Global Scientific JOURNALS

GSJ: Volume 9, Issue 7, July 2021, Online: ISSN 2320-9186
www.globalscientificjournal.com

MATRIX CONVERTER: A REVIEW FOR INDUCTION MOTOR

Madhulika Yadav, Electrical Engineering Department, NIT Hamirpur

Dr. R.K. Jarial Associate Prof. Electrical Engineering Department, NIT Hamirpur

Abstract-In this paper a brief review of matrix converter is presented. The absence of the dc link in MC (Matrix converter) has led to extensive use for Artificial Loading in Induction motors. Earlier for the indirect power conversion system, first it ac-dc conversion was done then dc-ac but MC is an alternative to this due its advantages like in sinusoidal input output current ,unity distortion factor for any load and its four quadrant operation. Matrix converter is an energy conversion device which directly connects a three-phase voltage source to a three-phase load without dc-link components. Therefore, the output of the matrix converter is directly affected by the disturbance or imbalance in the input voltages. Its use for the induction motor control is also presented in this paper.

INTRODUCTION

The matrix converter is the most general converter-type in the family of ac to ac direct converters. On the one hand, the matrix converter fulfills the requirements to provide a sinusoidal voltage at the load side and, on the other hand, it is possible to adjust the unity power factor on the mains side under certain conditions. The matrix converter is an array of bidirectional switches. It interconnects directly the three-phase power supply to a three phase load, without using any DC link or large energy storage elements, and therefore it is called the all-silicon solution. The important characteristics like sinusoidal input and output current, simple and compact power circuit, regeneration capability, operation at unity power factor makes its suitable for the induction motor applications [3]. Matrix converter is a direct AC to AC converter, for converting one frequency AC supply to another frequency AC supply without involving DC link capacitor. Generation of controlled switching pulses has attracted much attention of Scientist and engineers. Two modulation schemes, the Venturini modulation or direct method and the space vector modulation or indirect method are well known. Both the scheme has different design approaches and has different performances [6]. On the other hand, since matrix converter uses many switches therefore due to these harmonics are also introduced. Preventing harmonic pollution and improving the quality of power supply have become the hotspot of research in the electrical engineering [7].

MATRIX CONVERTER TOPOLOGY

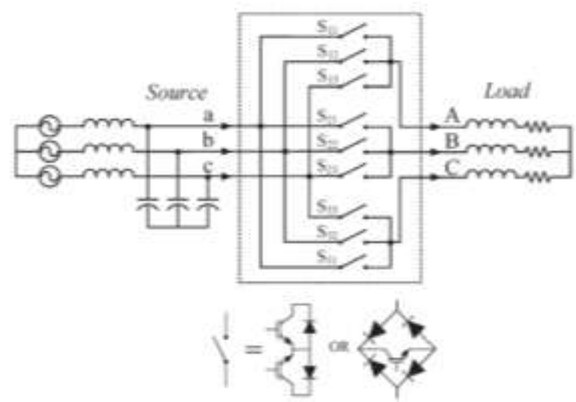

Fig. 1: Three-phase matrix converter

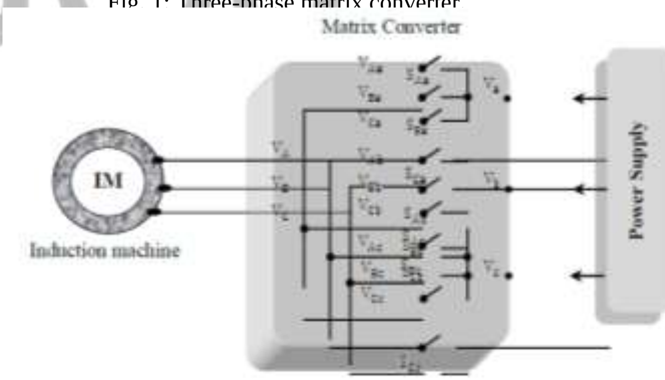

Fig2. .Schematic block diagram of matrix converter induction motor drive

The basic topology of three phase matrix converter is shown in the fig 1. A single stage matrix converter is used to convert nine AC phase input voltage into three AC phase output, with a control of magnitude and frequency current output. So, matrix converter can generate unlimited output frequency compared to those of input. The switching functions for fig 2 are defined as follows [2]:

$$S_{ij} = \begin{cases} 0 & \text{open} \\ 1 & \text{closed} \end{cases}$$

Where, i= {a ,b ,c} j={A, B, C}

By using the following equations the output voltages in terms of input voltages and input currents in terms of output current can be obtained;

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} S_{Aa} & S_{Ba} & S_{Ca} \\ S_{Ab} & S_{Bb} & S_{Cb} \\ S_{Ac} & S_{Bc} & S_{Cc} \end{bmatrix} \begin{bmatrix} V_A \\ V_B \\ V_C \end{bmatrix} \quad \ldots\ldots\ldots\ldots 1$$

$$\begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix} = \begin{bmatrix} S_{Aa} & S_{Ab} & S_{Ac} \\ S_{Ba} & S_{Bb} & S_{Bc} \\ S_{Ca} & S_{Cb} & S_{Cc} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad \ldots\ldots\ldots\ldots 2$$

Consequently, from the equations (1) and (2), the output line currents and input line voltages are presented by equations (3) and (4) as follows:

$$\begin{bmatrix} i_{AB} \\ i_{BC} \\ i_{CA} \end{bmatrix} = \begin{bmatrix} S_{Ab} & S_{Ac} & S_{Aa} \\ S_{Bb} & S_{Bc} & S_{Ba} \\ S_{Cb} & S_{Cc} & S_{Ca} \end{bmatrix} \begin{bmatrix} i_{ab} \\ i_{bc} \\ i_{ca} \end{bmatrix} \quad \ldots\ldots\ldots\ldots 3$$

$$\begin{bmatrix} V_{ab} \\ V_{bc} \\ V_{ca} \end{bmatrix} = \begin{bmatrix} S_{Ab} & S_{Bb} & S_{Cb} \\ S_{Ac} & S_{Bc} & S_{Cc} \\ S_{Aa} & S_{Ba} & S_{Ca} \end{bmatrix} \begin{bmatrix} V_{AB} \\ V_{BC} \\ V_{CA} \end{bmatrix} \quad \ldots\ldots\ldots\ldots 4$$

The modulation function for output line is given as:

$$S_{Aa} = \frac{1}{3}(S_{Ac} - S_{Aa}) - \frac{1}{3}(S_{Bc} - S_{Ba}) \quad S_{Ab} = \frac{1}{3}(S_{Aa} - S_{Ab}) - \frac{1}{3(S_{Ba} - S_{Bb})} \quad S_{Ac} = \frac{1}{3}(S_{Ab} - S_{Ac}) - \frac{1}{3}(S_{Bb} - S_{Bc})$$

$$S_{Ba} = \frac{1}{3}(S_{Bc} - S_{Ba}) - \frac{1}{3}(S_{Cc} - S_{Ca}) \quad S_{Bb} = \frac{1}{3}(S_{Ba} - S_{Bb}) - \frac{1}{3}(S_{Ca} - S_{Cb}) \quad S_{Bc} = \frac{1}{3}(S_{Bb} - S_{Bc}) - \frac{1}{3}(S_{Cb} - S_{Cc})$$

$$S_{Ca} = \frac{1}{3}(S_{Cc} - S_{Ca}) - \frac{1}{3}(S_{Ac} - S_{Aa}) \quad S_{Cb} = \frac{1}{3}(S_{Ca} - S_{Cb}) - \frac{1}{3}(S_{Aa} - S_{Ab}) \quad S_{Cc} = \frac{1}{3}(S_{Cb} - S_{Cc}) - \frac{1}{3}(S_{Ab} - S_{Ac})$$

MODULATION TECHNIQUES

At present there are many modulation techniques are used. Some of them are Direct Modulation Indirect modulation State Vector Modulation, Venturini Modulation technique. A new modulation based on Singular Value Decomposition is introduced by Hossein Hojabri, Hossein Mokhtari [1], this proposed model yields a new limitation between MC and Input power factor.

