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Modeling and Simulation of Matrix Converter Using Space Vector PWM Technique

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Abstract: ***Matrix Converters can directly convert an ac power supply of fixed voltage into an ac voltage of variable amplitude and frequency. Matrix Converter is a single stage converter. The matrix converters has following advantages over conventional converters with low volume, sinusoidal input current, bidirectional power flow, minimizing of lower order harmonics and lack of bulky reactive elements. All the reasons lead to the development of matrix converter. Based on the control techniques used in the matrix converter, the performance varies. So this paper analyses the performance of matrix converter with two different modulation techniques such as PWM and SVPWM. 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 analyzed by using Matlab/Simulink software. The simulated results are analyzed and show that the THD is better for SVPWM technique.***

Keywords: Matrix Converter, Pulse Width Modulation (PWM), Space Vector Pulse Width Modulation (SVPWM), Total Harmonic Distortion (THD)

1. Introduction

The need to increase the quality and the efficiency of the power supply and the power usage, the three phase matrix converters becomes a modern energy converter and has emerged from the early conventional energy conversion modules. The matrix converter is an alternative to a inverter drive for a frequency control. The matrix converter is also known as an „all-silicon solution‟. The matrix converter is a single stage converter which does not require any capacitor as the dc-link energy storage component.

There are many electrical loads like linear loads, non-linear loads, lightning loads etc. But in this thesis linear passive resistance and inductance (RL) loads are considered to evaluate the performance of matrix converter. In order to get the desired response the output currents are compared with the reference current, which gives an error value from the difference of two currents. In this paper matrix converter [1] is made to operate in the following modulation techniques namely PWM and SVM. Compared to PWM technique SVM is more suitable for digital implementation.

2. Matrix Converter

A matrix converter is a variable amplitude and frequency power supply that converts the three phase line voltage directly into three phase output voltage. It is very simple in structure and has powerful controllability.

Fig 1 shows the three phases to three phase configuration of the matrix converter. The matrix converter consists of nine bidirectional switches which are arranged into 3 groups of three switches.

Each group is connected to each output phase. It shows that converter switches are switched on rotational basis. In this case no two switches in a leg switched on simultaneously.

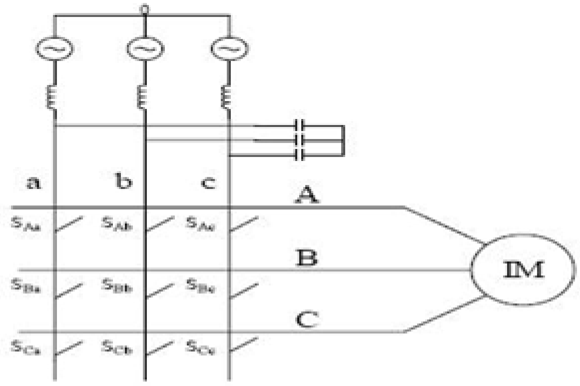

Figure 1: Topology of Three Phase Matrix Converter with Bridge Configuration

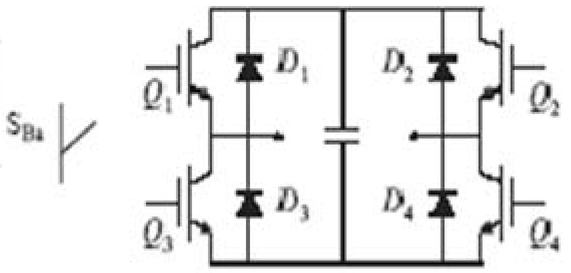

Figure 2: H-bridge Switch Cell with Capacitor

Fig 2 shows modular H-bridge capacitor-clamped switch cell. It can buck or boost the voltage and inductive filters are employed at the input terminal. The terminal ac voltages of the converter are synthesized from the modulation techniques such as PWM, SPWM and SVM. The switching pulses for the power devices in each H-bridge are obtained from any of the modulation techniques.

3. Pulse Width Modulation Technique

Because of advances in solid state power devices PWM based converters are becoming most widely used in drives. PWM[3] 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, 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 .

