

# Matrix Converter Technology: A Review Paper

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**Abstract-** An array of  $m \times n$  bidirectional power switches is directly connected to the  $m$ -phase source and  $n$ -phase load is referred as a matrix converter. The forced commuted cycloconverters is described as a Matrix Converter (MC); various researchers are carried out form last few years. The increasing research work in matrix converter (MC) draws the attention towards the characteristics, topologies and advantages of matrix converter. The previous work explored the idea about development of matrix converter topology; semiconductor devices and the matrix converter application are presented. This paper is discussed about different topologies such as indirect matrix converter, direct matrix converter, Z-source matrix converter with reduced number of switches. The drawback of conventional matrix converter such as only buck or boost capability can be solve in Z- source matrix converter.

**Keywords**—Matrix Converter (MC), Z-Source matrix converter (ZMC), AC-AC Converter,.

## I. INTRODUCTION

The matrix converter received the more attention towards in recent year; because of their extensive characteristics and feature. The first time review of the MC technology was developing in the 2002 by Wheeler et al<sup>2</sup>. In that first review single stage matrix converter idea is explored and solves the commutation related problem in matrix converter [1]. The most useful features of power electronic converter are as following:

- 1) Simple as well as brief power circuit;
- 2) Production of load voltage with instantaneous amplitude and frequency;
- 3) Sinusoidal input as well as output currents;
- 4) Unity power factor operation for any load;
- 5) Reproduction capability.

The tremendous interest in the matrix converter topologies is because of the above stated feature and characteristics are easily achievable in the MC. The very interesting characteristics of matrix converter such as sinusoidal input output waveform, controllable power factor, four quadrant operation and avoidance of large storage element [1]-[4]. The Previous researches have carried out in control methods, theoretical analysis, and implementation issues related to the MC [1]-[7]. These researches gives the better alternative scheme than conventional back-to-back

converters because of in proposed research [11] use the reverse blocking insulated gate bipolar transistors (RB-IGBTs).

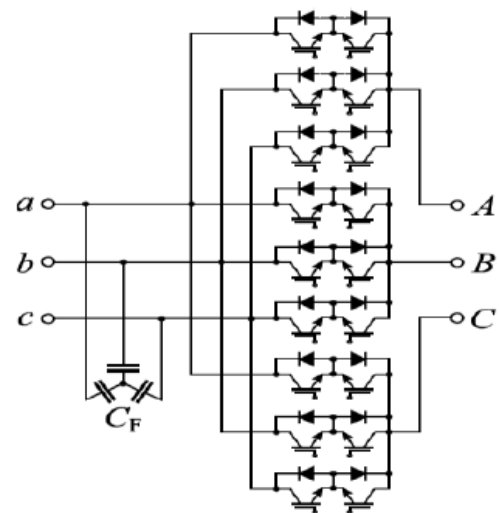


Fig 1: Three-phase Voltage Source matrix Converter

Fig. 1 [12] shows the configuration of a three-phase voltage source matrix converter (VS-MC). The voltage source matrix converter consist the nine bidirectional IGBT switches which are controlled by an appropriate modulation index. The VS-MC can produce a desired ac output voltage as well achieved the unity power factor as well as controllable input current waveform [1]. The VS-MC is fed by an ac voltage- source through the capacitive filter and connected to the load. The operating principle of VSI (Voltage Source Inverter) is same as the Voltage Source Matrix converter (VS-MC). For the production of active voltage at the load always connect the one of input voltages to each selectively output terminal and for production of a zero voltage always connect the output terminals to the one of input source terminals. The VS-MC features inherent buck operation with the maximum voltage ratio of 0.866 [1].

