Available online at http://www.journalijdr.com

International Journal of
DEVELOPMENT RESEARCH

ISSN: 2230-9926

International Journal of Development Research
Vol. 4, Issue, 3, pp. 565-569, March, 2014

Full Length Research Article

SIMULATION AND SPEED CONTROL OF INDUCTION MOTOR FED BY INDIRECT MATRIX CONVERTER

***[1]Natarajan, R., [2]Dr. Baskaran, B., [3]Irusapparajan, G. and [4]Rasheed Ahmed, K. B.**

[1]Research Scholar, Department of Electrical Engineering, Annamalai University, India
[2]Professor, Department of Electrical Engineering, Annamalai University, India
[3]Professor, Department of Electrical and Electronics Engineering, Mailam Engineering College, India
[4]PG Scholar, Department of Electrical and Electronics Engineering, PSV College of Engineering, India

ARTICLE INFO

Article History:
Received 08th January, 2014
Received in revised form
11th February, 2014
Accepted 15th February, 2014
Published online 14th March, 2014

Key words:
Indirect Matrix Converter,
Induction Motor,
PI controller, Speed Control v/Hz,
Space Vector PWM.

ABSTRACT

A matrix converter is used as an alternative AC–AC power converter that has received wide research concentration as an alternative scheme to fixed AC–DC–AC converter. To convert the energy from an AC source to an AC load without the need of bulky and limited-lifetime energy-storage elements matrix converters are preferred. This paper presents a simulation of speed control of Induction motor fed by Indirect Matrix Converter (IMC) using v/Hz technique by space vector PWM technology. Out of the several methods of speed control of an induction motor such as pole changing, frequency variation, variable rotor resistance, variable stator voltage, constant V/f control, slip recovery method etc., the closed loop constant V/f speed control method is most widely used. The simulation results were carried out for very sparse indirect matrix converter fed induction motor drive and the performances of indirect matrix converter is analyzed and verified using the response obtained through Matlab/Simulink.

INTRODUCTION

In recent researches for direct frequency conversion technique focus is made on using a matrix converter (MC). The main reason for the interest in MCs is that it provides a compact solution for a four quadrant frequency converter producing sinusoidal input and output currents without passive components in dc link. The absence of dc link also has its disadvantages: input and output disturbances are not filtered and additional commutation strategies are needed to avoid a short circuiting of the supply voltage or open circuiting of the load current path (Bueno *et al.,* 2008). The IMC offers the same benefits and disadvantages as the DMC, but it also provides an option to reduce the number of switches of the line bridge to three if no bidirectional power flow is needed (Yao *et al.,* 2008), (Friedli and Kolar 2010). Safe commutation of semiconductor devices produce smooth variation in converter output voltage. In sensor less motor drives this is a disadvantage especially in the low speed region and needs to be compensated (Kolar *et al.,* 2011; Wheeler *et al.,* 2002; Yoon and Sul 2006). To develop suitable compensation methods the construction and effectiveness of the used converter has to be known. The motor control industry is a strong, aggressive sector. To remain competitive, new products must address several design constraints including cost reduction, power consumption reduction, power factor correction, and reduced EMI radiation. In order to meet these challenges, advanced control techniques are necessary. According to market analysis, the majority of industrial motor applications use AC induction motors. The reasons for this are higher robustness, higher reliability, lower prices and higher efficiency (up to 80%) on comparison with other motor types. However, the use of induction motors is challenging because of its complex mathematical model, its nonlinear behavior during saturation and the electrical parameter oscillation that depends on the physical influence of the temperature.

Scalar control is the term used to describe a simpler form of motor control, using non-vector controlled drive schemes. An AC Induction motor can be led to steady state by simple voltage fed, current controlled, or speed controlled schemes. The scalar variable can be manipulated after obtaining its value either by direct measurement or calculation, and can be

****Corresponding author: Natarajan, R.** Research Scholar, Department of Electrical Engineering, Annamalai University, India.*

used in both open loop and closed loop feedback formats. Although its transient behavior is not ideal, a scalar system leads to a satisfactory steady state response.

Indirect Matrix Converter

The indirect matrix converter (IMC) has received considerable attention as it provides a good alternative to double-sided PWM voltage source rectifier-inverter having advantage of being a two stage converter with six bidirectional switches and six unidirectional switches for three phase to three phase conversion and inherent bidirectional power flow, sinusoidal input/output waveforms with modulate switching frequency, the possibility of compact design due to the absence of dc-link reactive components and controllable input power factor independent of output load current. The main disadvantages of matrix converter are the inherent restriction of the voltage transfer ratio (0.866), more complex control and protection strategy.