CONVENTIONAL SVPM TECHNIQUE

It is the type of indirect modulation technique in which first there is the rectifying stage then inverting stage. There are majorily six active current vectors and three zero vectors. There are two poles of the fictitious dc link namely positive (P) and negative (N), these are connected with the inputs a, b and c. The switching state can take up the values of 0 or 1

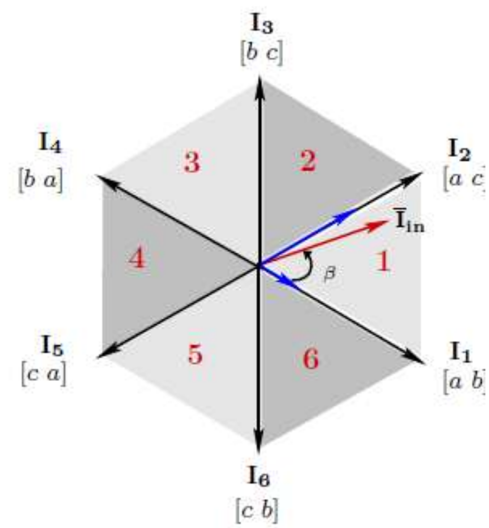

Fig: Space Vectors of CSR

The zero vectors are defined as [a a], [b b], [c c] when P and N of DC link connected to input phases a b and c respectively. The I_{in} is the average reference value current space vector and can be represented as combination of three sinusoidal varying input currents as shown below. This is generated by using one zero vector and two adjacent active vectors.

$$\overline{I}_{in} = i_a + i_b e^{j2\pi/3} + i_c e^{-j2\pi/3} = \frac{3}{2} I_i e^{j\omega_i t}$$

$$\begin{aligned} dI_1 &= m_I \sin\left(\frac{\pi}{3} - \beta\right) \\ dI_2 &= m_I \sin\beta \\ dI_z &= 1 - dI_1 - dI_2 \end{aligned}$$

Β is the angle between reference vector and the first vector ,

m_I is modulation index $m_I = \frac{Ii}{Idc}$

I_i =Peak value that is to be synthesized

I_{DC} =Corresponding average dc link current

This modulation generates the pulsating DC-link voltages as shown in following figure[16].

This all synthesizing was of the rectifying stage .

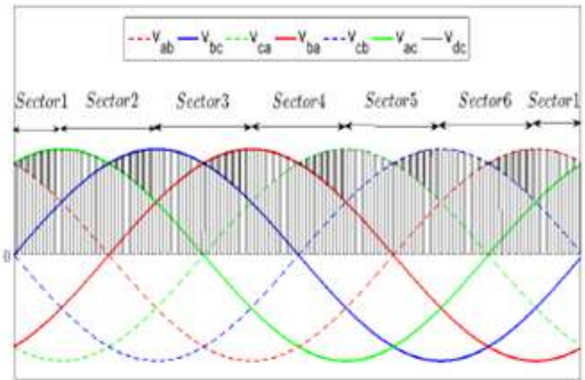

Fig: Instantaneous DC-link voltage waveform formed

The space vector diagram of inverting stage comprises of six active and two zero vectors.

