Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 16 Issue 5 Version 1.0 Year 2016
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

# AC Voltage Analysis using Matrix Converter

By Anubhab Sarker
*American International University*

*Abstract-* The purpose of this thesis is to design a three phase converter, whose switching pattern is arranged in a Matrix form and the converter is commonly known as three phase Matrix converter. This AC-AC system is proposed as an effective replacement for the conventional AC-DC-AC system which employs a two-step power conversion. The thesis analyzes the performance of matrix converter with two modulation techniques such as SVPWM and SVM. The basic principle and switching sequence of these modulation techniques have been presented. The output voltage, output current waveforms, voltage transfer ratio and THD spectrum of switching waveforms connected to different type of loads are analyzed by using Matlab/Simulink software.

*GJRE-F Classification : FOR Code: 290901p*

# AC Voltage Analysis using Matrix Converter

Anubhab Sarker

*Abstract-* The purpose of this thesis is to design a three phase converter, whose switching pattern is arranged in a Matrix form and the converter is commonly known as three phase Matrix converter. This AC-AC system is proposed as an effective replacement for the conventional AC-DC-AC system which employs a two-step power conversion. The thesis analyzes the performance of matrix converter with two modulation techniques such as SVPWM and SVM. The basic principle and switching sequence of these modulation techniques have been presented. The output voltage, output current waveforms, voltage transfer ratio and THD spectrum of switching waveforms connected to different type of loads are analyzed by using Matlab/Simulink software.

## I. Introduction

Matrix converters are capable of AC/AC direct power conversion. It does not have any dc-link circuit and does not need any large energy storage elements. The key element of a Matrix Converter is the fully controlled four quadrant bidirectional switch, which allows high frequency operation. The matrix converter consists of 9 bi-directional switches that allow any output phase to be connected to any input phase. space-vector modulation technique is used in Matrix converter modulation technique. The SVM technique was adapted for the matrix converter by employing a basic concept of indirect modulation using a fictitious DC bus, then dividing the converter into a rectification stage and an inversion stage. Furthermore, this modulation technique allows simplifying a converter model, making it easier to control the converter under imbalanced and distorted power supply conditions. BY using this technique Matrix converter generate variable frequency.

## II. Literature Review

This part of the thesis consists of the details of modulation technique and the switching topology of matrix converter. The working principal of most of the technique will also be explained. The main technique 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 used for the creation of ac wave forms. It is a general technique for any three-phase load, although it has been developed for motor control. Space vector pulse width modulation is applied to output voltage and input current control. This method is an advantage because of increased flexibility in the choice of switching vector for both input current and output voltage control. It can yield useful advantage under unbalanced conditions. The three phase variables are expressed in space vectors. For a sufficiently small time interval, the reference voltage vector can be approximated by a set of stationary vectors generated by a matrix converter. The modulation process thus required consists of two main parts: selection of the switching vectors and computation of the vector time intervals. SVPWM refers to a special switching sequence of the upper three power transistors of a three-phase power inverter. It has been shown to generate less harmonic distortion in the output voltages and or currents applied to the phases of an AC motor and to provide more efficient use of supply voltage. There are two possible 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. By applying Equations 1 and .2 to determine the output voltage and input current vectors respectively, the magnitude and phase of these vectors for all possible combinations are needed. To find current and voltage modulation index power balance condition can be used. With balanced output load current condition such as,

$$\overline{V_{(it)}} = (qVim\sqrt{3}) \cos(\omega ot) \quad (1)$$

$$\overline{V_{(0t)}} = \frac{2}{3}(v1o + av2o +) a^2 v3o \quad (2)$$

Where, $a = e^{j\frac{2\pi}{3}}$

The vector $\overline{V_{(0t)}}$ has a constant length of qVin√3 and it is rotating at frequency ωo. The basis of the space vector modulation technique is that the possible output voltages for the converter can be expressed in the same form as Equation 2. At each sampling instant, the position of $\overline{V_{(0t)}}$ is compared with the possible vectors and the desired output voltage is synthesized by time averaging (within the switching interval) between

*Author:* Faculty of Engineering, American International University–Bangladesh (AIUB). e-mail: anubhabsarkar578@gmail.com

adjacent vectors to give the correct mean voltage. For a conventional DC link inverter this process is very simple because there are only eight possible switching. The situation with a Matrix Converter is more complex as there are twenty seven possible switching states and the input voltages are time varying.

