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Implementation of Space Vector PWM Techniques in Matrix Converter Control

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Abstract: The paper analyzes the overall performance of matrix converter with two different control strategies, SVPWM and SVM. The basic principle and switching sequence of these modulation techniques are presented in this paper. The output voltage, output current waveforms and THD spectrum of switching waveforms connected to RL load are studied by using Matlab/Simulink software. The simulated results are analyzed and show that the THD is better for SVPWM technique.
Keywords: Matrix Converter; SVPWM; SVM; THD;

I. INTRODUCTION

The matrix converters is a new single stage generation of the direct power converter AC/AC and can contribute to the realization of low volume, sinusoidal input current, bidirectional power flow and lack of bulky reactive elements Due to all these reasons, recently a lot of research has been picked up in the field of matrix converters. And the performance of this converter varies based on the control technique and the different topologies. Matrix converters are capable of AC/AC direct power conversion. It does not consist of any dc-link circuit and does not need any large energy storage elements. The important component of a Matrix Converter is the completely controlled four quadrant bidirectional switch, which permits high frequency operation.

The grid converter comprises of 9 bi-directional switches that enable any output stage to be associated with any input stage. Space-vector regulation method is utilized as a part of Matrix converter modulation procedure. The SVM method was adjusted for the lattice converter by utilizing an essential procedure of indirect modulation utilizing an imaginary DC bus, at that point separating the converter into a rectification and an inversion. Furthermore, this modulation method permits streamlining a converter design, making it simpler to control the converter under imbalanced and distortion power supply conditions. By utilizing this method Matrix converter produce variable frequency.

Power electronic static converters have played a major role in the transformation of energy. In the recent past, MC has gained importance for the speed control of IM in industrial application particularly where size is of much importance. MC is a direct AC to AC converter with both voltage and unrestricted output frequency control. The MC structure has nine bidirectional switches which connect input phases to output phases in controlled manner. The absence of dc-link justifies the topology of MC over the bulky two-stage converter. Furthermore, controllable power factor and AC input currents are salient features of MC but lack of bi-directional switches and low voltage transfer capabilities have affected the considerable growth of the aforesaid converter. Due to current commutation problems of bi-directional switches, complex control algorithms and protection issues, the power converter performance is adversely affected.

II. PULSE WIDTH MODULATION TECHNIQUES (PWM)

Because of advances in solid state power devices PWM based converters are becoming most widely used in drives. PWM inverters make it possible to control both the frequency and magnitude of the voltage and current applied to drive 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 are existing, they 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).

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 as shown in fig.1. The rectangular wave is the result of this comparison. As the sine wave is reaching its peak, the pulse gets 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 voltage. This 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.

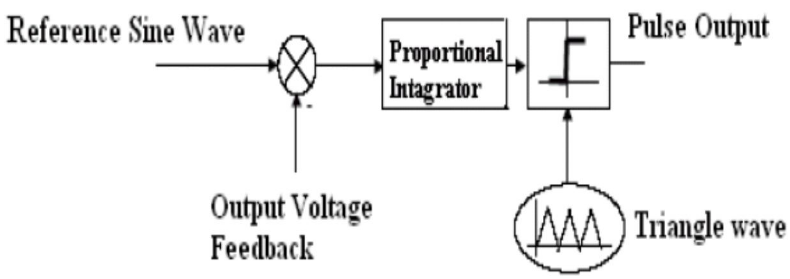

Fig.1 PWM Pulse Generation Circuit

This paper comprises of the points of interest of balance system and the exchanging topology of grid converter. Determination of these procedures is to change the voltage exchange proportion. The distinctive classes of Modulation methods are Basic Modulation strategy, Voltage ratio control and optimization, Alesina – Venturini regulation system, Scalar modulation procedure, Space vector modulation method, derivative balance system. The fundamental regulation methods which have wide applications are Venturini modulation system and the space vector adjustment procedure.
The main techniques those are used for analysis Matrix converter are:-