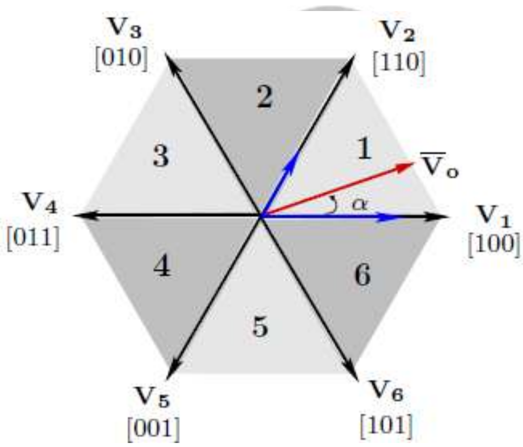

Fig: State vector of Voltage source Inverter

If the switching function is defined as S_y. When switch is on S_y takes value of 1 and 0 when it is off.

The zero vectors switching states is [000] and [111] where all the three outputs are connected to P or N of DC link ,By the three phase output voltages Vo is as the generated reference vector and given by-

$$\overline{V}_0 = v_{AN_o} + v_{BN_o} e^{j2\pi/3} + v_{CN_o} e^{-j2\pi/3} = \frac{3}{2} V_o e^{j\omega_o t}$$

This is generated by using one zero vectors and two adjacent active vectors as given by following duty ratio terms-

$$\begin{aligned} dV_1 &= \sqrt{3} m_V \sin\left(\frac{\pi}{3} - \alpha\right) \\ dV_2 &= \sqrt{3} m_V \sin\alpha \\ dV_z &= 1 - dV_1 - dV_2 \\ dV_0 &= dV_7 = \frac{dV_z}{2} \end{aligned}$$

m_V = modulation index

Vo= the peak output voltage that has to be synthesized

Vi= Average DC link Voltage

The zero vectors are to be chosen carefully so as to minimize the switching states.

The total output voltage generated by IMC is –

$$V_o = \frac{3}{2} m_I m_V V_i \cos\phi_i = m V_i \cos\phi_i$$

φi = Input power factor Angle.

The total voltage transfer ratio of the IMC is given by m which has a maximum value of 0.866.

DIRECT METHODS

The direct methods are also known as Venturini method of matrix converter modulation. In this case the main aim of this case is to generate variable frequency and variable amplitude sinusoidal voltage (v_{jN}) from the fixed frequency and amplitude of input voltage (V_i). A signal whose low frequency component is the desired output voltage and the signal that is used to synthesize such signal is the instantaneous value of input voltage.The following principle is used for the synthesizing signal:

$$\overline{v}_{jN} = \frac{t_{Aj} v_A + t_{Bj} v_B + t_{Cj} v_C}{T_s}$$

Where, V_{jN} is the low frequency component of j^{th} phase. t_{ij} is defined as the time during which switch S_{ij} is on and T_s as the sampling interval, v_{jN} is the low-frequency component that changes in every sampling interval . By using this strategy a high frequency switched output is generated. The expression for the duty cycle is defined as following and by replacing these values the output voltage expression in terms of transfer matrix is expressed below [11].

GSJ: Volume 9, Issue 7, July 2021
ISSN 2320-9186

$$m_{Aj}(t)=\frac{t_{Aj}}{T_s} \qquad m_{Bj}(t)=\frac{t_{Bj}}{T_s} \qquad m_{Bj}(t)=\frac{t_{Bj}}{T_s}.$$

$$\overline{\boldsymbol{v_o}(t)}= \mathbf{M}(t)\mathbf{v_i}(t)$$

$\mathbf{M}(t)$ is the transfer matrix, and defined as

$$\mathbf{M}(t) = \begin{bmatrix} mAa(t) & mBa(t) & mCa(t) \\ mAb(t) & mBb(t) & mCb(t) \\ mAc(t) & mBc(t) & mCc(t) \end{bmatrix}$$

For current also following the analogous procedure it can be shown as

$$\overline{\boldsymbol{i_i}}\,(t) = \mathbf{M}^T(t)\mathbf{i_o}(t)$$

where $\mathbf{i_i}(t)$ is the low-frequency-component input current vector, $\mathbf{io}(t)$ is the instantaneous value of output current vector, $\mathbf{M}^T(t)$ is the transpose of $\mathbf{M}(t)$. $\overline{\boldsymbol{i_i}}\,(t)$ and $\overline{\boldsymbol{v_o}(t)}$ equations are the basis of the Venturini modulation method, leading to the conclusion that the low-frequency components of the output voltages are synthesized with the instantaneous values of the input voltages and that the low-frequency components of the input currents are synthesized with the instantaneous values of the output currents.