*Matrix Converter Switching States:* In matrix converter 27 switching combination is taken place. 18 combinations where the output voltage and the input current vectors have fixed directions with magnitudes that vary with the input voltage phase angle and the output current phase angle respectively.3 combinations giving null output voltage and input current vectors. All three output phases are connected to the same input phase in these combinations. Space vectors of output take one of 6 fixed positions (varying amplitude), Space vectors of input current take one of 6 fixed positions (varying amplitude). All space vectors are at the origin (zero length). 6 combinations in which each output phase is connected to a different input phase. Both magnitude and phase of the resultant vectors are variable in these cases. By this way total 27 switching combination is taken place in Matrix converter.

*Topologies of Bi-directional Switch:* Bi-directional switches capable of blocking voltage and conducting current in both directions are required by the Matrix Converter. Common Emitter Bi-directional Switch is used in this thesis which consists of two diodes and two IGBTs those are connected in anti-parallel. The diodes are included to provide the reverse blocking capability. The reverse blocking capability is a weak of the early IGBT technology . The advantage is that it is possible to independency control the direction of the current.

## III. Designing of Simulink Models and Outputs

This part is carrying the whole design of Space vector modulation and Matrix converter models and analysis their outputs.

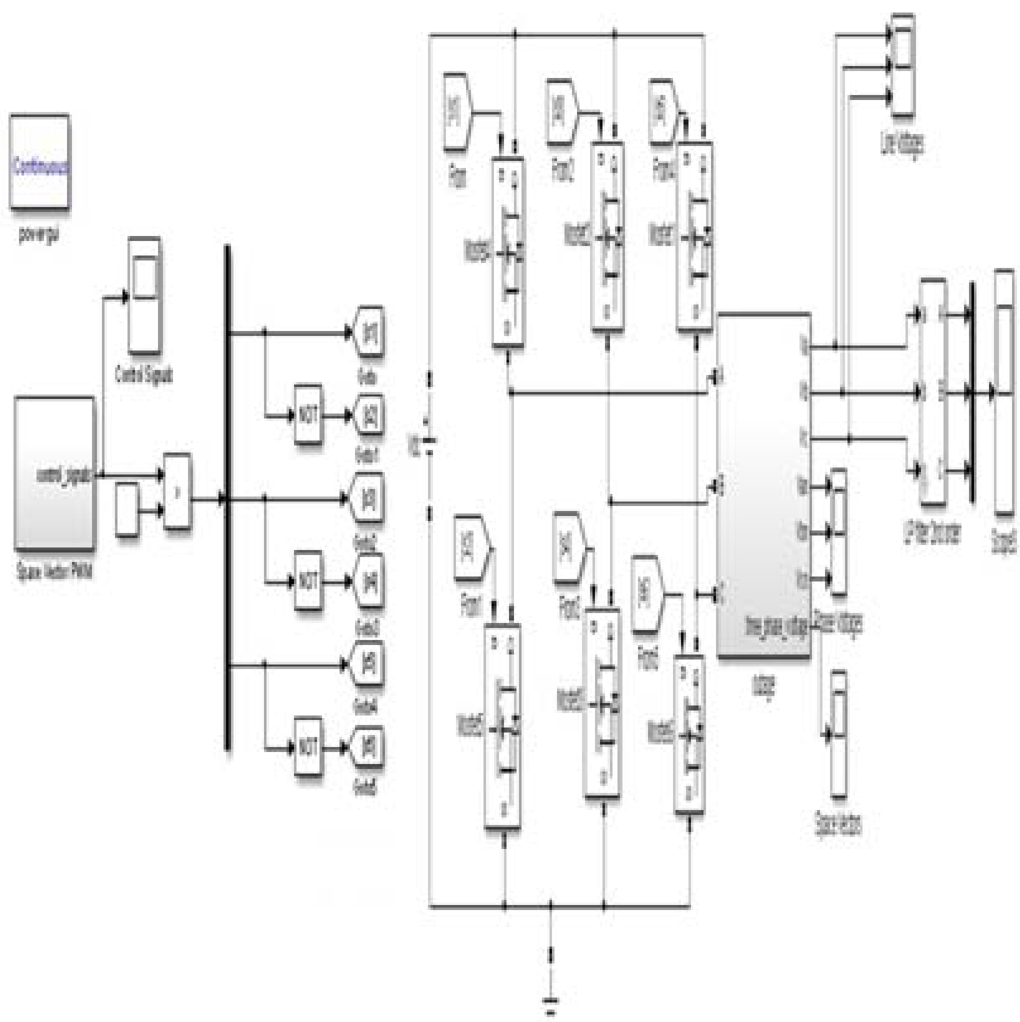

*Figure 1 :* Space vector modulation process

Global Journal of Researches in Engineering ( F ) Volume XVI Issue V Version I Year 2016