1) Space vector modulation
2) Modulation technique of Matrix converter
3) Matrix Converter Switching States
4) Topologies of Bi-directional Switches

Space vector modulation: Space vector modulation is an algorithm for the control of Pulse Width Modulation (PWM). It is utilized for the formation of AC waveform. It is a general strategy all loads in three phases, despite the fact that it has been produced for controlling motor. Space vector PWM is connected to yield voltage and to control input current.
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. 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 so, it is widely used in high performance AC drives.
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. It can yield valuable preferred standpoint under unequal conditions. Three phase factors are communicated in space vectors. For an adequately little time interim, the reference voltage vector can be approximated by an arrangement of stationary vectors produced by a network converter. Modulation procedure consequently required comprises of two fundamental parts: determination of the exchanging vectors and calculation of the vector time periods.
SVPWM alludes to a unique exchanging grouping of the upper three power transistors of a three-stage control inverter. It has been appeared to create less consonant distortion in the yield voltages and additionally streams connected to the periods of an AC engine and to give more proficient utilization of supply voltage. There are two conceivable vectors called zero vector and Active vector.
Modulation technique of Matrix converter: Matrix Converter operation can be explained in more general terms using a space vector approach. For operation of the Matrix Converter one and only one switch in each output phase must be conducting. This leads to twenty-seven possible switching combinations for the Matrix Converter.
Among all systems, SVM is the most broadly utilized and examined as of late. Since the SVM technique cannot just control the yield voltage and the info current individually, yet additionally alter the information control factor helpfully. 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

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converter output. SVM treats the sinusoidal voltage as a constant amplitude vector rotating at constant frequency. This technique approximates the reference voltage Vref by a combination of the eight switching patterns (V0 to V 7) as shown in fig.2.

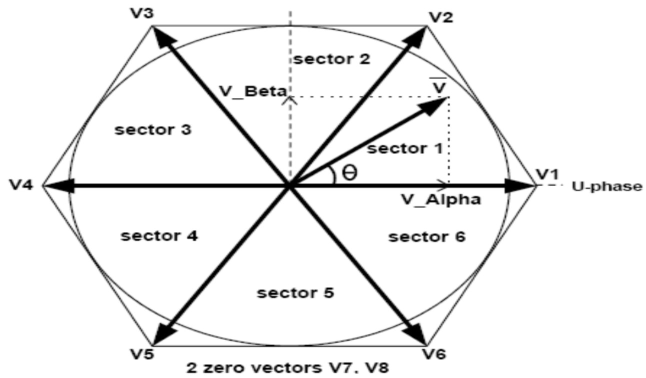

Fig.2 Representation of Rotating Vector in Complex Plane

III. MATRIX CONVERTER TOPOLOGIES

Based on the number of input and output phases, a Matrix Converter has the following topologies

1) Single Phase Matrix Converter.
2) Three phase to single phase matrix converter.
3) Three phase to Three Phase Matrix Converter.

The Single-Phase Matrix Converter consists of a matrix of input and output lines with four bidirectional switches connecting the single-phase input to the single-phase output at the intersections. It comprises of four ideal switches Sl, S2, S3 and S4 capable of conducting current

in both directions, blocking forward and reverse voltages and switching between states without any delays.

A Three Phase to Single- Phase Matrix Converter is composed of three bidirectional switches S1, S2 and S3. Each switch connects the output line to an input phase. To avoid short-circuit in the source side (three-phase side) and current interruption in the load side (single-phase side), only one switch can and must be on at any time. The switches are turned on the off in a sequential.