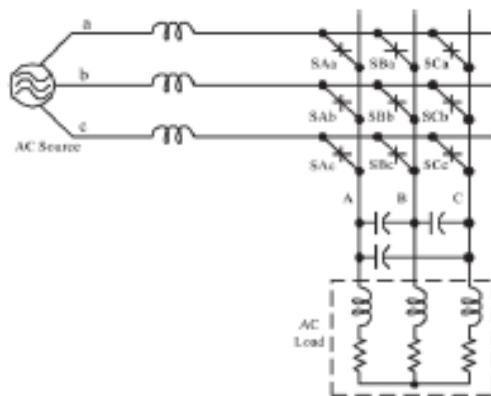


Fig. 2: Current Source Matrix Converter

The CS-MC is supplied by a current source through inductive filter, and the load has to RLC. The output voltage of current source matrix converter is always greater than input voltage and the CS-MC cannot have open-circuit to the input side and short-circuit to the output side. The buck-boost matrix converter is made up of the combination of both VS-MC (Voltage source matrix converter) and CS-MC (Current source Matrix converter). Therefore buck-boost matrix converters include 18 ac bidirectional switches and operated in two stages which increase in high cost, complex control strategy, low efficiency as well as low reliability. The short circuit and open circuit at output and input side of current source matrix converter is avoided by using proper commutation method and safe switching. The latest development in the Z-source matrix converter gives the inherent buck-boost capability [8]. However, the frequency is not changed in their Z-source AC/AC converters [9], [10]. This paper is explored the reviews on Z-source matrix converters (ZS-MCs) along with different topologies of matrix converter.

## II. MC TOPOLOGY AND DEVELOPMENT

### A. Basic Matrix Converter Topologies

Matrix converter is defined as Forced commutated ac-ac converter topologies which can provide instantaneous amplitude and frequency transformation of multi-phase voltage-current systems without use of energy storage. [34]. MCs can produce the sinusoidal input currents and output voltages with higher electrical output frequencies. Nowadays, the direct or conventional matrix converter is referred as a three phases to three phases Half-Bridge MC topology (Fig. 1) [12]. The direct or conventional Matrix converter is operated in one semiconductor stages by using an array of nine controlled bidirectional switches. The second topology is Indirect Matrix Converter is shown in Fig. 3[13] but it can operated on two-stage (indirect) power conversion, one is unipolar current source input stage with six bidirectional switches and other two level voltage source converter output stage. The researcher Venturini and Alesina in 1980 develop the actual high frequency CMC topology

[12]. The power circuit of the CMC with bidirectional switches is described as a Matrix Converter. To prove the concept of Matrix Converter in practical System, various application research project is conducted such as AC motor drive supplied by CMSs. Neft and Schauder in 1988 [15] has carried out the experiment successfully on vector control of induction machine using CMC.

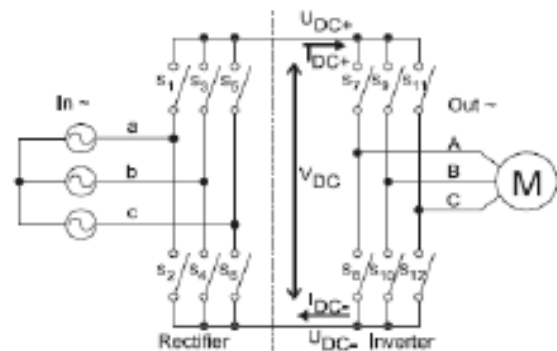
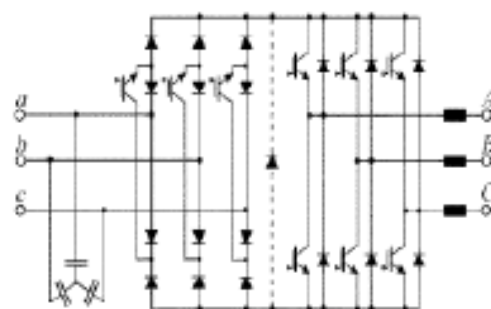


Fig.3: Indirect Matrix Converter

In 1986 Ziogas recommend an indirect MC topology, which is similar to the Voltage Source Back-to-Back Converter (V-BBC) without a dc link capacitor [16]. The indirect Mc-topology cannot provide the sinusoidal input current and it named as Fundamental Frequency Front-End Converter by Gopfrich and Reberh in 2003 [17]. This drawback is overcome in the implementation of a separate input stage for each input phase proposed in 1988 by Mino et al in [18].

