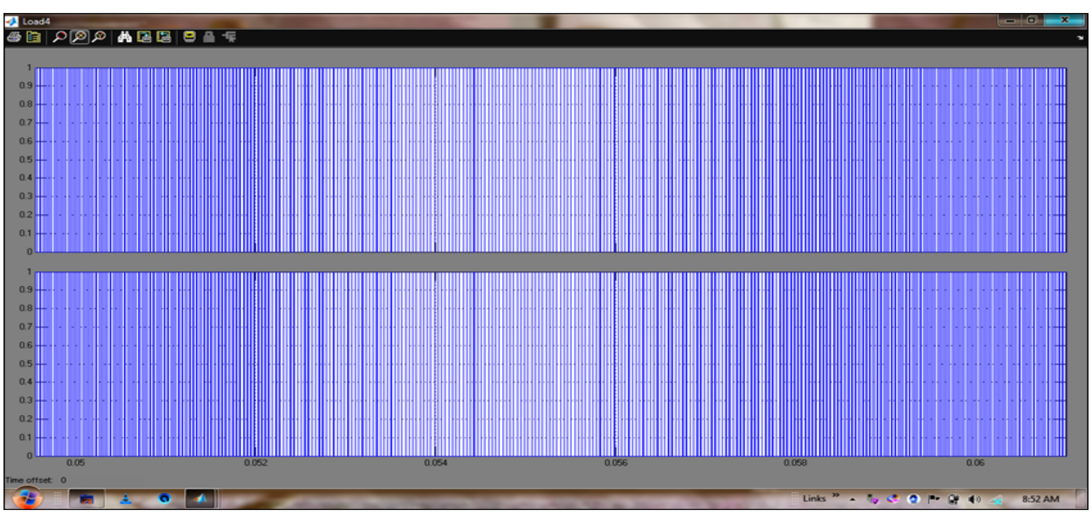


Figure 9. PWM Pulses for Upper and Lower Switches of Phase A.

Figure 9 shows the PWM pulses for upper and lower switches of phase A. The pulses for the lower switches are 180^0 out of phase with upper switch pulses. Similarly, the pulses can be obtained for phase B and C with a shift of 120^0 and 240^0 respectively.

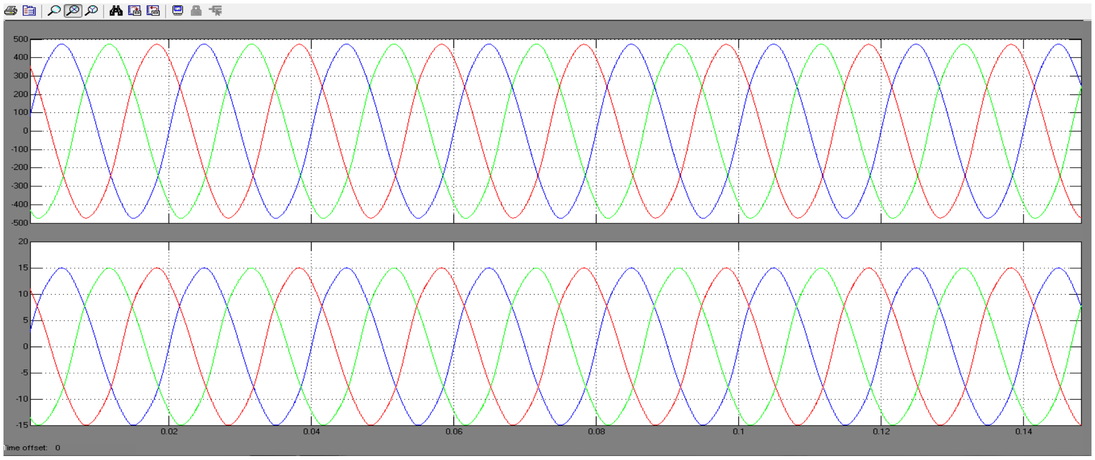


Figure 10. Output Voltage and Current Waveform of Matrix Converter using PWM Technique