A Three-Phase to Three-Phase Matrix Converter is structured based on the Three-Phase to Single-Phase Matrix Converter. If three sets of the single output Matrix Converters are connected to the same input voltages, a three-output Matrix Converter is constructed. A three-phase/three-phase MC converter consists of nine bidirectional switches, which allow any output phase to be connected to any input one. The capacitances located at the input side of the converter and the inductances located at the output side are necessary for MC operation and make it possible to mitigate any high frequency components

IV. OPERATING PRINCIPLE OF MATRIX CONVERTER

The MC network depends on a high frequency union control which interfaces 'm' input stages to 'n' yield phases. In specific, it is a three-stage to three-stage constrained commutated cyclo-converter, comprises a variety of bidirectional switches that associate each yield stage to each information stage without utilizing dc-connect components as appeared in Fig.3. The general structure consists of input power circuit, a small input filter, MC and the load. Fig. 3 Basic power circuit of MC The yield voltage is constructed by proper cutting of input voltages using an appropriate switching algorithm. MC has several advantageous features over the other existing AC-AC commercial converters such as prolonged life and less maintenance, controllable power factor, four-quadrant operation and regenerative capability due to presence of bidirectional switches.

The prototype of MC demands the Bi-directional Switches (BS) which is capable of bi-directional flow of power, but there is scarcity of such switches. Hence, these BS are designed using the proper combination of switching device and diodes. In the present study, diode bridge arrangement of BS is considered as shown in Fig. 4. This configuration is preferred over other existing arrangements to avoid the need of two isolated power supplies for the two gate drivers of the MOSFET's. For smooth input current, a small filter is required at the front end of the converter. A reasonable exchanging frequency is in charge of sinusoidal yield voltage and information.

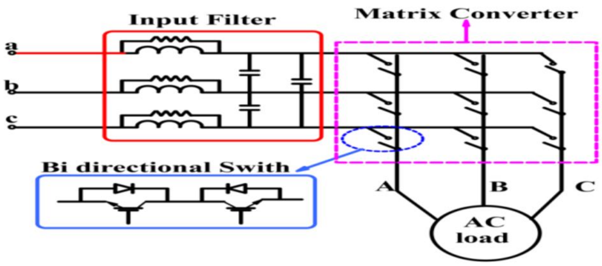

Fig.3 Basic power circuit of MC

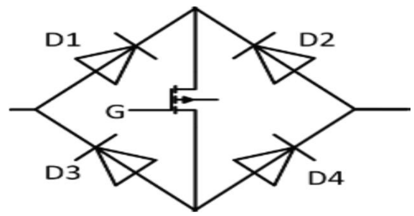

Fig. 4 Diode bridge arrangement BS

The following are the some of advantages of the matrix converters

1) No dc link capacitor or inductor
2) Sinusoidal input and output currents
3) Possible power factor control
4) Four-quadrant operation
5) Compact and simple design
6) Regeneration capability

V. DESIGNING OF SIMULINK MODELS AND RESULTS

This part is carrying the whole design of Space vector modulation and Matrix converter models and analysis their outputs. To control the input current and yield voltage PWM space vector is applied. The PWM space vector technique aim is to inexact the reference voltage vector Vref utilizing the six exchanging designs. The switches present in a phase cannot be ON at a time. Otherwise short circuit will occur in the same input side. One switch is always on at different phase with V_{ref}.

In figure 3 3φ supply is provided where the frequency is used 50Hz. This SVM technique modulates the fundamental frequency. In this procedure to trigger it needs high switching frequency. The proposed control rule is tried with a perfect nine-change three stages to three stage matrix converters sustaining a R-L load. For this reason, digital simulations were done utilizing Matlab/Simulink programming. The parameters of simulation are set as; supply frequency = 50Hz, the supply voltage = 480 V, the supply current = 27 A, switching frequency =2 kHz, resistor =20 O, inductance =310 mH.