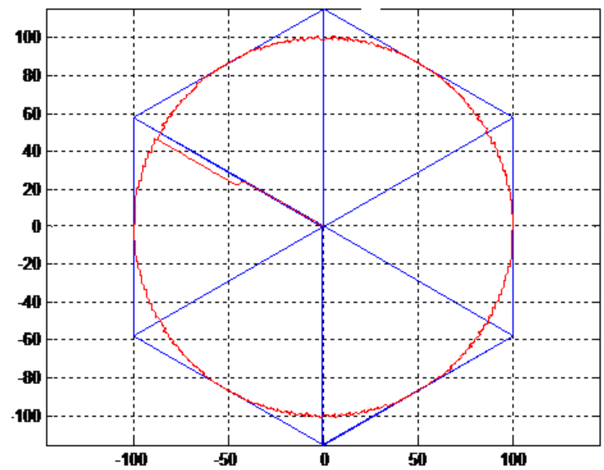


*Figure 2 :* space vector trajectory

Space vector pulse width modulation is applied to output voltage and input current control In figure 2 six sectors are shown for six switches. The objective of space vector PWM technique is to approximate the reference voltage vector Vref using the six switching patterns. Two switches from the same phase should not be on at the same time, otherwise short circuit will occur in the same input side. One switch is always on at different phase with Vref. So a continuous flow of bus voltage is shown in circle(red marked).