The three phase to angle phase MC topology is explored by Jones and Bose in 1986. In 1997; Zuckerberger exhibit the operating principle of a single-phase to single-phase MC [19]. The major step is taken in the 2006 by reducing the number of switches for further development of MC topology it is known as Sparse Matrix Converters as shown in Fig. 4[14]. The researcher Kolar et al' carried out the experimental results on a Very Sparse Matrix Converter [14] (Fig. 5). The same concept was proposed in 2002 by Kolar et alfor about the Sparse Matrix Converters which is known as Ultra Sparse Matrix Converter as shown in [36] (Fig. 6).



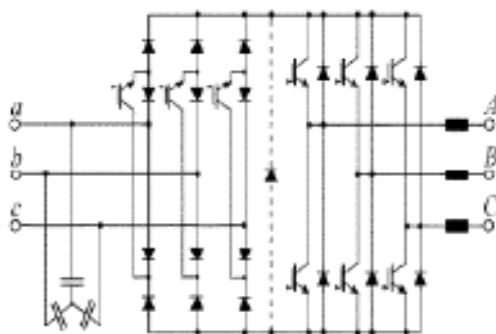


Fig.4: Sparse Matrix Converter

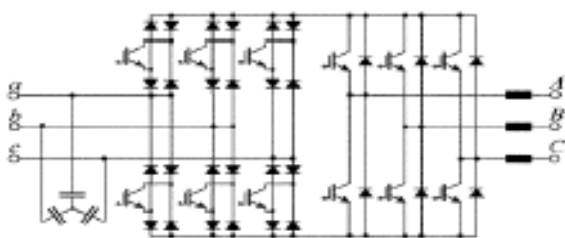


Fig.5: UltraSparse Matrix Converter

**B. Z Source Matrix Converter Topologies**

The both Voltage-source Matrix converter and the Current-source Matrix converter have the following common problems.

- 1) The Z-source matrix converter is cannot act as a Buck-Boost converter but it acts as a either buck converter or boost operation. That means, the buck and boost converter has limited output and it is a smaller or greater than the output range.
- 2) Their main circuits cannot be interchangeable because it cannot be act as an I-source as V-source converter or vice versa. That is in other word neither the V-source converter main circuit can be used for the I-source converter and vice versa.
- 3) They have vulnerable to EMI noise in terms of reliability.

The above problems of conventional Voltage-source and Current- source converter is overcome by an impedance-source (or impedance-fed) power converter (known as Z-source converter). The control method of impedance power converter is implementing dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion has been recently explored in Ge and Peng [11]. The Fig. 7 and Fig. 8 shows the Z-source matrix converter (ZS-MCs), which consist three parts such as source-side MC, Z-source network, and load-side MC. The Z-source inverters has two type can be a voltage-fed and current-fed types. The Voltage fed Z-source matrix converter is shown in Fig. 6, while in Current-fed Z-source matrix converter in fig. 7. The main feature of the ZS-MCs is to

satisfy for both buck and boost operation. That is, they can step down or step up the source voltage. The simplified current-fed ZS-MC is display in Fig. 9 in that figure the source-side MC in Fig. 7 is replaced by a three-phase ac switch  $S_0$ . The operation of simplified voltage-fed ZS-MC is same as the traditional VS-MC in Fig. 1 when the three-phase switch  $S_0$  is kept on,