The direct AC-AC matrix converter topology has a trouble less structure and it includes several 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 (Arevalo *et al.*, 2010; Klumpner *et al.*, 2006; Garcia-Vite *et al.*, 2010). It is a two -stage converter topology known as an indirect matrix converter. This topology is similar to the conventional AC-DC-AC converter topology without any reactive DC-link energy storage components for the intermediate imaginary DC -link bus. A block diagram of the indirect matrix converter topology is shown in Figure 1.

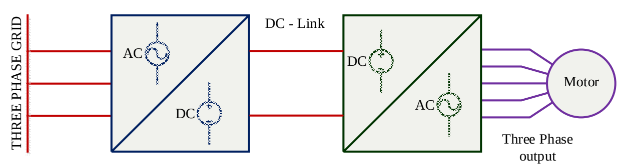

Figure 1. Indirect matrix converter topology block diagram feeding to an AC -Load

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, elimination of 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.

Very Sparse Matrix Converter

The Characteristics of Very Sparse Matrix Converter topology includes 12 Transistors and 30 Diodes. There is no limitation in functionality compared with the Direct Matrix Converter and Sparse Matrix Converter. When compared to the Sparse Matrix Converter it uses reduced number of transistors but increases the conduction losses due to more number of diodes in the conduction paths. Figure 2 shows the circuit diagram of Very Sparse Matrix Converter.

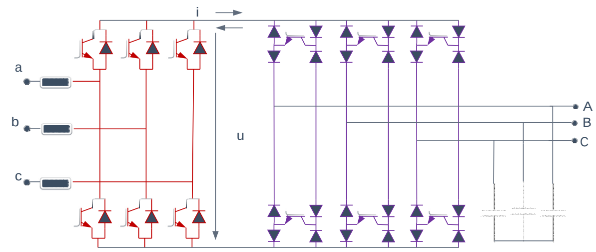

Figure 2. Very Sparse Matrix Converter

V/F Control of Three Phase Induction Motor

The torque developed by the motor is directly proportional to the magnetic field produced by the stator. So, the voltage applied to the stator is directly proportional to the product of stator flux and angular velocity. This makes the flux produced by the stator proportional to the ratio of applied voltage and frequency of supply. Therefore by varying the voltage and frequency by the same ratio, the torque can be kept constant throughout the speed range.

This makes constant V/F is the most common speed control of an induction motor. The torque developed by the induction motor is directly proportional to the V/F ratio. If we vary the voltage and frequency, keeping their ratio constant, then the torque produced by induction motor will remain constant for all the speed range.

Stator voltage (V) $\propto$ Stator flux (Φ) x Angular velocity (ω)

$V \propto \Phi \times 2\pi f$

$\Phi = V/f$

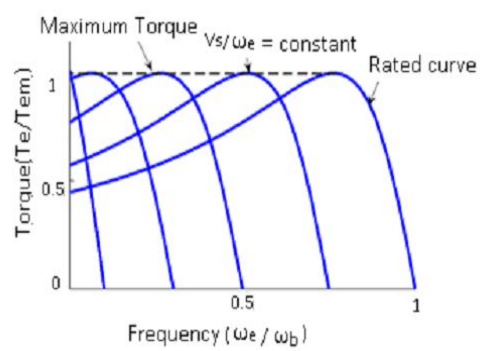

Figure 3. Torque-speed characteristics of the induction motor

Figure 3 shows the torque -speed characteristics of the induction motor with V/F control. The voltage and frequency reaches the maximum value at the base speed (Hojabri *et al.*, 2011). We can drive the induction motor beyond the base speed. But by doing so only frequency varies but not voltage. Hence the ratio of V/F will no longer remain constant. Since the torque developed by the induction motor is directly proportional to the V/F ratio it will not remain constant throughout the speed. Other than the variation in speed, the torque-speed characteristics of the V/F control reveal the following:

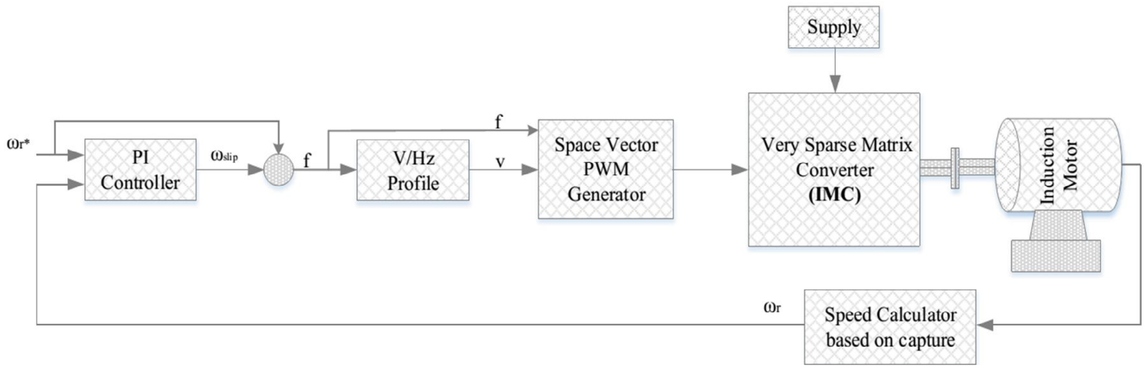

Figure 4. Block diagram of speed Control of Induction Motor fed by Indirect Matrix Converter

- The starting current is low.
- The stable operating region of the motor is increased. Instead of simply running at its base/ rated speed (NB), the motor can be run typically from 5% of the synchronous speed (NS) up to the base speed. The torque generated by the motor can be kept constant throughout this region.
- Since almost constant rated torque is available over the entire operating range, the speed range of the motor becomes wider. User can set the speed as per the load requirement, thereby achieving the higher efficiency.

Control Strategy

The overall system implementing a 3-ph induction motor with V/Hz control strategy is depicted in Figure 4. The induction motor is driven by the Indirect Very Sparse Matrix Converter. The PI controller is being used to generate the six pulse width modulation (PWM) signals using a space vector PWM technique, for six power switching devices in the indirect matrix converter. The proposed scheme consists of three phase matrix converter connected in series with motor load. Matrix converter and Asynchronous motor parameters are shown in Table 1. Space vector PWM technique is proposed for *v/f* speed control scheme. Speed is taken as control element for the proposed method. From the error difference between reference and actual speed (negative feedback), PI controller is used to give provide dq plane voltage (V_d, V_q) for the space vector control scheme. Voltage and frequency both are controlled by varying the reference voltage and frequency of the system. To prove the stability of the system, test has been carried out for no load as well as load conditions to verify the speed regulation of the system, through simulation.

Simulation Results

To demonstrate the feasibility of proposed scheme, the results and waveforms have been obtained through simulation for different conditions before realization in real time. Figure 5 displays the simulated source end voltage and current response of very sparse indirect matrix converter, Figure 6 portrays simulated Voltage and Current response of very sparse indirect matrix converter at load end, Figure 7 displays the simulated voltage response of matrix conveter at source and load side at time t=0 sec(Tm=0 & ω = 157 rad/sec), Simulated voltage response of matrix conveter at source and load side at time t=1 sec (T_m=3 N-m & ω = 157 rad/sec) is shown in Figure 8,

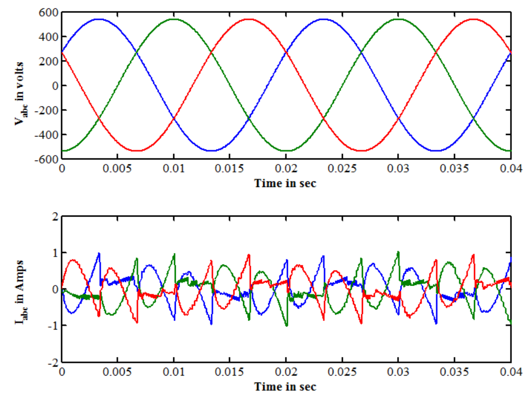

Figure 5. Simulated Voltage and Current response of very sparse indirect matrix converter at source side

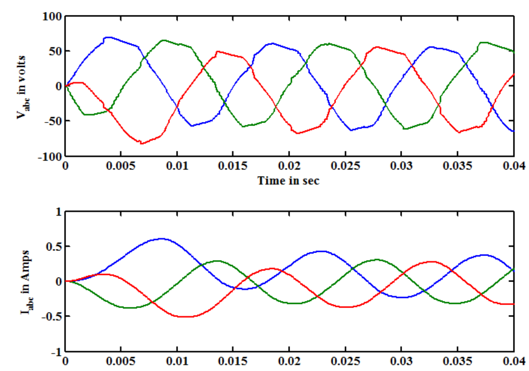

Figure 6. Simulated Voltage and Current response of very sparse indirect matrix converter at load side