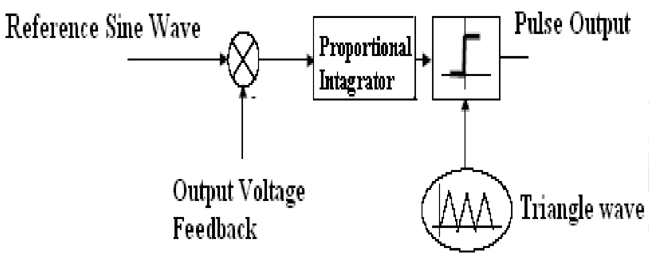

Figure 3: PWM Pulse Generation Circuit

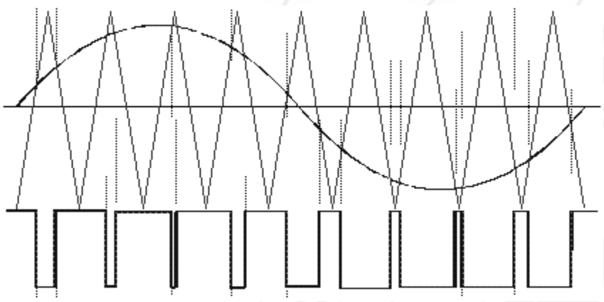

Figure 4: PWM Triggered Pulse Pattern for Power Devices

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 as shown in figure 3. 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 as show in figure 4. 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.

4. Space Vector Pulse Width 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 ($V_1$to V_6) is 2/3 V_{dc} (dc bus voltage).

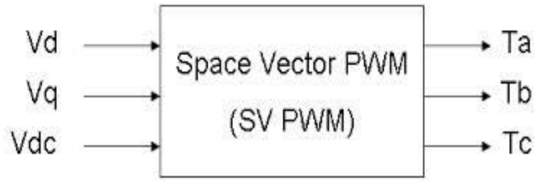

Figure 5: SVPWM Pulse Generation

SVPWM [5] 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

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 6

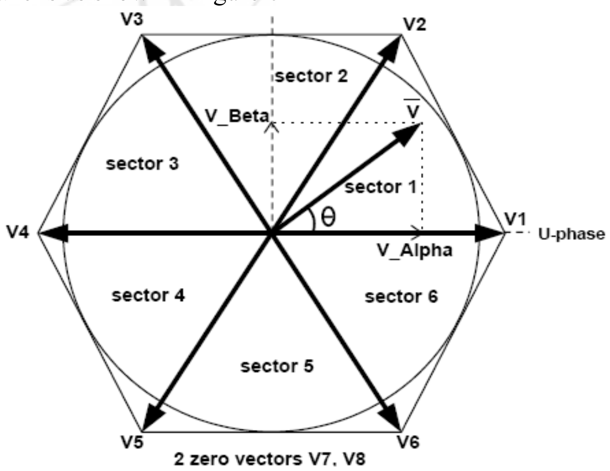

Figure 6: Representation of Rotating Vector in Complex Plane

5. 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.

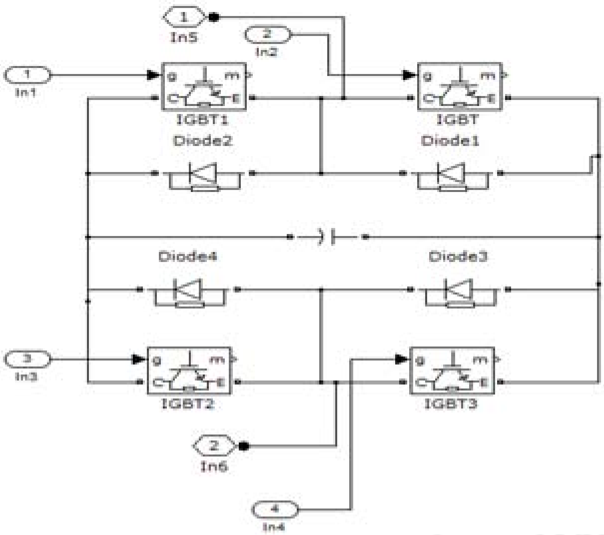

Figure 7: Simulink diagram of H-Bridge Switch Cell with Capacitor

Figure 8 -9 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.