PROTECTION SCHEMES

The switches need to be protected in the event of short circuit at input side and open circuit at the output side. Protection for high current during shorting of input terminals can be realized on the gate drivers of the switches themselves. Standard technique like sensing the collector to emitter voltage across an IGBT to detect short circuit can be employed. Interruption of load current, during communication or due to activation of protection circuit following any fault, may result in high voltage at the output side. Normally a diode clamp circuit along with a capacitor (Cc) and discharging resistor (R_C) is used to absorb the energy of inductive load.

MATRIX CONVERTER FED INDUCTION MOTOR DRIVE

Speed control of induction motor with matrix converter is presented in **[21]** with the help of simulink tool in MATLAB. The P and N of the dc link are substituted by the maximum positive and maximum negative input line to neutral voltage. The simulink model for the three phase induction motor control with the help of matrix converter is shown in the figure below. The carrier based modulation has been implemented and used to control the induction motor. Proposed method has been simulated in MATLAB/Simulink and the simulation model is shown.

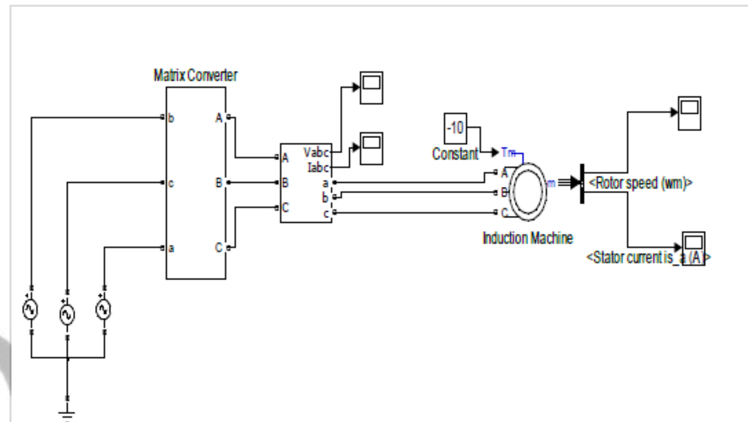

Fig: MATLAB/Simulink model of the matrix converter based induction motor control

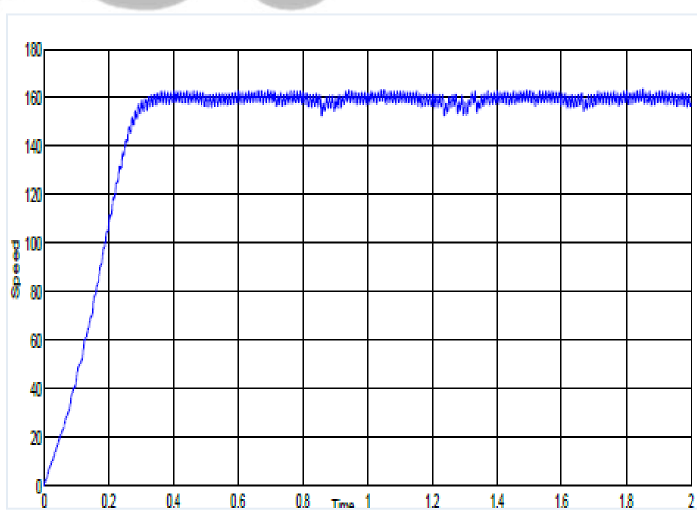

Fig: Speed of the induction motor

APPLICATIONS AND ISSUES IN MATRIX CONVERTER

The work [22] simulation results show that the modulation algorithm provides a unity input displacement factor even if the load has inductive characteristics.The main disadvantages of MC for like a like replacement for its use in industrial drive is the low voltage transfer ratio. The most appropriate load selected for its use is Induction motors since the voltage transfer ratio is not an issue. The over modulation problem was also accessed but due to that the power quality of input side has to be sacrified in favor of output drive capability. By changing some of the topologies of indirect matrix converter but its complexity increased has been presented in the work and the size also has increased[12].

