A Survey on Topologies and Controls of Z-Source Matrix Converter

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***Abstract*--This paper describes the Z-source matrix converter (ZS-MC) topology which specifically discusses topology and control on the ZS-MC. There are two topologies on the ZS-MC, namely Z-source direct-MC (ZS-DMC) and indirect-MC (ZS-IMC). The difference of each of these topologies is in the number of switching mosfets, where ZS-DMC put on nine switches, while ZS-IMC eighteen switches. ZS-IMC topology overcomes the limitations of traditional MC voltage reinforcement and accommodates the operation of buck and boost converter by reducing the number of switches and providing high efficiency.**

Keywords--- Z-source matrix converter (ZS-MC), Z-Source direct matrix converter (ZS-DMC), Z-Source Indirect matrix converter (ZS-IMC), Topologies, Modulation, Control

I. Introduction

There are several converter techniques, namely ac-to ac converters which are often called cyclo-converter, dc-to-dc converter, dc-to ac inverter, and rectifier ac-to dc from some of these techniques, how it works with directional models. The classification of the model is a weakness that can only work in one direction, so there are still many stress losses [1]. Therefore the emergence of a matrix converter, matrix converter topology is promising for universal power conversion. The converter matrix offers several significant advantages, like a power factor that can be adjusted. ac-to ac matrix converter topology provides a transformation system for both amplitude and frequency simultaneously in multi-phase voltages without the use of energy storage [2]. Matrix converter can produce sinusoidal signal input current and output frequency higher than input frequency [2][3]. There are two matrix converter topologies including direct matrix converter (DMC) and indirect matrix converter (IMC), DMC can convert voltage and current in one step by using a bidirectional switch that is controlled [4].

As an alternative IMC has a two-stage power conversion with an input stage with six bidirectional switches. The constraints on this topology are voltage reinforcement. therefore z-source topology has high performance and can operate at various load susceptibility [5], by implementing the Z-source network to the conventional three-phase matrix converter utilizes the boost operation, so that the transfer ratio of voltage reached by combining the two topologies to design the Z-source matrix converter (ZS-MC).

ZS-MC does not use a complicated turnover strategy because the Z-source matrix converter intentionally employs the short circuit that is avoided in the conventional matrix [6][7]. Z-source matrix converter is divided into two, namely Z-source indirect matrix converter (ZS-IMC) and Z-source direct matrix converter (ZS-DMC). The operation of the ZS-MC is explained by two modes, such as shoot through zero states and non-shoot through the states. In this paper discusses topology and control in ZS-MC. Section II discusses ZS-MC method, by applying Z-source to utilize the voltage ratio gain feature. Section III discusses ZS-IMC which explains the configuration, control, modulation, and the development of ZS-IMC which is quasi Z-source indirect matrix converter. For section IV discusses the ZS-DMC which consists of configuration, control, and modulation. In section V it represents the two topologies, ZS-IMC topology overcomes the limitations of traditional MC voltage reinforcement and accommodates the operation of buck and boost converter by reducing the number of switches and providing high efficiency.

II. Z-Source Matrix Converter Topologies

ZS-MC is a new topology that implements the Z-source network (ZS-N), to overcome the limitations of the voltage transfer ratio that has been carried out on conventional matrix converters. The converter uses an exclusive impedance network on the main circuit of the converter to the main power source to create the operation of buck and boost [8]. Deploying the ZS-N to utilize the voltage ratio gain feature is intended to remove complicated switching strategies because ZS-MC deliberately uses the short circuit that is avoided in conventional matrix converters. Fig.1 is a scheme of ZS-MC.

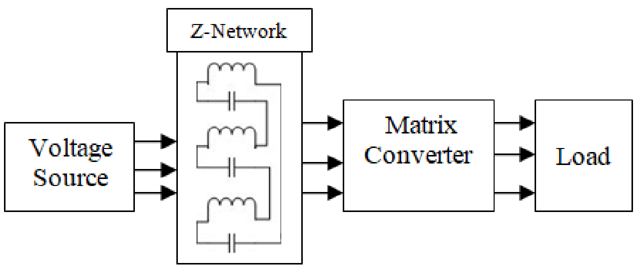

Fig. 1. ZS-MC scheme

Fig. 2 shows the structure of the ZS-MC. There are two structure, namely ZS-IMC and ZS-DMC. The ZS-IMC has been possibly developed as Quasi ZS-IMC.

