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"Matrix Converter and its Basic Apprehension"

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***Abstract* - Matrix converter is a three phase to three phase AC-AC conversion topology with no charge up circuit i.e electrolytic capacitor. The Matrix Converter has various advantages in comparison with conventional converters. The matrix converter has less number of switches and low cost and no bulky configuration. This paper presents a technical review on various topologies of matrix converter, current commutation technique, control and modulation strategies demonstrating their pros and cons autonomously.**

Keywords - Matrix converter, Current commutation, Control and modulation.

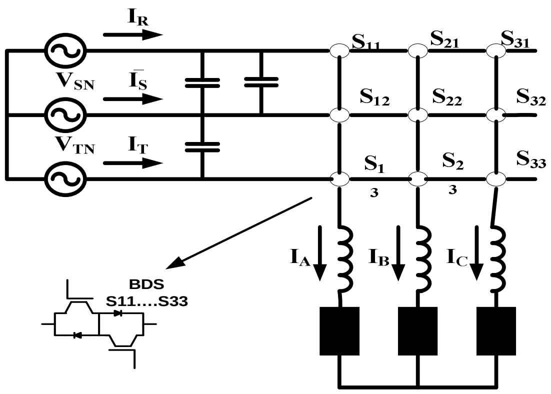

Fig.1.1- Basic matrix converter

I. INTRODUCTION

Matrix converter (MC) is a three phase to three phase configuration with direct AC-AC converter topologies in its basic structure. The matrix converter has several advantages over traditional rectifier-inverter type power frequency converters. It provides sinusoidal output waveforms bidirectional, as it has inherent bi-directional energy flow capability and therefore, the input power factor can be fully controlled. Also, it has minimal energy storage requirements that allow to get rid of bulky and lifetime-limited energy storing capacitors. In spite of above advantages, the matrix converter also has some disadvantages like its maximum voltage transfer ratio is limited to approximately 87% for sinusoidal voltage transfer.

The matrix converter consists of nine bi-directional switches that allow any output phase to be connected to any input phase. The general architecture of matrix converter is shown in Fig.1.1.

With nine bi-directional switches the matrix converter can theoretically assume 512 (2^9) different switching state combinations. However, not all of them can be usefully employed. The choice of matrix converter switching states combination has to comply with two basic rules. First, taking into account the condition, that the converter is supplied by a voltage source and usually feed an inductive load, the input load should never be short-circuited. Secondly, the output currents should not be interrupted. From a practical point of view these rules imply that one and only one bi-directional switch per count output phase must be switched on at any instant.

With this constraint in a three phase to three phase matrix converter only 27 switching combinations are permitted. Matrix converter has received considerable interest, because it possesses the topological and operational features to fulfil current trends of the drives [13], [17], [18]. The converter has also attracted the industry application and the technical development has been further accelerated because of strong demand in power quality, energy efficiency downsizing of the converters. This paper talks

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about various topologies and modulation techniques available in the literature to simplify the decision making from application point of view.

II. LITERATURE REVIEW

In 1976 , L Gyurgyi and B.R. Pelly are first who proposed the first silicon based converters[1]. The first name given to Martix Converters was the "Unrestricted frequency Changer". This name is given by L.Gyurgyi and B.R. Pelly. This Unrestricted frequency changer has number of good and useful characteristics.

The configuration of unrestricted frequency changer consists of nine bi-directional switches. The Unrestricted Frequency Changer worked at only low switching frequencies. In [1] authors discussed about the drawbacks of the Unrestricted Frequency changer. The drawbacks of Unrestricted Frequency Changer was that the UFC has inappropriate input currents and the its output voltage contains harmonics. The harmonics in the output voltage was very low and due to this they cannot be easily filtered.

In [2] authors A.Alesina and M.Venturini introduced an improvement in the modulation scheme of Matrix Converters. The modulation scheme given by the A. Alesina and M.Venturini solved the main drawback of the Unrestriced frequency changer upto some extent with a new PWM voltage modulation scheme. This new scheme given in [2] solved the problem of any type of harmonics. But this modulation scheme has a serious drawback. The ratio of the maximum output to input voltage was only 0.5 i.e. 1/2 .