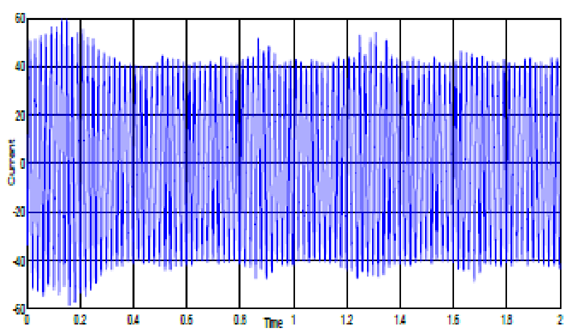

Fig: Stator current supplied to the induction motor

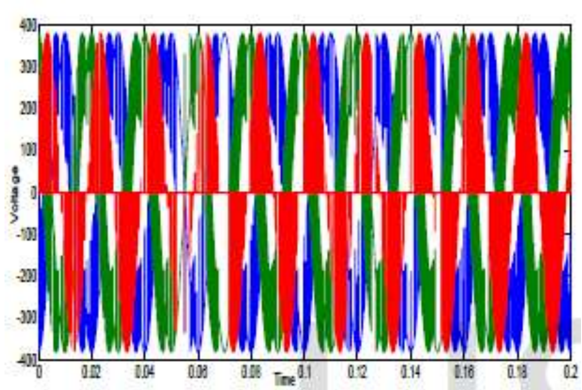

Fig.: Output voltages of the matrix converter

A fault tolerance topology developed which can be efficiently used to drive a permanent magnet synchronous motor for studying in the vital applications with specifically emphasis on aerospace applications[14]. The first integrated regenerative frequency converter was developed [15], which may be successfully used to drive a permanent magnet synchronous motor (PMSM) for studies in crucial applications with main emphasis on aerospace applications. A 4KW motor prototype fed with Matrix converter was developed using standard frequency converter enclosure for testing industrial application techniques [15].

REFERENCES

1. Hossein Hojabri, Hossein Mokhtari and Liuchen Chang "A Generalized Technique of Modeling, Analysis, and Control of a Matrix Converter Using SVD", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 58, NO. 3, MARCH 2011.
2. Khouloud Bedoud1, Tahar Bahi, Sundarapandian Vaidyanathan, Hichem Merabet, "Control of Matrix Converter Fed Induction Motor Drive", International Journal of ChemTech Research Vol.10 No.2, 2017.
3. J. Rodríguez , E. Silva , F. Blaabjerg , P. Wheeler , J. Clare & J. Pontt "Matrix converter controlled with the direct transfer function approach: analysis, modelling and simulation", J, International Journal of Electronics Vol. 92, No. 2, February 2005
4. Hulusi Karaca, Ramazan Akkaya, "Modelling and simulation of matrix converter under distorted input voltage conditions", Simulation Modeling Practice and Theory 19 (2011) September 2010
5. Senad Huseinbegovic and Omer Tanovic, "Matrix Converter Based AC/DC Rectifier", , IEEE Region 8 SIBIRCON-2010, Irkutsk Listvyanka, Russia, July 11 — 15, 2010.
6. Pankaj Bisht, Akhilesh Dobhal, "Modeling, Design and Analysis of Three Phase Matrix Converter for Different Loads", International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue 9, September- 2014.