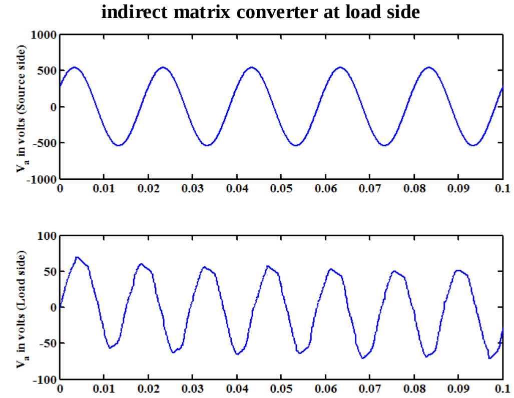

Figure 7. Simulated voltage response of matrix conveter at source and load side at time t=0 sec(T_m=0 & ω = 157 rad/sec)

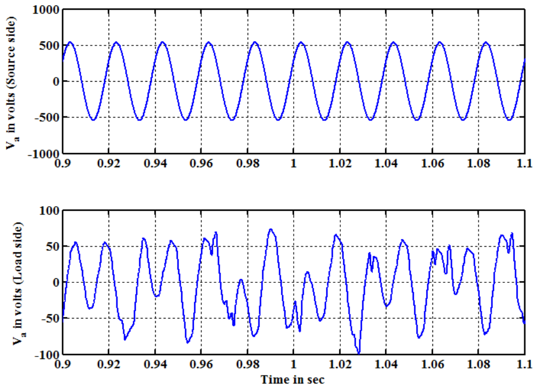

Figure 8. Simulated voltage response of matrix conveter at source and load side at time t=1 sec (T_m=3 N-m & ω = 157 rad/sec)

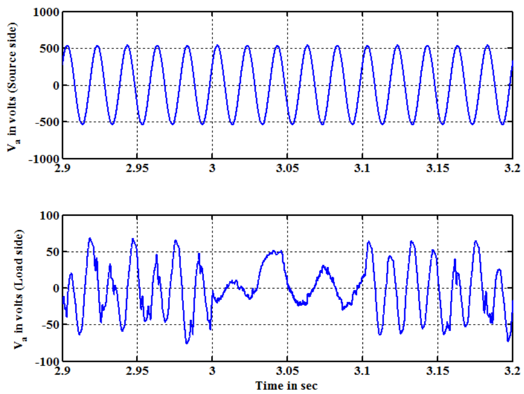

Figure 9. Simulated voltage response of matrix conveter at source and load side at time t=3 sec (T_m=3 N-m & ω = 130 rad/sec)

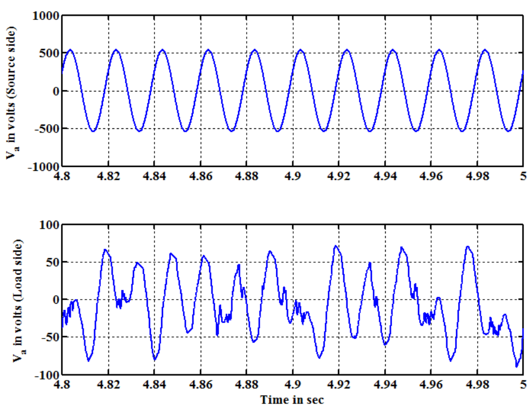

Figure 10. Simulated voltage response of matrix conveter at source and load side after load and speed disturbance (T_m=3 N-m & ω = 130 rad/sec)