In [3,4] A. Alesina and M.Venturini again proposed an improved schem. This new scheme increased the maximum output to input voltage ratio up to 0.866 i.e.$\sqrt{3}/2$. In this new scheme zero sequence components are added to the desired output voltages. These two methods were able to control the input supply displacement factor. In [5, 6] author P.Ziogas was proposed a new modulation method. This new method gave boost to the improvement in research of matrix converter.

In this new scheme the author divide the Matrix Converter into an imaginary rectifier and a imaginary inverter with a imaginary DC-link. In this method the input voltage was firstly rectified and then inverted to get required output voltage . This new method was named as indirect approach and it becomes very useful for the Matrix Converter.

In [7,8] author Huber was proposed Space Vector Modulation to control the three –phase to three-phase matrix Converter. The space vector modulation was able to give maximum output input voltage ratio but this method failed to control input current displacement. The result of input phase current obtained with space vector modulation was very similar to the results of a three phase bridge diode rectifier. In [9] by same authors a new modulation method is presented which applied the space vectors in both rectifier and inverter sides. When the space vector modulation is applied at the input side it gives sinusoidal input currents and it also control the input displacement factor. In 1987[10] and 1991[11] authors Roy and Ishiguro introduced a new method. In this method instantaneous values of the input voltages are used to calculate the duty cycles. This new method very effectively deals the problem of unbalanced and distorted input voltages abut it fails to control the input displacement factor.

III. MATRIX CONVERTER TOPOLOGIES

Various MC topologies have been discussed since 1970 [14], wherein the research is not only concerned on conventional direct matrix converter (DMC) presented in Fig.3.1, but an indirect matrix converter (IMC), presented in Fig.3.2 has also been studied [20],[15],[19],[16] and can be considered as an alternative to DMC based on topology.

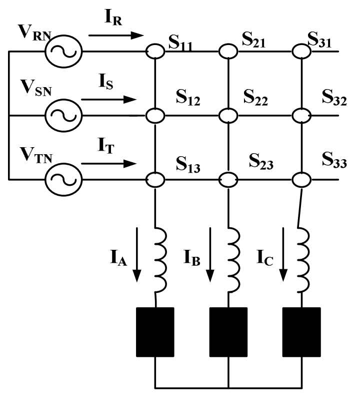

Fig.3.1 - Direct matrix converter

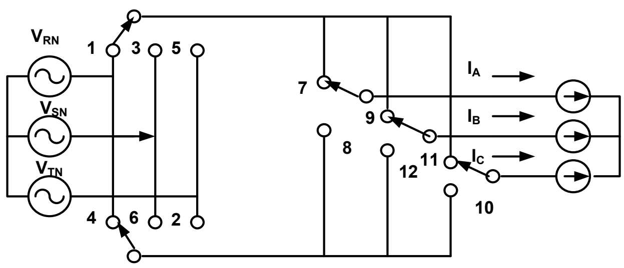

Fig.3.2 - Indirect matrix converter

In [15] authors done a comparison between Direct matrix converter and Indirect matrix converter both are supplying

Induction motor drive. After this comparison, authors find that in ideal case and for same control system the Direct matrix converter and Indirect, matrix converter gives same performance. But when they done the comparison of Direct matrix converter and Indirect matrix converter for real induction motor drives, they observed different output voltages for both the configuration and due to difference in main circuit they also power losses and these losses increase when different commutation methods are applied for the safe operation of both the configuration. The output voltage of indirect matrix converter is more distorted than the direct matrix converter. When the overload is applied the efficiency of Indirect matrix converter is less than the Direct matrix converter.

In [21] authors introduced a new configuration of matrix converter. They named this configuration sparse matrix converter (SMC). This new configuration consist of less number of elements, easy modulation scheme .The sparse matrix converter topology was introduced in 2001. This new topology does not require multi-step commutation and gives reliable operation in industrial operations. The sparse matrix converter topology is mostly used for integrated AC drives. The Sparse matrix converter consist of 18 diodes, 15 transistors, and 7 isolated drivers potential (IDP). When Sparse matrix converter and direct matrix converter are compared there functionality are almost same. But the Sparse matrix converter consists less number of switches than direct matrix converter. In sparse matrix converter a new and improved commutation scheme was used named as zero- DC link current commutation scheme.