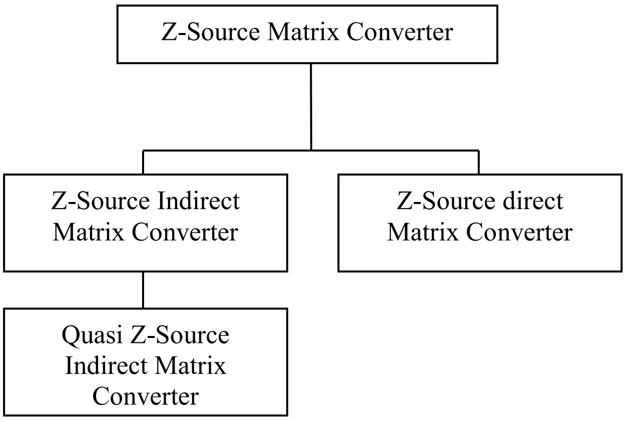

Fig. 2. ZS-MC classification

III. Z-SOURCE INDIRECT MATRIX CONVERTER

ZS-IMC has 18 bidirectional switches that convert voltage and current in one step as development for a choice to matrix converter. This configuration is made of two conventional converters combined together; this indirect converter circuit has two stages. The first stage is the rectifier and the second stage is the inverter. Two switching cells form rectifier for the proposed topology.

A. *Configuration of ZS-IMC*

The topology of ZS-IMC is illustrated in Fig 3. The fundamental idea of the ZS-IMC is a separation in three stage for AC/AC conversion: In the Z-source, the rectifier stage is constructed from six switches, two directions are constructed with 18 switch directions [9][10], while the inverter level has six feedback. a two-port circuit consisting of a capacitor separator L4 and L5 and C4 and C5 connected, form X is used to provide the source of the combined impedance of the router level to the inverter stage, section S1 is used bidirectional [11].

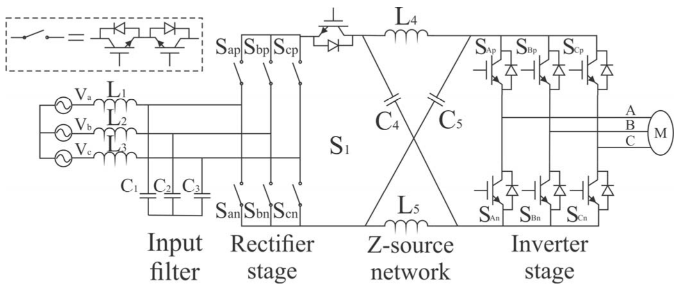

Fig. 3. Topology configuration of ZS-IMC [11].

B. *Control of ZS-IMC*

The ZS-IMC consists of three parts: the source-side Matrix Converter, Z-source network, and matrix converter side-load [2], [12], [13]. The most important aspect of ZS-MC is to execute the operation of buck and boost converter. The topology can increase and decrease the output voltage compared to the input voltage. Each ZS-IMC utilizes 18 ac switches, so in practical it will be difficult to direct implementation [14]. However, this gave us the finishing point for the proposed topology and assisted us to conclude several practical ZS-MCs. Fig. 4 shows an example of simplified ZS-MC, where the MC source-side in Fig. 3, substituted by three-phase AC switch symbolized as S0 When S0 is stored, then the operation of simplified ZS-MC is the same as traditional VS-MC procedure [9], [15]. An active voltage and zero voltage to the shoot-through status load is produced and included in the PWM MC, and the S0 is in off position during the shoot-through status. As the interval of the shoot-through become longer, then the output voltage becomes greater and increase. The proposed mechanism clearly reduces the number of switches, compared to the combination shown in Fig. 4.

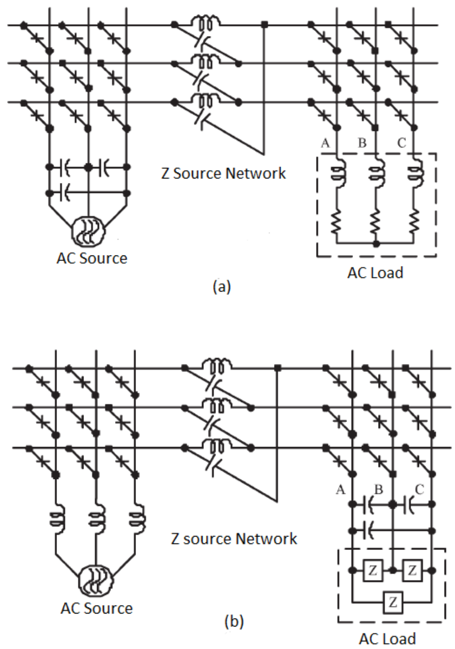

Fig. 4. ZS-IMC (a) Voltage-fed, (b) Current-fed [16].

C. *Modulation Techniques on ZS-IMC*

Modulation techniques used in ZS-IMC use carrier-based pulse width modulation (PWM) compared to space vector modulation (SVM) techniques. Another technique proposed with space vector, in the switching period to minimize harmonic generation in the output waveform. therefore it takes overmodulation, the result of over modulation on the inevitable low-order harmonics produced in the output. Harmonic generation in the vector space d2-q2 results in increased losses. minimize harmonic attention as the desired output is in the over modulation area [17].

The development of ZS-IMC that has been carried out by [18] is a Quasi-Z-source indirect matrix converter (QZS-IMC). By utilizing the Z-source network to integrate filter functions so that they do not require an input filter. The QZS-IMC topology is shown in fig. 5. From this series it can be seen that there is a combination of one switch two inductors L1 and L2 and capacitors C1 and C2. It can overcome the voltage ratio, consisting of two stages of correction and inversion stage. But the results are not easy for system integration and manufacturing processes.