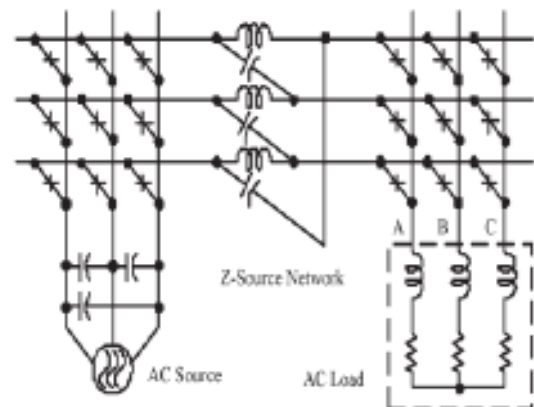


Fig. 6: Voltage Fed Z-source Converter

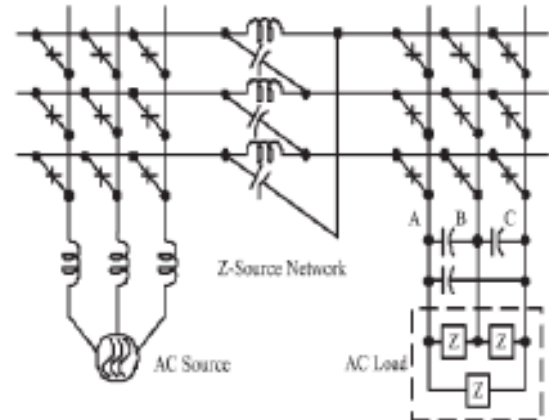


Fig. 7: Current Fed Z-source inverter

For producing the active voltage and zero voltage to the load, which is nothing but a buck mode. The voltage boost is required the shoot-through state is inserted in the PWM pulses of MC. To avoid the short circuit at input side, the three phase switch is turned off during the shoot through state. The voltage is boosted with some distortion of original indented output voltage waveform by shooting-through the MC during the zero-voltage switching states. The longer shoot-through interval is obtain the greater the output voltage. Also, it has minimum number of switching count compared with current fed Z-source inverter. The simplified

current-fed ZS-MC in fig. 10, in which the source-side MC is replaced by a three phase switch.

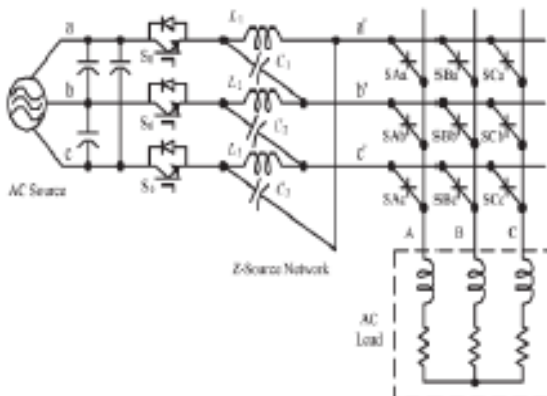


Fig. 8: Simplified Voltage Fed Z- Source Inverter

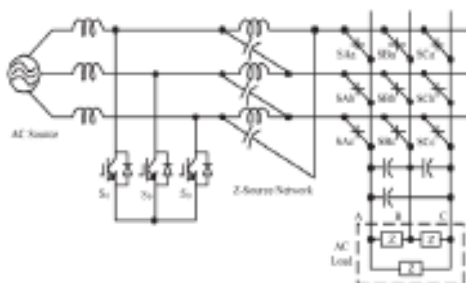


Fig. 9: Simplified Current Fed Z- Source Inverter

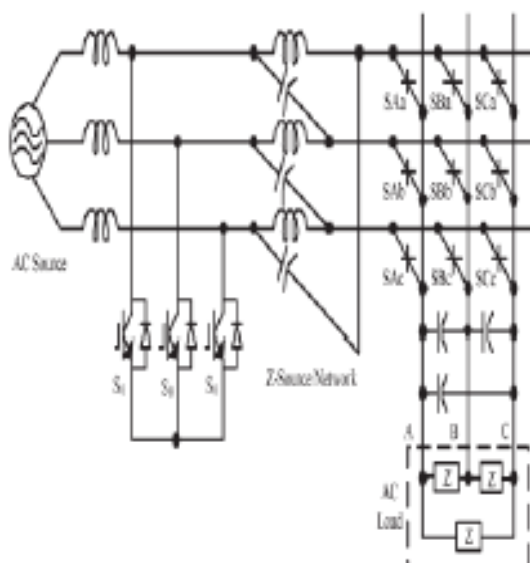


Fig 10: Simplified Current-fed Z Source Matrix Converter

The voltage-fed and current-fed quasi-Z-source matrix converters (qZS-MCs) is display in fig. 11. The operation of the quasi Z-source MC is similar to the simplified ZS-

MCs. The feature of quasi Z-source MC have infinite voltage gain and minimum number of source network..