This commutation technique is easy to control and it provides high safety to the Matrix converter topology. A new topology of matrix converter named as Very sparse matrix converter it consist of 30 diodes, 12 transistors and 10 isolated driver potentials, when this topology is compared with direct matrix converter and sparse matrix converter , the Very sparse matrix converter performs very well than direct matrix converter and sparse matrix converter. The Very sparse matrix converter consist of less number of transistor in comparison with sparse matrix converter but it contains more number of diodes than sparse matrix converter, this more number of diodes in Very sparse matrix converter increases conduction losses in the matrix converter topology. After some time a new topology of matrix converter was introduced named Ultra sparse matrix converter (USMC).

This new topology consist of 18 diodes, 9 transistors and 7 isolated driver potential. The maximum phase displacement factor between input voltage and input current is limited up to $\pm$ 30^0. This drawback of topology was comes out when it was compared with the sparse matrix converter topology. Now a days latest topology of matrix converter is in trend known as Z-source matrix converter. this toplogy is further classified as; Voltage-fed Z- source matrix converter & Current-fed Z-source matrix converter. This new topology of matrix converter gives maximum output to input voltage ratio other than any topology of the matrix converter and it has many more advantages discussed by the authors in [22].

The configuration of Z-source matrix converter consist nine bi-directional switches in addition of passive elements. No extra semiconductor switches are required in the topology of Z-source matrix converter. The Current-fed Z-source matrix converter [12],[26] is a combination of Current-fed matrix converter and Z-source AC-AC converter. This new topology gives higher reliability over the input currents, displacement factors and output voltage.

IV. Modulation Techniques

A. VENTURINI MODULATION

In [14] authors introduced the first modulation technique for the matrix converter named as Venturini modulation. In Venturini each leg of the matrix converter was is switched one by one for a sampling period of *T*. To understand Venturini modulation more clearly let us assume only one leg of the matrix converter. One leg of the matrix converter consist only three semiconductors switches, these switches are switched ON one by one for switching interval of T_1, T_2, T_3.

Now, the output voltage of one leg of the matrix converter is given by:

$$v_1 = \frac{1}{T}[v_{11}(t)t_1 + v_{12}(t)t_2 + v_{13}(t)t_3] \qquad (1)$$

And the duty cycles of one leg associated to the times t_1, t_2, t_3, are given by-

$$m_1 = \frac{t_1}{T} = \frac{1}{3} + \frac{2}{3}\frac{V_s}{V_e}\cos[(\omega_o - \omega_i)t] \qquad (2)$$

$$m_2 = \frac{t_2}{T} = \frac{1}{3} + \frac{2}{3}\frac{V_s}{V_e}\cos[(\omega_o - \omega_i)t + \frac{2\pi}{3}] \qquad (3)$$

$$m_3 = \frac{t_3}{T} = \frac{1}{3} + \frac{2}{3}\frac{V_s}{V_e}\cos[(\omega_o - \omega_i)t - \frac{2\pi}{3}] \qquad (4)$$

The Equation (1) shows the output voltage of the one leg of the matrix converter. Equation (2),(3) & (4) shows the modulating signals of the three switches of one

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leg of the matrix converter . The Ventutini modulation technique is very easy to implement but it has the drawback to limit the output voltage to input voltage ratio is only 50%.

B. SPACE VECTOR MODULATION

The SVM strategy, based on space vector representation became very popular due to its simplicity[27]. 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)[29].

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a	b	c	V_a	V_b	V_c	V_{ab}	V_{bc}	V_{ca}
0	0	0	0	0	0	0	0	0
1	0	0	2/3	-1/3	-1/3	1	0	-1
1	1	0	1/3	1/3	-2/3	0	1	-1
0	1	0	-1/3	2/3	-1/3	-1	1	0
0	1	1	-2/3	1/3	1/3	-1	0	1
0	0	1	-1/3	-1/3	2/3	0	-1	1
1	0	1	1/3	-2/3	1/3	1	-1	0
1	1	1	0	0	0	0	0	0

Table 4.1 – Switching states and corresponding outputs of a matrix converter.