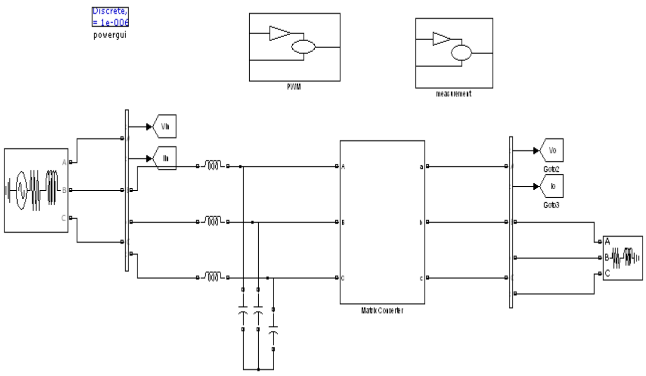

Figure 8: Simulink model of Matrix Converter Employing PWM Technique

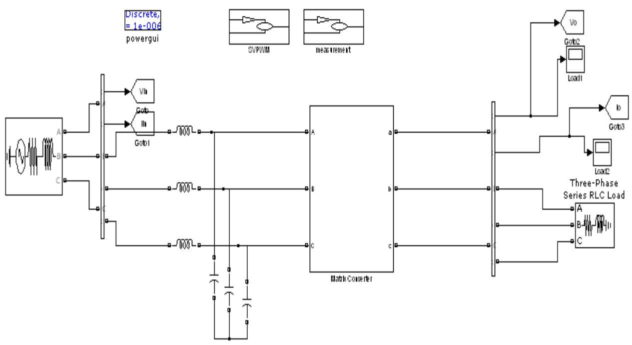

Figure 9: Simulink model of Matrix Converter Employing SVPWM Technique

6. 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.

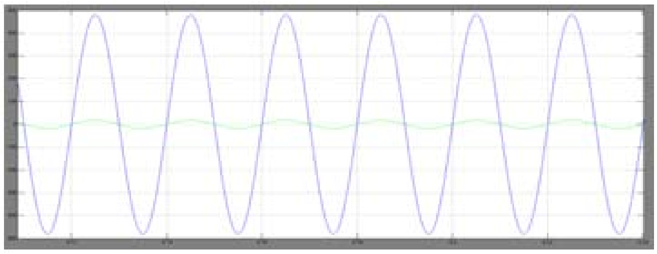

Figure 10: Input Voltage and Current Waveforms in Steady State Condition for PWM.

Figure 10 shows the input voltage and current waveform given to the matrix converter. The input voltage and current is same for both the modulation techniques.

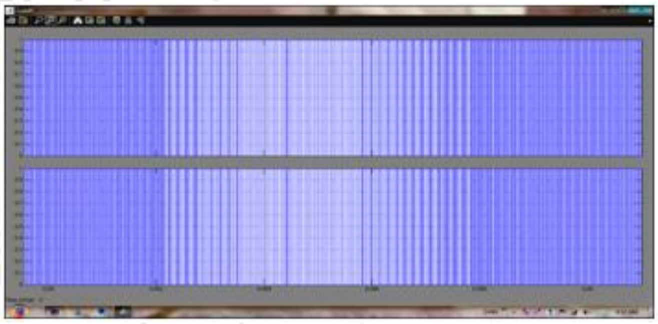

Figure 11: PWM Pulses for Upper and Lower Switches of Phase A

Figure 11 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

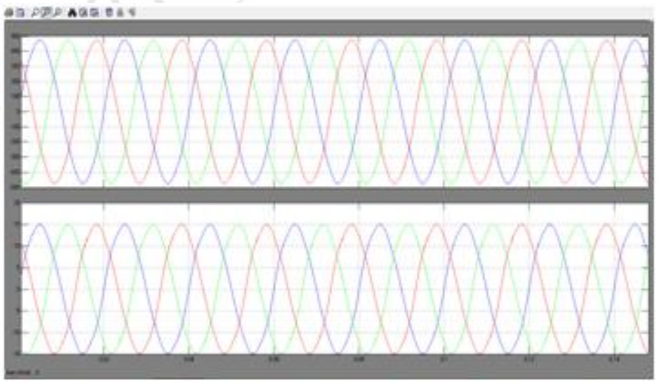

Figure 12: Output Voltage and Current Waveform of Matrix Converter using PWM Technique

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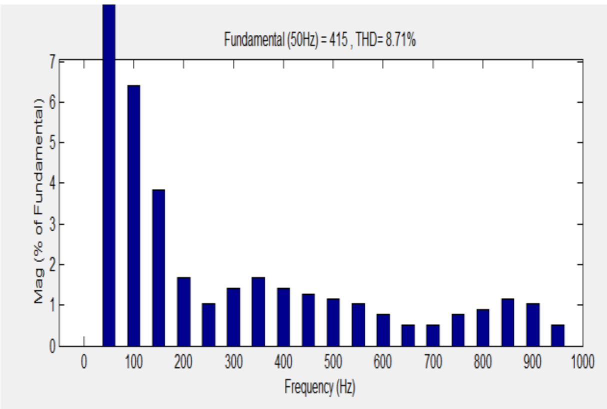

Figure 13: Harmonic Profile of Output Voltage Employing PWM Technique.