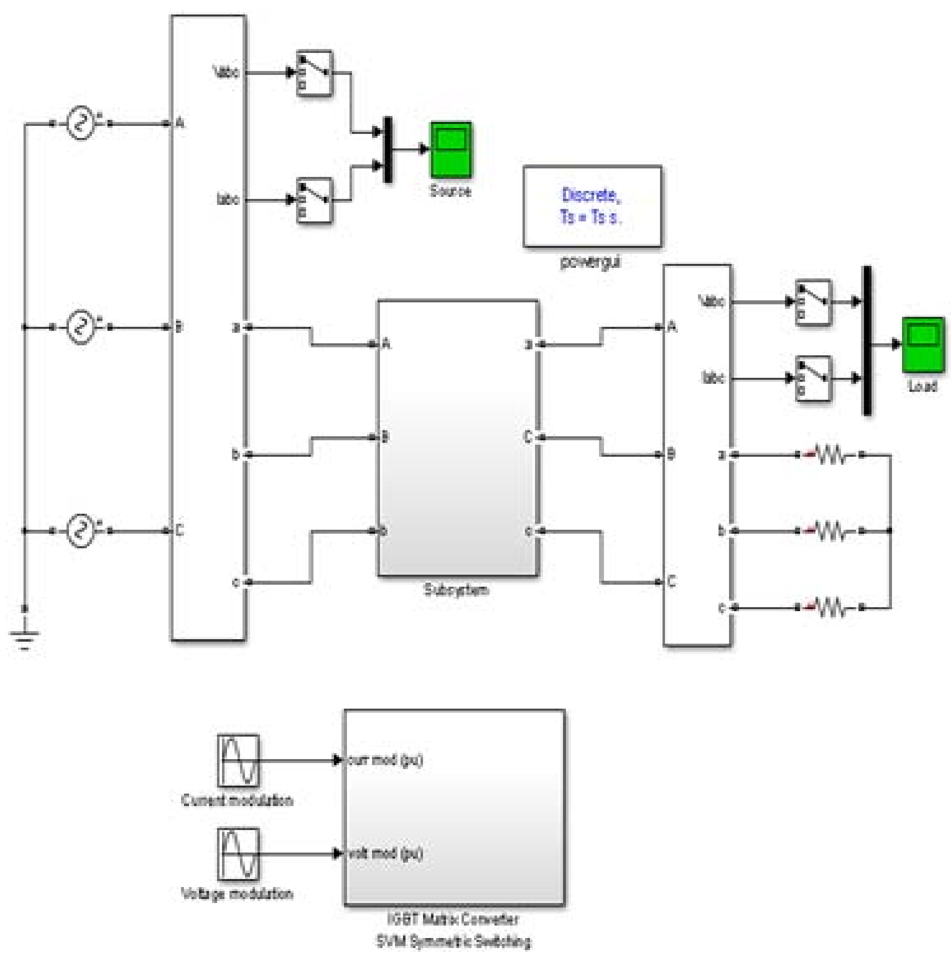


*Figure 3 :* General model of Matrix converter

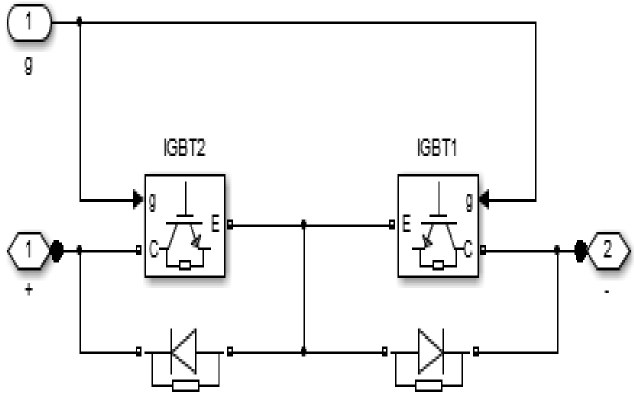


*Figure 4 :* Bidirectional switch

In figure 3 3ϕ supply is provided where the frequency is used 60Hz. This fundamental frequency is modulated by SVM technique. In this technique high switching frequency is needed for triggering. In figure 4 common ammeter bidirectional switch is used where the modulated signal is used as input signal. After finishing all the switching combination inside the SVM symmetric switching part the desired frequency will be gotten.

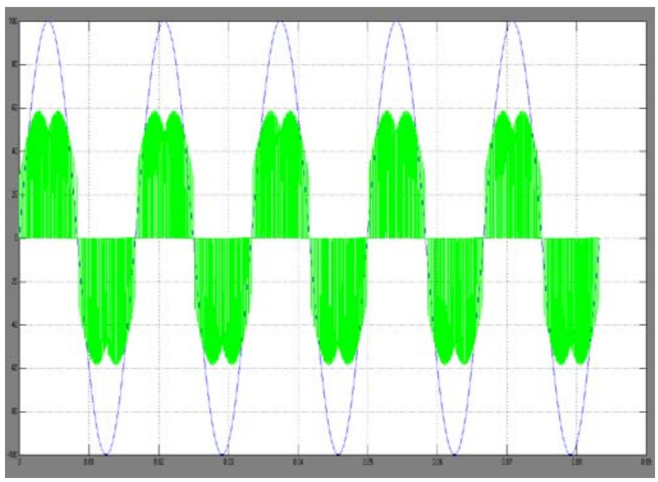

*Figure 5 :* Input wave shape of Matrix converter

Where, input voltage=100V(P-P)
Time period T=0.0168sec (approx)
And frequency f=1/T=59.82Hz

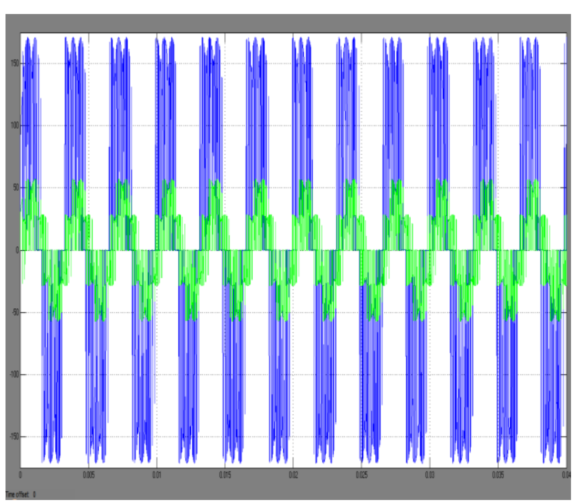

*Figure 6 :* Wave shape across the load

From the Output wave shape of the matrix converter, desired frequency is gotten. The input frequency is approximately 60hz but the output frequency is almost 333Hz. that's why it is called the unlimited frequency changer. And voltage also increased 160v (p-p).