V. COMMUTATION TECHNIQUES

The commutation techniques are very much important for the reliable operation of the matrix converters. The commutation is quite difficult in matrix converter as compared to the conventional converters due to the absence of the natural freewheeling paths in the matrix converter. The commutation has to be actively controlled at all times and must respect to two basic rules which are described in the introduction.[23]

SIMPLE COMMUTATION METHODS

A. DEAD TIME COMMUTATION METHOD

The dead time method is commonly used in inverter systems. The load current free- wheels through the anti-parallel diodes during the dead time period. In the case of a Matrix Converter using dead time commutation will cause an open circuit of the load. This will result in large voltage spikes across the switches which would destroy the Matrix Converter unless snubbers or clamping devices are used to provide a path for the load current during the dead time period [19, 25]. The dead time commutation method is not suitable for the matrix converter because for commutation dead time between the switching of switches is used during this dead time the snubber circuit losses its energy for each commutation. Because of the bi-directional switches configuration of the matrix converter the design of snubber circuit becomes more complicated. Matrix Converter circuit further complicates the snubber design.

B. OVERLAP COMMUTATION METHOD

This method also breaks the rules of Matrix Converter current commutation and needs extra circuitry to avoid destruction of the Matrix Converter. In overlap current commutation, the incoming switch is turned on before the outgoing switch is turned off. This will cause a line-to-line short circuit during the overlap period unless extra line inductance is added to slow the rise of the current [21][24]. This is not a desirable method since the inductors are in the main conduction path therefore the conduction losses would be increased. in addition to this disadvantage there will be significant distortion of the output voltage waveform during the overlap period. The switching time for each commutation is increased and will vary with commutation voltage which may cause control problems.

VI. CONCLUSION

In this paper, literature of the matrix converter is discussed from the beginning of matrix converter up to the latest trend of the matrix converter. Different modulation techniques are discussed like DMC, IMC , SMC, VSMC, USMC and Z-source MC. These different topologies are compared with each other and there advantages and disadvantage are discussed and we find Z-source matrix converter is more convenient for today's scenario research. Numbers of modulation techniques are applied to the matrix converter to get the desired results of the matrix converter and space vector modulation technique comes forward with gives desired and satisfactory results for the matrix converter. Commutation is needed in the matrix converter and simple commutation methods are discussed. Each commutation methods has its own advantages and disadvantages. These advantages and disadvantages depend upon the topology of the matrix converter for which it is used. So, we get matrix converter gives much better performance than conventional converter but matrix converter also needed attention over its

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commutation methods.

VII. REFERENCES

[1] L. Gyurgyi and B.R. Pelly, *Static Power Frequency Changers*, Wiley-Interscience, Newyork, 1976.

[2] Alesina A., Venturini M.G.B., "Solid State Power Conversion; a Fourier analysis approach to generalized transformer synthesis ," *IEEE Trans. on Circuit and Systems*, April 1981.

[3] Alesina A., Venturini M.G.B., "Intrinsic amplitude limits and optimum designs of 9-switches direct pwm ac-ac converters ," in PESC ' 88 Record. *19th Annual IEEE Power Electronics Specialists Conference*, 1988 .

[4] Alesina A., Venturini M.G.B., " Analysis and design of optimum-amplitude nine – switch direct ac-ac converters", *IEEE transactions on Power Electronic*, ed.4(1), pp. 101–112, 1989.

[5] P.D Ziogas, S.I Khan, and M.H. Rashid," Some improved forced commutated cyclo-converters structures", *IEEE Transactions On Industry Applications*, 1985.

[6] P.D Ziogas, S.I Khan, and M.H. Rashid, " Analysis and design of forced commutated cyclo-converters structures with improved transfer function characteristics," *IEEE Transactions on industrial Electronics* , 1986.

[7] L. Huber and D. Borojevic," Space vector modulator for forced commutated cyclo-converters ," in *Conference Record of the IEEE Industry Applications*, 1989.

[8] L. Huber and D. Borojevic," Voltage space vector based pwm control of forced commutated cyclo-converters, *15th Annual Conference of IEEE Industrial Electronics Society*, 1989.

[9] L. Huber and D. Borojevic," Space vector modulation with unity input power factor for forced commutated cycloconverters, " in *conference Record of the 1991 IEEE Industry Applications Society Annual Meeting*, 1991

[10] G.Roy, L. Duguay, S. Manias, and G.E. April, "Asynchronous operation of Cyclo-converter with improved voltage gain by employing a scalar control algorithm," in *Conference Record of the 1987 IEEE Industry Applications Society Annual Meeting*, 1987.

[11] A.Ishiguro, T. Furuhashi, and S. Okuma," A novel control method for forced commutated cyclo-converters using instantaneous values of input line-to-line voltages ," *IEEE Transactions On Industrial Electronics*, 1991.