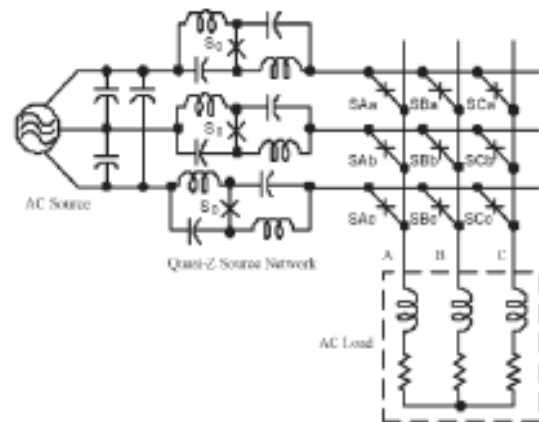


Fig. 11: Voltage Fed Quasi – Z source Inverter

### III POWER SEMICONDUCTOR DEVICE

#### A. Bidirectional Switches

The possibilities of the implementation the bidirectional switch with IGBTs are presented in Fig. 12[34]. The configuration in Fig. 12(a) include only one active switch. However, it cannot be used in MCs with most safe commutation methods. IN figure12.(b-F) configuration have minimum number of conducting component in supply to load current path than first configuration. That's why it can be used for two stage MC topology. The common-emitter and common-collector configuration and their combination are the more popular in MC switches. [1]. The both common-emitter and common collector have a single active switch and a single diode conducting per output phase. The only difference is the number of required isolated emitter potentials. A common-collector switch-based DMC requires six isolated gate control units while the common-emitter-based DMC requires nine isolated gate control units. That's why always common-collector switch-based DMC is preferred.

The separated series combinations of diode and switch in fig. 12 (d-e) are not mostly used than previous two and they have similarities with the switches required in the current source converter (CSC). However, differences arise with the number of isolated gate drivers: with the DMC, the configuration in Fig. 15(d) requires eighteen isolated gate drivers and the configuration in Fig. 15(e) requires only six, as in the common-collector configuration.

The similarity between the MCs and the CSCs is providing the benefit due to the RBIGBTs Fig. 15(f) [18].The concept a single RBIGBT conducting per output phase. The result of full DMC system with 18RBIGBT are explored and voltage is lower than 400 V, e.g. in [19], [20]. In addition, there seem to be differences which depend on the manufacturer who's RBIGBT are applied in each case.

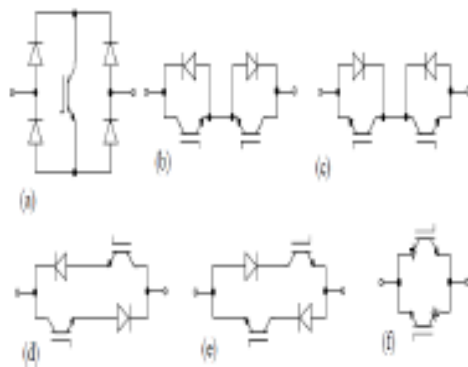


Fig. 12: Bidirectional switch configurations in practice: (a) switch and Diode Bridge, (b) common-emitter, (c) common-collector, (d) diode and switch in series, (e) diode and switch in series and (f) anti parallel RBIGBT configuration.

### B. Integrated Power Module

The common emitter bidirectional power switches cell is possible to design using discrete components, but it is also possible to design a complete matrix converter with six pack IGBT module. This technology can be used to develop a full matrix converter power circuit in a single package. This has been done by Eupec using devices connected in the common collector configuration as shown in Fig. 12 [21] and is now available commercially.

## IV Conclusion

IN AC drive application Matrix Converter is widely used as compare to the other conventional Matrix Converter. Matrix converter circuits offer various advantages such as 1. **Suppression of power harmonics:** Realizes less than 7% THD of input current and more than 98% input power factor without any specific measures taken. 2. **Longer operating life:** The main circuit does not contain the sophisticated parts such as capacitor, that's making increase the operating life of main converter and also increase the maintenance time.

3. **Elimination of derating:** With the elimination of current constriction on any specific device, the reduced operation during low-frequency operation is unnecessary. 4. **Power regeneration:** Unique bi-directional switches provide the continuous regeneration. **High-efficiency:** Due to the connection of bidirectional switches to the power supply and load, it allows higher efficient operation as compare to the conventional converter. However the various researches explored the various application of Matrix converter from last three past year decades. The reason for the same till now is the low input to output voltage transfer ratio of 86%. But a major future task of research is seen to use recently proposed Z source converter topology to improve the voltage transfer ratio of matrix converter.

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