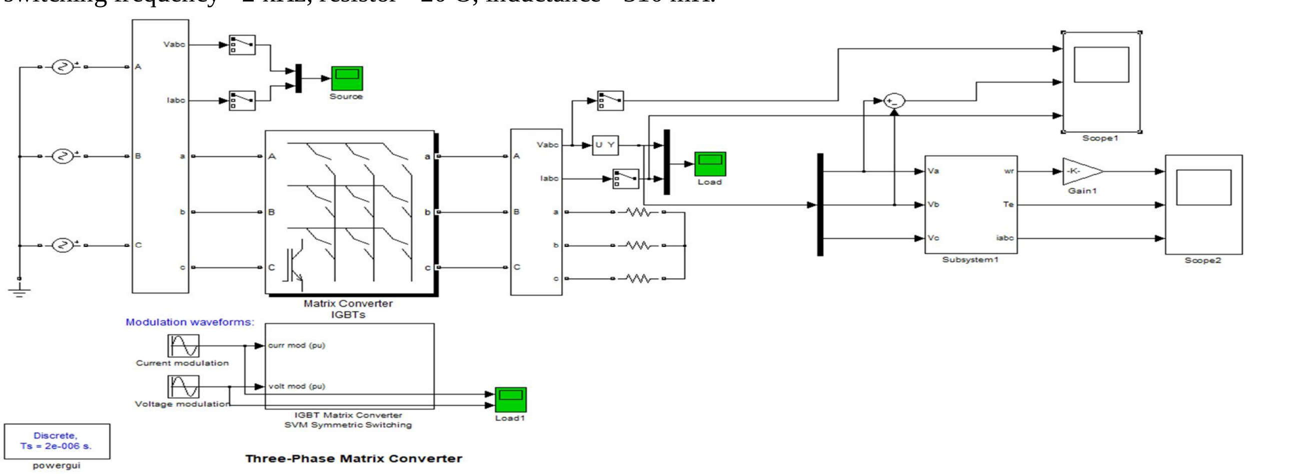

Fig. 5 Simulink model of Matrix Converter Employing SVPWM Technique

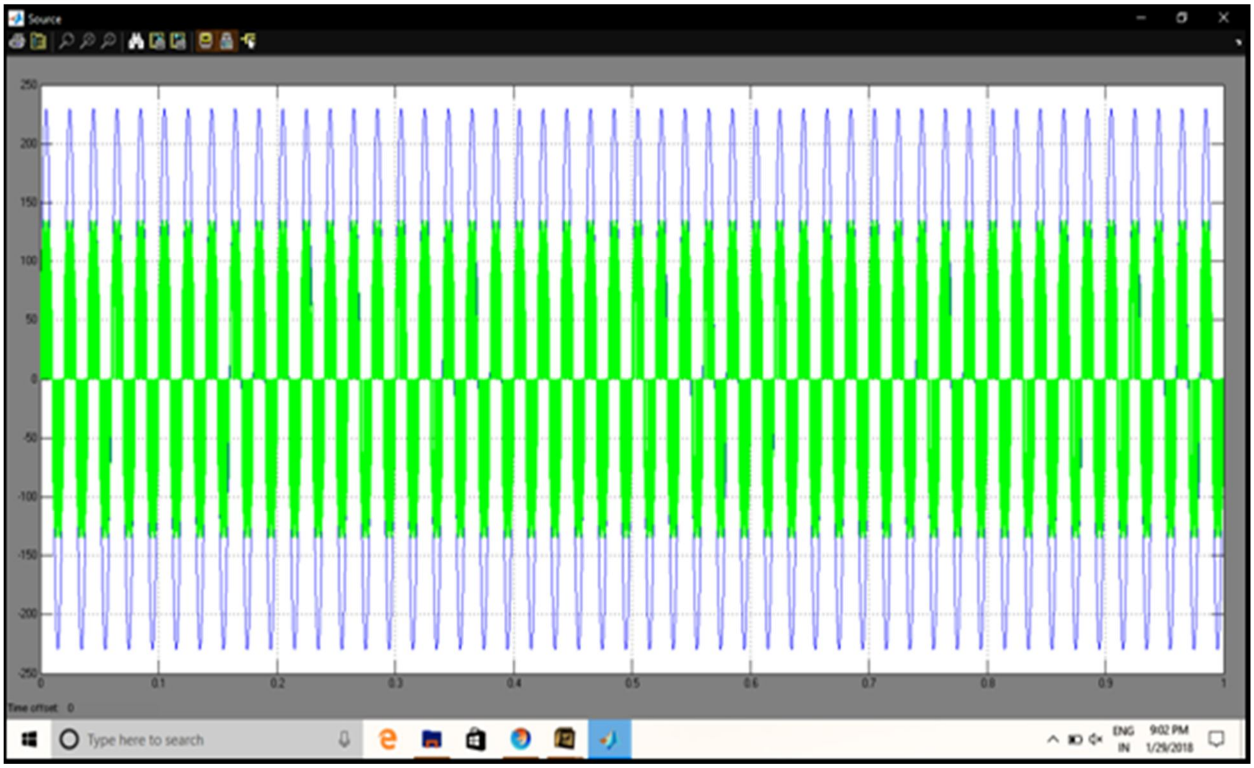