Here, $T_{1/2} = 0.002$

So Frequency, F = 333.33 Hz

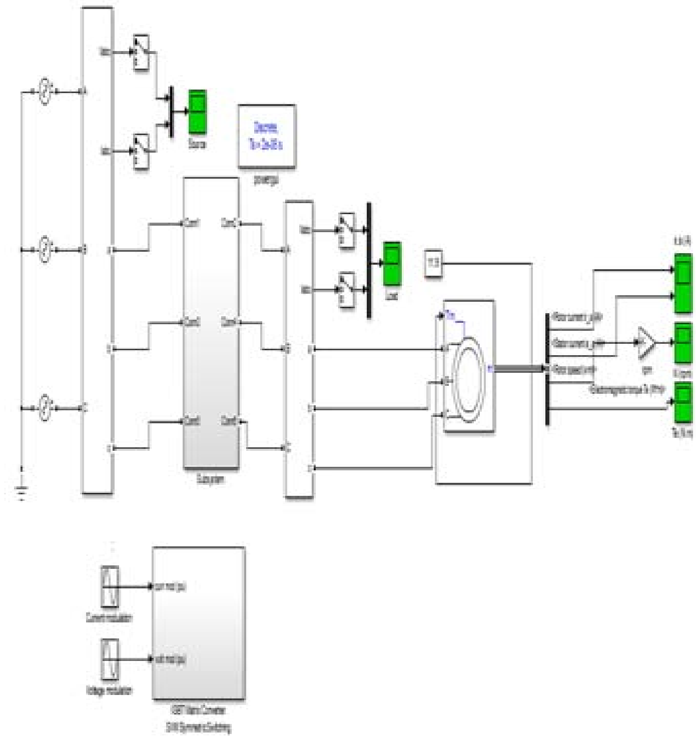

*Figure 7 :* Using induction machines as a load

A 220v, 60Hz asynchronous machine is used here as a load of Matrix converter in figure 7. The basic concept of an induction motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. Connecting this machine across the Matrix converter in figure 7 the stator current, rotor current, torque and the speed will be checked.

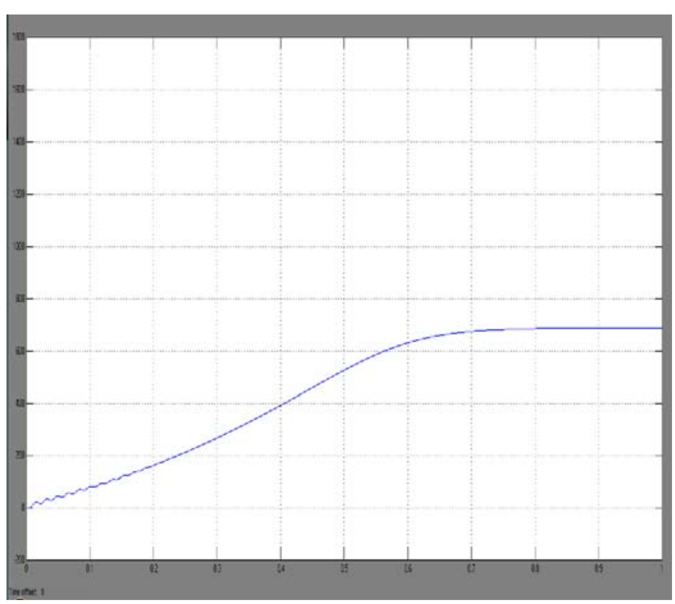

*Figure 8 :* induction motor speed

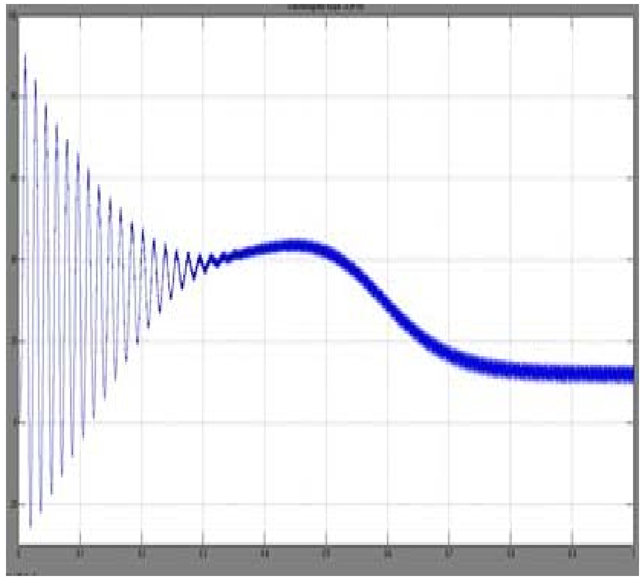

*Figure 9 :* Graphical representation for torque

In figure 9 it is shown that the motor speed is going 0 to 700rpm. in figure 10 electromagnetic troque is represented in a graph. A noisy level is observed because the stator fed by PWM.