[12] Fang X., Chen Z. ,"Current-fed Z-source matrix converter", *Proceedings of 2009 IEEE International Conference on Applied Superconductivity and Electromagnetic Devices*, Chengdu, China. pp. 93-96, 2009.

[13] Huber L, Borojevic D. , "Space vector modulated three-phase to three-phase matrix converter with input power factor correction", *IEEE Transactions* .,ed 31(6), pp.1234-1246, 1995.

[14]Gyugyi L., "Generalized theory of static power frequency changers", *Electrical Engineering*, University of Salford, UK, 1970.

[15]Jussila M, Salo M, Tuusa H., " Induction motor drive fed by a vector modulated indirect matrix converter", *Proceeding Conference Record IEEE* PESC, pp. 2862–2868, 2004

[16] Takeshita T, Andou Y., " PWM control of three-phase to three- phase matrix converters for reducing the number of commutations" *Electrical Engineering* , Japan , ed. 170(2): 60-69, 2010

[17] Venturini M., "A new sine wave in sine wave out conversion technique which eliminates reactive elements", *Proceedings Powercon'80 Conference* ., 7: E3-1–E3-15, 1980

[18] Kazmierkowski MP, Krishnan R, Blaabjerg F.. "Control in power electronics -selected problems", San Diego: Academic Press, 2002

[19] Klumpner C, Blaabjerg F. "Modulation method for a multiple drive system based on a two- stage direct power conversion topology with reduced input current ripple", *IEEE Transactions on Power Electronics*, ed.20: pp.922-929, 2005

[20] Kolar JW, Baumann M, Stögerer FS, Ertl H., "Novel three-phase AC-DC-AC sparse matrix converter, part i - derivation, basic principle of operation, space vector modulation, dimensioning, part ii - experimental analysis of the very sparse matrix converter", *IEEE Proceedings of the 17th APEC'02*, Dallas, USA. 2: 777 – 791, 2002

[21] Kolar JW, Schafmeister F, Round SD, Ertl H., "Novel three phase AC-AC sparse matrix converters" ,*IEEE Transactions Power Electronics.*, 22. pp 1649-1661, 2007

[22] Zhang S, Tseng KJ, Nguyen TD., "Novel three-phase AC-AC z-source converters using matrix converter

theory", *IEEE Transactions on Power Electronics* pp. 3063-3070, 2009

[23] Zhou D, Sun K, Huang L, Sasagawa Y., " A novel commutation method of matrix converter fed induction motor drive using rb-igbt", *IAS*, pp. 2347-2354, 2005

[24] Wheeler PW, clare JC, Empringham L,. "A vector controlled MCT matrix converter induction motor drive with minimised commutation times and enhanced waveform quality",*IEEE Transactions on Power Electronics* pp.466-472, 2002.

[25] Tabone M. Staines CS, Cilia J. "Low cost three phase to single phase matrix converter",*IEEE International conference, (ICIT)* pp. 474-479, 2004.

[26] Baoming Ge, Qin Lei, Wei Qian, Fang Zheng Peng, "A Family of Z-Source Matrix Converters", *IEEE transactions on Industrial Electronics,* Vol.,59,NO.1, January, 2012.

[27] J.Vadillo, J.M.Echeverria, L.Fontan, M.Martinez-Iturralde,I.Elosegui," Modelling and Simulation of a Direct Space Vector Modulated Matrix Converter using different Switching Strategies", *International Symposium on Power Electronics, Electrical Drives, Automation and Motion,* SPEEDAM,2008.

[28] Hoang M.Nguyen, Hong-Hee Lee, Tae-Won Chun," Input Power Factor Compensation Algorithms Using a New Direct-SVM Method for Matrix Converters", *IEEE Transactions on Industrial Electronics,*Vol.,58, No.1, January 2011.

[29] Marcelo A. Perez, Christian A. Rojas, Jose Rodriguez, Haitham Abu-Rub," A Simple Modulation Scheme for a Three-Phase Direct Matrix Converter", *IEEE Transactions on Industrial Electronics*,2012.

[30] Ahmed AN, Ghoni R, Zakaria NF, " Simulation Model of Space Vector Modulated Control Matrix Converter –fed Induction Motor", *International Journal of Applied Science,* 2011.