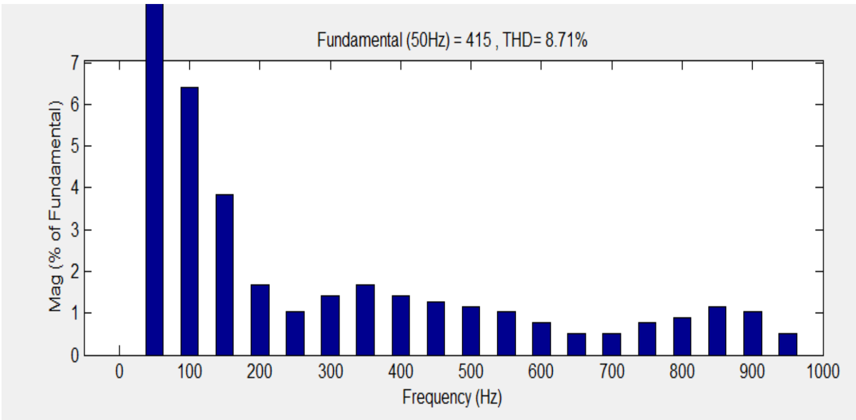


Figure 11. Harmonic Profile of Output Voltage Employing PWM Technique

It can be seen that both output voltage and current are sinusoidal. The fundamental component of the input current waveform is in phase with the input voltage i.e. the input displacement factor is close to unity likewise same in output current waveform is in phase with the output voltage.

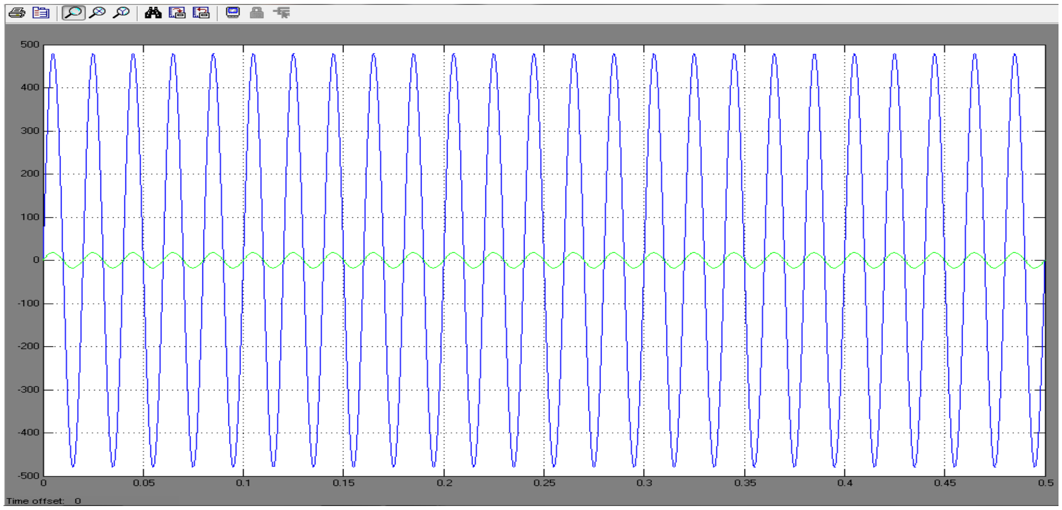


Figure 12. Input Voltage and Current Waveforms in Steady State Condition for SVPWM