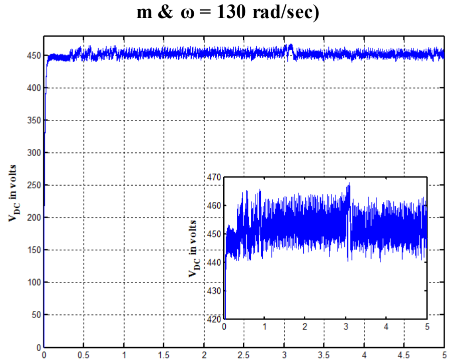

Figure 11. Simulated response of DC link voltage of matrix converter

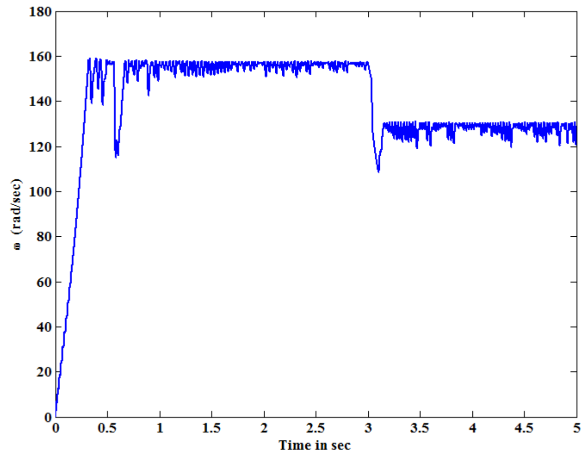

Figure 12. Simulated speed response of Asynchronous motor under difference conditions (t=0s , ω = 157 rad/sec; t=1s, T=3 N-m& t=3s, ω = 130 rad/sec) for v/f control scheme

Figure 9 shows simulated voltage response of matrix converter at source and load side at time t=3 sec (T_m=3 N-m & ω = 130 rad/sec), Simulation is also camed out under load disturbance and the response obtained is shown in Figure 10. (T_m=3 N-m & ω = 130 rad/sec), Simulated response of DC link voltage of matrix converter is displayed in Figure 11, Figure 12 shows simulated speed response of Asynchronous motor under disturbed load conditions and setpoint change at t=0.1 and 3 sec respectively. (t=0s , ω = 157 rad/sec; t=1s, T=3 N-m & t=3s, ω = 130 rad/sec). From the response it is observed that the system with constant v/f control scheme has rejected the load disturbance with in the time interval of 0.1 sec and responds instantaneously for set point change.

Table 1. Matrix converter and Asynchronous motor parameters

Parameter	Value
Matrix Converter rating (V_{rms}) (P-N)	220 V
Asynchronous Machine Rating	3.73 KVA, 350 V, 50 Hz, 2p
Stator Resistance and Inductance (R_s,L_s)	(1.115Ω , 0.005974H)
Rotor Resistance and Inductance (R_R,L_R)	(1.083 0.005974)
Mutual Inductance (L_M)	0.2037 H
Moment of Inertia (J)	0.02 N-m.
Asynchronous motor Mathematical modelling type	Rotor reference frame

Conclusion

From the voltage and speed response of the simulation results (Fig.7-10 and Fig.12), it is obtained that Indirect matrix converter (Very sparse matrix converter) can be made suitable for motor drive application. In the area of Energy conservation field in future indirect matrix converter can play a significance role in motor drives, with benefits of direct AC-AC control with reduced switching and conduction losses. Also it opens can up new avenue for lead to researches in the area of various drive control scheme which has superior performance.

REFERENCES

Alfredo, Thomas A. Lipo and Donald W. Novotny, "A New Induction Motor V/f Control Method Capable of High-Performance Regulation at Low Speeds" IEEE Trans. Industry Applications, Vol. 34, No. 4 July/ August 1998.

Arevalo S. L., P. Zanchetta, P. W. Wheeler, A. Trentin, and L. Empringham, "Control and implementation of a matrix-converter-based AC ground power-supply unit for aircraft servicing," IEEE Trans. Ind. Electron., vol. 57, no. 6, pp. 2076–2084, Jun. 2010.

Baumann M., F. St¨ ogerer, and J. W. Kolar, "Novel three-phase ac-dc-ac sparse matrix converter. Part II—Experimental analysis of the very sparse matrix converter," inProc. 17th Annu. IEEE Appl. Power Electron. Conf. Expo., Dallas (TX), vol. 2, Mar. 10–14, 2002, pp. 788–791.

Bueno E. J., S. Cobreces, F. J. Rodriguez, A. Hernandez, and F. Espinosa, "Design of a back-to-back NPC converter interface for wind turbines with squirrel-cage induction generator,"IEEE Trans. Energy Convers., vol. 23, no. 3, pp. 932–945, Sep. 2008.

Friedli T. and J. W. Kolar, "Comprehensive comparison of three-phase acac matrix converter and voltage dc-link back-to-back converter systems," inProc. IEEE/IEEJ Int. Power Electron. Conf., Sapporo, Japan, Jun. 21– 24, 2010, pp. 2789–2798.