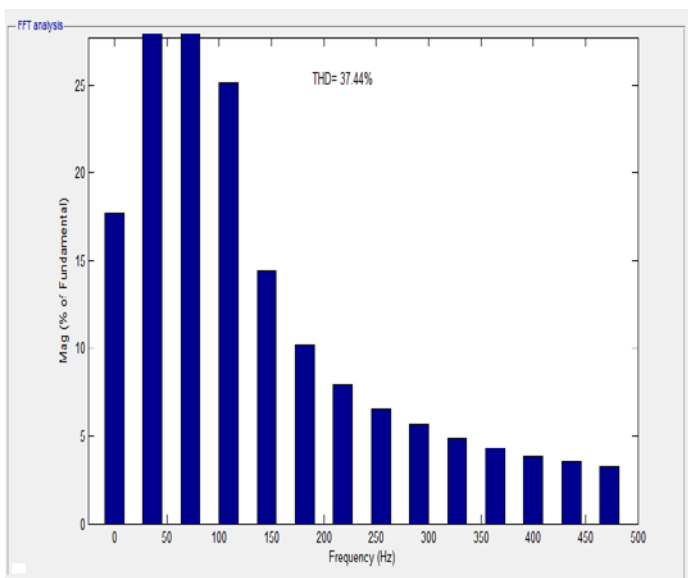


*Figure 10 :* THD analysis using FFT

When pulse signal is converted into ac signal some harmonic distortion is created that should not be cancelled. The lower the percentage, the higher the speed performance. It is related to frequency.

Calculation:

For a 4 pole induction machine:

Synchronous speed Ns = (120*f)/P

= (120*60)/4

Thus $N_s$ = 1800 rpm

Since slip for a normal induction motor ranges between 0 and 1, $S_{Tmax}$=0.5

$N_{Tmax}$ = (1-s)$N_s$

= (1-0.5)1800

$N_{Tmax}$ = *900 rpm*

*But due to some extra harmonics, we are getting 700 rpm.*

## IV. Conclusion

The conversion from ac to ac is quite difficult. but matrix converter makes it simple and easy. It has appeared as an alternative solution for adjustable speed AC drive applications. This thesis presented easier methods for implementing complex switching strategies, studying and mitigating the effects of unbalance, and topological changes to increase the performance indices. The thesis also suggests modulation techniques to eliminate the common mode voltage and a new direct torque control procedure for controlling an induction motor fed by the modified matrix converter topology. The work also introduces a simple carrier based modulation technique, termed as the SVM technique, as an alternative way of implementing the space PWM technique for the matrix converter. Based on the analysis carried out on the original SV PWM technique, the thesis proposes a modified control algorithm. This modified algorithm reduces the input current harmonic distortion without affecting the output side performance.

## References Références Referencias


1. Yugo Tadano, Shota Urushibata, Masakatsu Nomura, Yukihiko Sato, and Muneaki Ishida, "Direct Space Vector PWM Strategies for Three-Phase to Three-Phase Matrix Converter ", Research & Development Center, MEIDENSHA CORPORATION, 1-17, Osaka 2-Chome, Shinagawa-Ku, Tokyo 141-8565, Japan., July 19, 2010.
2. Zhanjun Qiao and Wei Xu, "Research on Matrix Converter Based on Space Vector Modulation", Department of Mechanical and Electronic Engineering, North China Institute of Science and Technology, Beijing 101601, China. Research Journal of Applied Sciences, Engineering and Technology 6(16): 2899-2906, 2013
3. D. Kuzmanovic and J. Lettl, " Optimization of Indirect Space Vector Modulation Strategy for Matrix Converter", Faculty of Electrical Engineering, Czech Technical University in Prague, Czech Republic, PIERS Proceedings, Kuala Lumpur, MALAYSIA, March 27, 2012.
4. Wheeler, P. W., J. Rodriguez, J. C. Clare, and L. Empringham, \Matrix converter: A tech- nology review," IEEE Transactions on Industrial Electronics, Vol. 49, No. 2, 276-288, 2002.
5. Casadei, D., G. Sera, A. Tani, and L. Zarri, "Matrix converter modulation strategies: A new general approach based on space-vector representation of the switch state," IEEE Transactions on Industrial Electronics, Vol. 49, No. 2, 370-381, 2002.

This page is intentionally left blank