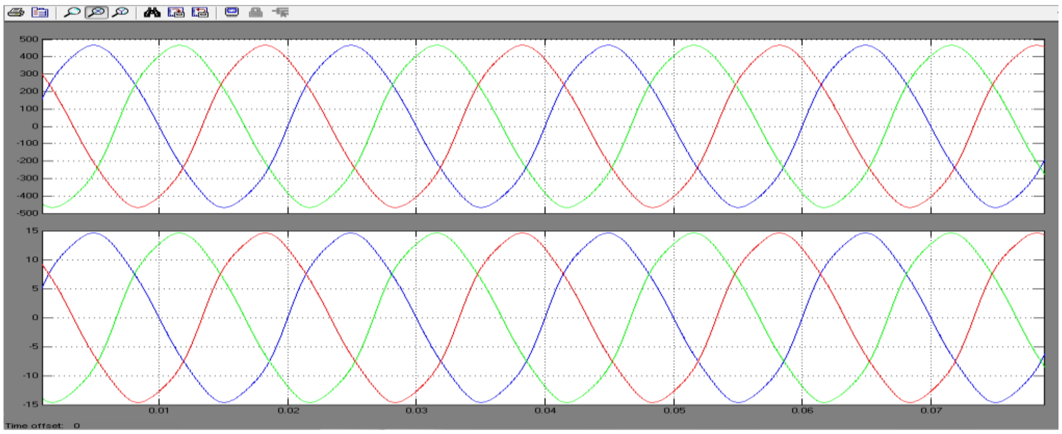


Figure 13. Output Voltage and Current Waveform of Matrix Converter using SVPWM Technique

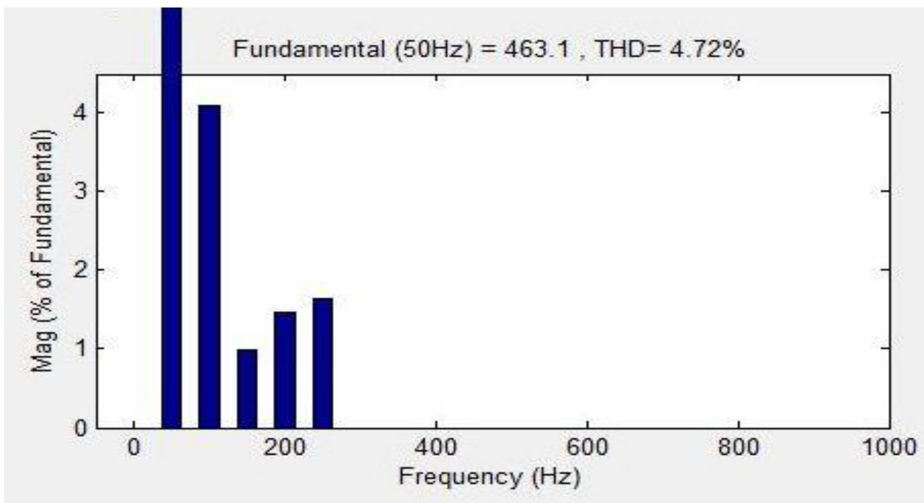


Figure 14. Harmonic Profile of Output Voltage Employing SVPWM Technique.