Fig. 6 Input Voltage and Current Waveforms in Steady State Condition for SVPWM

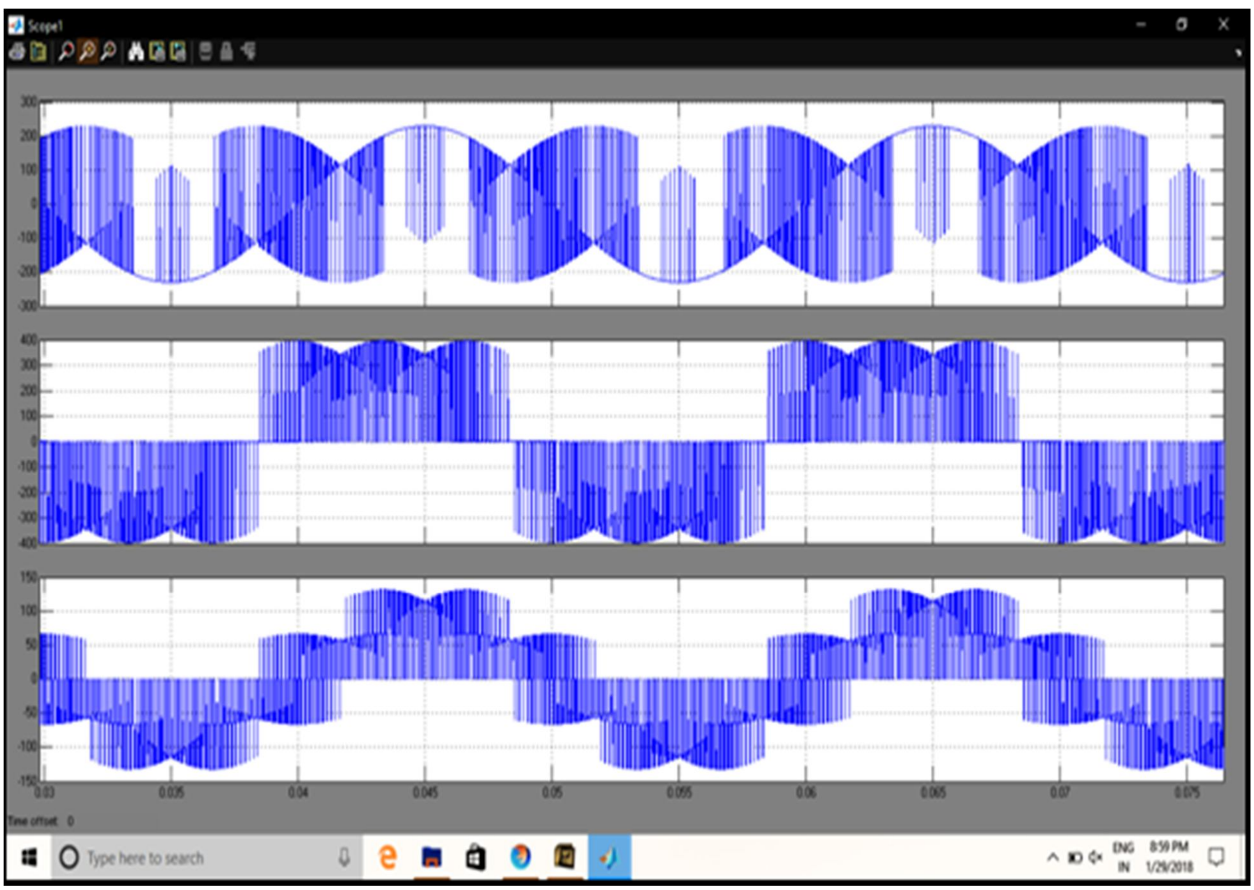

Fig. 7 Load voltage