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

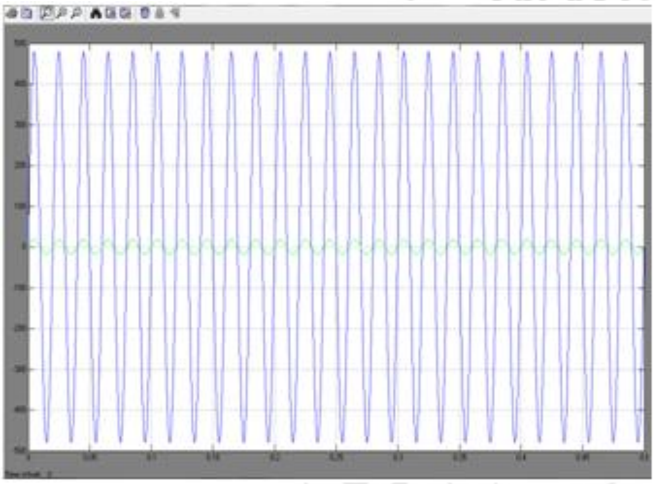

Figure 14: Input Voltage and Current Waveforms in Steady State Condition for SVPWM

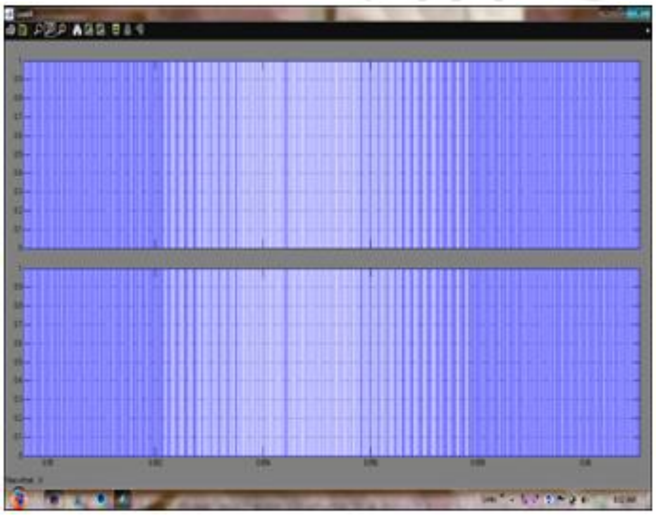

Figure 15: SVPWM Pulses for Upper and Lower Switches of Phase A

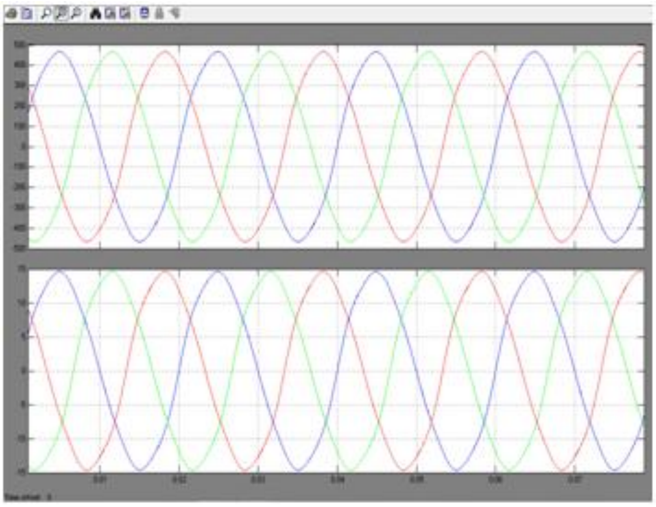

Figure 16: Output Voltage and Current Waveform of Matrix Converter using SVPWM Technique

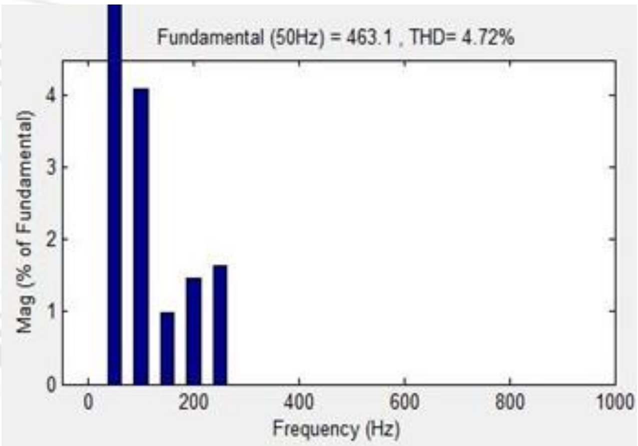

Figure 17: Harmonic Profile of Output Voltage Employing SVPWM Technique.

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 Techniques

S.No	Parameter	PWM	SVPWM
1	THD	8.73	4.72

7. Conclusion

The proposed Matrix Converter with different modulation techniques was simulated using Matlab/ Simulink model blocks. PWM, SVPWM 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 PWM, the SVPWM technique has better voltage transformation capability. The major disadvantage of the matrix converter can be overcome by eliminating third harmonics by injecting third harmonic voltage

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Author Profile

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