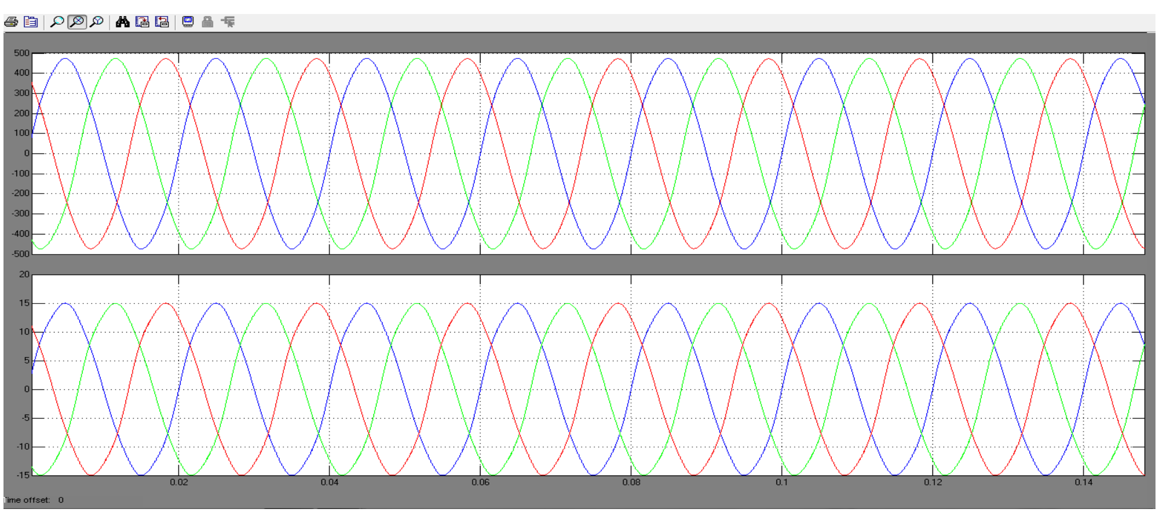
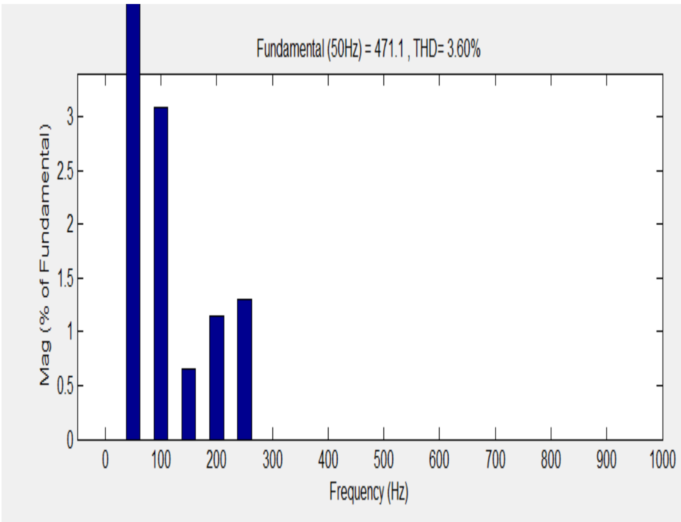


Figure 15. Output Voltage and Current Waveform of Matrix Converter using Near State SVPWM Technique



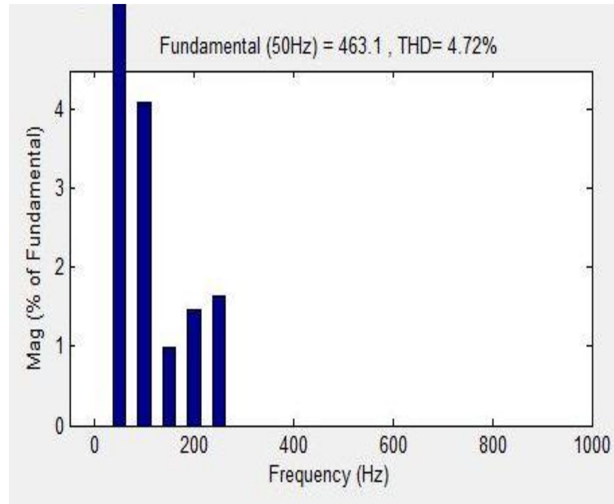


Figure 16. Harmonic Profile of Output Voltage Employing Near State SVPWM Technique

Compared to PWM, SVM has high output for the same value of input. The output current in all the three techniques are almost same. SVM has slightly higher value. The simulated values prove that the input and output voltages and currents are sinusoidal.

Table.1. Performance Comparison of PWM, SVPWM & Near SVPWM Techniques

S.No	Parameter	PWM	SVPWM	Near SVPWM
1	THD	**8.73 %**	**4.72 %**	**3.60 %**

8. CONCLUSION

The proposed Matrix Converter with different modulation techniques was simulated using Matlab/ Simulink model blocks. PWM, SVPWM,Near State Space Vector PWM techniques were analyzed in detail and the outputs were presented. The pulses obtained from various schemes are used to control the output parameters of the matrix converter to convert a given three phase input voltage into a three phase output voltage of a desired frequency and magnitude. Compared to SVPWM, Near State SVPWM technique has better voltage transformation capability.

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