7. Liu Yong , He Yikang Hangzhou "The Modeling and Simulation of a Three-phase Matrix Converter "College of Electrical Engineering, Zhejiang University.

8. Simone Orcioni , Giorgio Biagetti , Paolo Crippa and Laura Falaschetti , "A Driving Technique for AC-AC Direct Matrix Converters Based on Sigma-Delta Modulation" 18th International Conference on Environment and Electrical Engineering.

9. Varsha Padhee Ashish Kumar Sahoo Ned Mohan "Modulation Techniques for Enhanced Reduction in Common Mode Voltage and Output Voltage Distortion in Indirect Matrix Converters", IEEE Transactions on Power Electronics 2016

10. Abdelkader Djahbara, Bouhani Benzianea, Abdallah Zegaouia, "A Novel Modulation Method For Multilevel matrix converter" The International Conference on Technologies and Materials for Renewable Energy, Environment and Sustainability.

11. "A Review of Control and Modulation Methods for Matrix Converters", Jose Rodriguez, *Fellow*, *IEEE*, Marco Rivera, *Member*, *IEEE*, Johan W. Kolar, *Fellow*, *IEEE*, and Patrick W. Wheeler, *Member*, *IEEE* IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 59, NO. 1, JANUARY 2012.

12. T. Wijekoon, C. Klumpner, P. Zanchetta, and P. Wheeler, "Implementation of a Hybrid AC-AC Direct Power Converter With Unity Voltage Transfer," *Power Electronics, IEEE Transactions on*, vol. 23, no. 4, 2008.

13. Patrick W. Wheeler, *Member, IEEE*, José Rodríguez, *Senior Member, IEEE*, Jon C. Clare, *Member, IEEE*, Lee Empringham, *Member, IEEE*, and Alejandro Weinstein, "Matrix Converters: A Technology Review" IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 49, NO. 2, APRIL 2002

14. S. Khwan-on, L. De Lillo, L. Empringham , P.Wheeler, C. Gerada, "Fault Tolerant, Matrix converter, Permanent magnet synchronous mototr drve for open cirvcuit applications" Power electronics Machines and control group, Depoartment of Electrical and electronic Engineering, IET Power applications, 2011

15. A new Matrix converter model for industry applications Chistian Klumpner ,Member ,IEEE, Peter Nielsen, Ion bodea, Fellow IEEE, Frede Blaabjerg Senior Member IEEE.

16. A Dasgupta, P. Sensarma, "Low-frequency dynamic modelling and control of matrix converter for power system applications" Vol. 5, Iss. 3, IET Power Electronics , 2011

17. S. Pinto, J. Silva "Sliding mode direct control of matrix converter" , IET Power Applications Vol. 1, No. 3, May 2017.

18. Domenico Casadei, *Associate Member, IEEE*, Giovanni Serra, *Associate Member, IEEE*, Angelo Tani, and Luca 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, APRIL 2002

19. Seung Ki Sul, Min Ho Park, "A Novel Technique for Optimal Efficiency Control of a Current-Source Inverter-Fed Induction Motor", IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL 3, NO *2*, APRIL 1988,

20. Marian P. Kazmierkowski, Leopoldo G. Franquelo, Jose Rodriguez, Marcelo A. Perez, and Jose I. Leon, "High performance motor drives" IEEE INDUSTRIAL ELECTRONICS MAGAZINE SEPTEMBER 2011

21. Vinod Battu, Grandhi Ramu, "Simplified Matrix Converter Fed Induction Motor Drive"
International Journal of Scientific & Engineering Research, Volume 4, Issue 11, November-2013 IJSER

22. Hulusi Karaca and Ramazan Akkaya, "Modeling, Simulation and Analysis of Matrix Converter Using Matlab and Simulink", International Journal of Modeling and Optimization January 2012