Garcia-Vite P. M., F. Mancilla-David, and J. M. Ramirez, "A dynamic voltage restorer based on vector-switching matrix converters," inProc. IEEE Int. Conf. Ind. Technol., Mar. 2010, pp. 637–642.

Helle L., K. B. Larsen, A. H. Jorgensen, S. Munk-Nielsen, and F. Blaabjerg, "Evaluation of modulation schemes for three-phase to three phase matrix converters, "IEEE Trans. Ind. Electron., vol. 51, no. 1, pp. 158– 171, Feb. 2004.

Hojabri H., H. Mokhtari, and L. Chang, "A generalized technique of modeling, analysis, and control of a matrix converter using SVD, "IEEE Trans. Ind. Electron., vol. 58, no. 3, pp. 949–959, Mar. 2011.

Huber L. and D. Borojevic, "Space vector modulated three-phase to threephase matrix converter with input power factor correction, "IEEE Trans. Ind. Appl., vol. 31, no. 6, pp. 1234–1246, Nov. 1995.

Jahangiri A., A. Radan, and M. Haghshenas, "Synchronous control of indirect matrix converter for three-phase power conditioner," Electric Power Syst. Res., vol. 80, no. 7, pp. 857–868, Jul. 2010.

Klumpner C., F. Blaabjerg, I. Boldea, and P. Nielsen, "New modulation method for matrix converters, "IEEE Trans. Ind. Appl., vol. 42, no. 3, pp. 797–806, May 2006.

Klumpner, C., F. Blaabjerg, and P. and Nielsen, Speeding up the Maturation Process of the Matrix Converter Technology. Proceedings of the 32ndIEEEPower Electronics Specialist Conference, Vancounver, Canada, 2001. 2: p.1083 -1088.

Kolar J. W., F. Schafmeister, S. D. Round, and H. Ertl, "Novel three-phase ac–ac sparse matrix converters," IEEE Trans. Power Electron., vol. 22, no. 5, pp. 1649–1661, Sep. 2007.

Kolar J. W., M. Baumann, F. Schafmeister, and H. Ertl, "Novel three-phase ac-dc-ac sparse matrix converter. Part I—Derivation, basic principle of operation, space vector modulation, dimensioning," in Proc. 17th Annu. IEEE Appl. Power Electron. Conf. Expo., Dallas (TX), vol. 2, Mar. 10–14, 2002, pp. 777–787.

Kolar J. W., T. Friedli, J. Rodriguez, and P. Wheeler, "Review of threephase PWM ac–ac converter topologies," IEEE Trans. Ind. Electron., vol. 58, no. 11, pp. 4988–5006, Nov. 2011.

Loh P. C., R. J. Rong, F. Blaabjerg, and P. Wang, "Digital carrier modulation and sampling issues of matrix converters," IEEE Trans. Power Electron., vol. 24, no. 7, pp. 1690–1700, Jul. 2009.

Nguyen H. M., H. H. Lee, and T. W. Chun, "Input power factor compensation algorithms using a new direct-SVM method for matrix converter," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 232–243, Jan. 2011.

Wang B. and G. Venkataramanan, "A carrier-based PWM algorithm for indirect matrix converters," in Proc. IEEE-Power Electron. Spec. Conf., 2006, pp. 2780–2787.

Wei L., T. A. Lipo, and H. Chan, "Matrix converter topologies with reduced number of switches," inProc. Record IEEE Annu. Power Electron. Spec. Conf., 2002, pp. 57–63.

Wei, L. and T.A. and Lipo, A noval Matrix Converter Topology with Simple Commutation. Record on the 26th IEEE Industrial Applications Society Annual Meetings, Chicago, 2001. 3: p. 1749-1754.

Wheeler P., J. Rodriguez, J. Clare, L. Empringham, and A. Weinstein, "Matrix converters: A technology review," IEEE Trans. Ind. Electron., vol. 49, no. 2, pp. 276–288, Apr. 2002.

Yao J., H. Li, Y. Liao, and Z. Chen, "An improved control strategy of limiting the dc-link voltage fluctuation for a doubly fed induction wind generator," IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1205–1213, May 2008.

Yoon Y. D. and S. K. Sul, "Carrier-based modulation technique for matrix converter," IEEE Trans. Power Electron., vol. 21, no. 6, pp. 1691–1703, Nov. 2006.

Youm, J. and B. Kwom, "Switching Techniques for Current -Controlled AC-to -AC Converter", IEEE Trans. Industrial. Electronics, 1999. 46(2): p. 309 -318.

****