waveforms of Matrix Converter Employing SVPWM Technique

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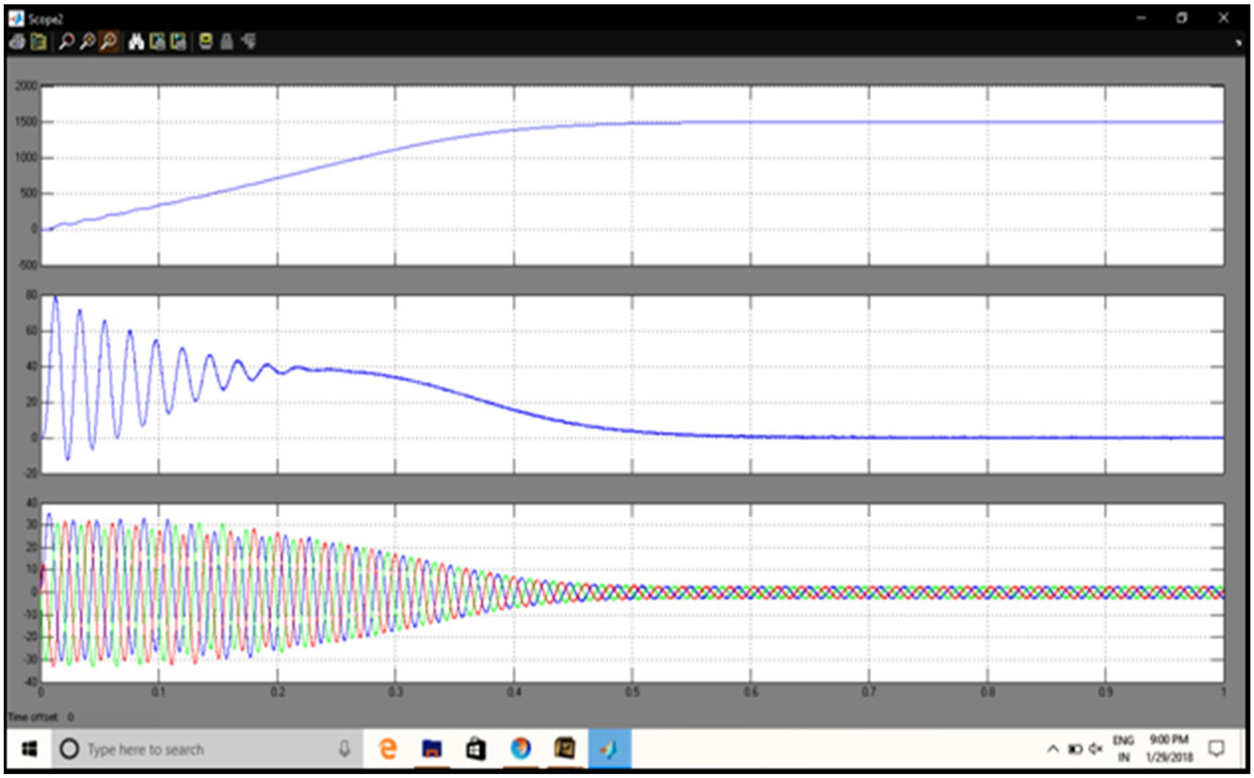

Fig. 8 Speed, Torque, Current waveforms of Matrix Converter Employing SVPWM Technique

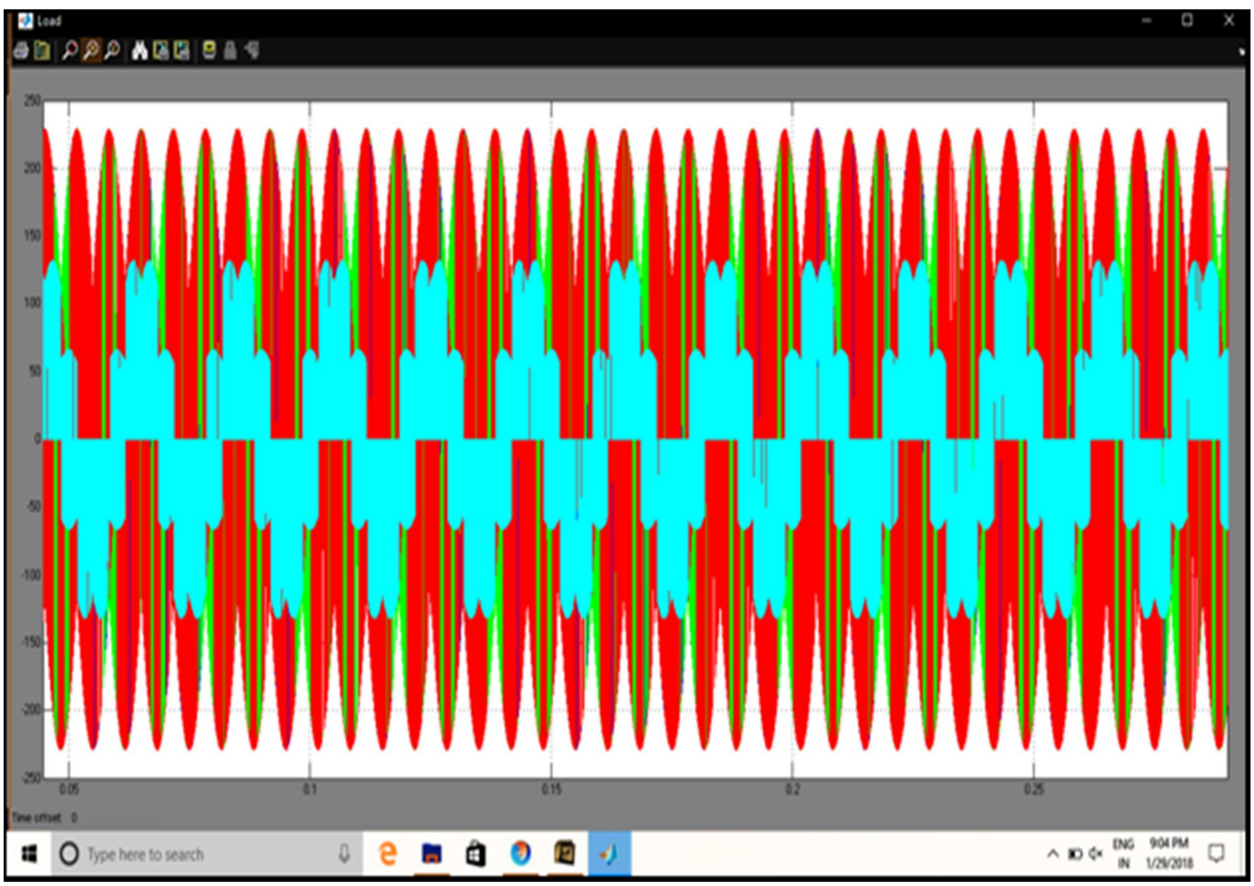

Fig 9: Output Voltage and Current Waveforms in Steady State Condition for SVPWM

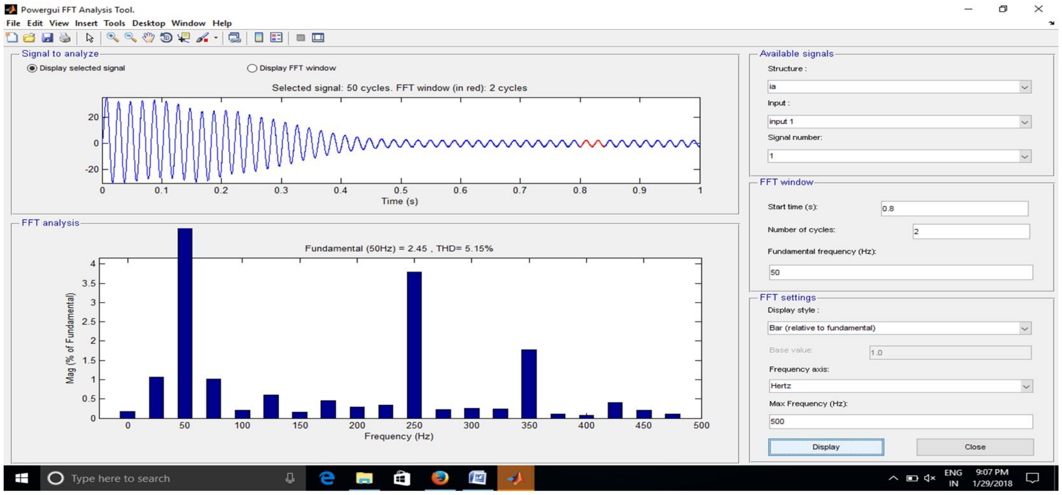

Fig 10: Harmonic Profile of Output Voltage Employing SVPWM Technique

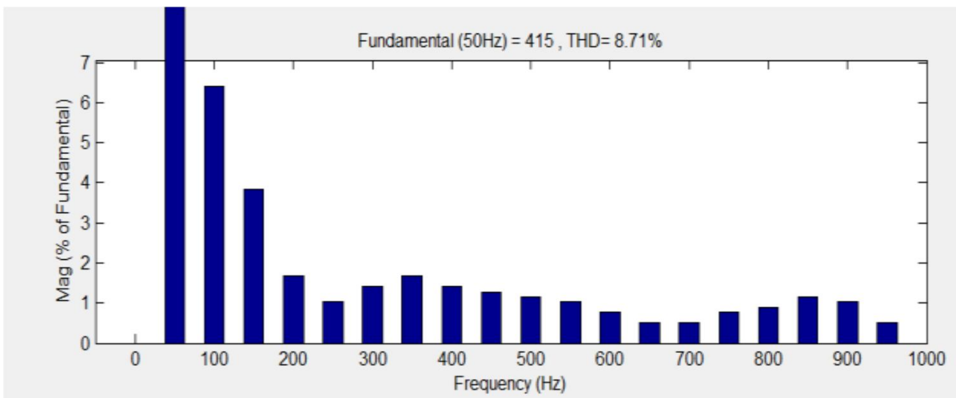

Fig.11: Harmonic Profile of Output Voltage Employing PWM Technique

VI. CONCLUSION

Matrix converter switching sequence is selected based on Space Vector Pulse Width Modulation (SVPWM) technique. Matrix converter operation is successful which can be used to reduce the constraints and identified the input/output characteristics. This AC/AC transformation network is proposed as a compelling substitution for the traditional AC-DC-AC framework which utilizes two-advance power change. Contrasted with PWM, the SVPWM strategy has better voltage change capacity. SVPWM additionally has the base THD level at the yield side and thus the losses are decreased on the drives. Performance comparison of these techniques is shown in Table 1.

Table 1: Performance Comparison of PWM, SVPWM Techniques

S.No	Parameter	PWM	SVPWM
1	THD	8.71%	5.15%

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