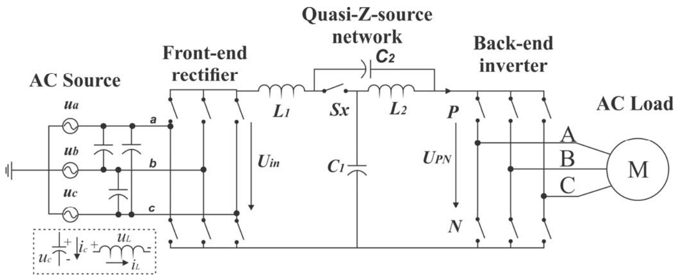

Fig. 5. Quasi Z-Source Indirect Matrix Converter

IV. Z-SOURCE DIRECT MATRIX CONVERTER

ZS-DMC has nine bidirectional switches that convert voltage and current in one step. The basic configuration of ZS-DMC [19][20]. It consists of ZS-N and three phase matrix converter connected between load and Z-source. The matrix converter has nine bidirectional switches and each bidirectional switch has two IGBT connected in anti-parallel [21]. The ZS-DMC is explained by two modes i.e. shoot through zero and non-shoot through state [8].

A. Configuration of ZS-DMC

The configuration of ZS-DMC shown in Fig. 6, has three main parts, namely, the AC input source, Z-source network, and load. A different level for step-up the voltage on the output side is executed by making a control mechanism the short circuit between the input phases. The ZS-N contains six capacitors, six inductors, and three bidirectional switches. All three switches must have the same status [22].

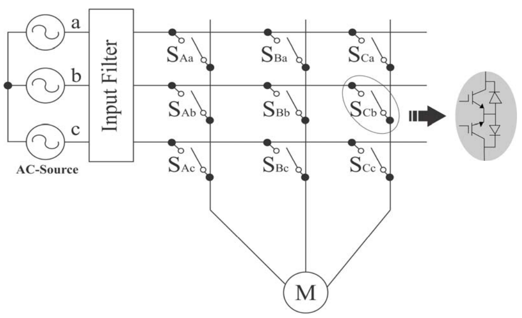

Fig. 6. Main circuit of Z-source direct matrix converter [23]

B. Control of ZS-DMC

The utilize the boost feature, ZS-DMC mechanism is carried out in two different states i.e. a shoot-through zero state as in Fig. 7 and a non-shoot-through state as shown in Fig. 8 [24]. During the shoot through the state, switches S1, S2, and S3 are off, which is Sz=0 for boosting operation. During the non-shoot through state, switches S1, S2, and S3 are on, which is Sz=1 for normal operation [25]. It is assumed that the inductors L1, L2, and L3 have the equal inductance value and capacitor C1, C2 and C3 are in identical capacitance. By this configuration, the symmetrical-N is created.

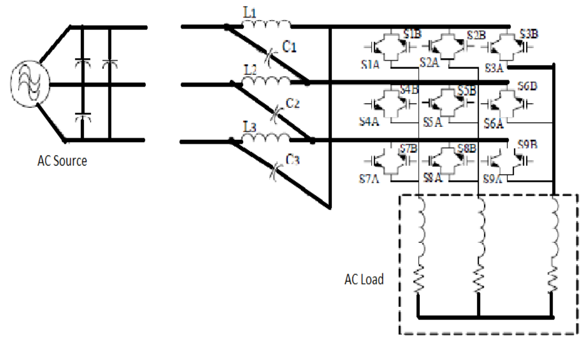

Fig. 7. ZS-DMC in shoot through zero state

Fig. 7 shows the configuration of the shoot-through state for the proposed topology at interval of T0 during a period of switching process [26]. The matrix converter by design is short-circuited and all switches S1, S2 and S3 are in off position. In Fig. 7, the reconfiguration of equivalent circuit deduces the voltage transfer ratio, by making assumption that there is a symmetrical three-phase system and expansion of input and output voltages.

ZS-DMC is in the non-shoot-through state at T1 interval during a period of the switching process, T [27][28]. Fig. 7 shows the configuration circuit for the non-shoot-through state.

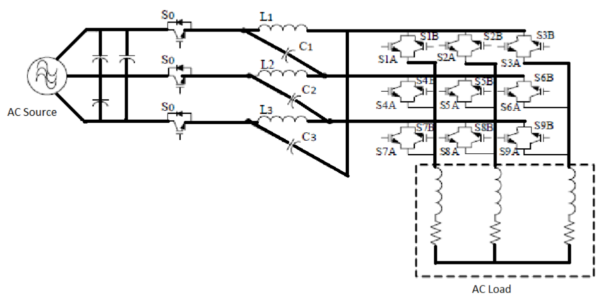

Fig. 8. ZS-DMC in non-shoot-through-state

C. Modulation Techniques on ZS-DMC

ZS-DMC uses the modulation space vector method. According to the principle, where each two-phase input does not get a short circuit and must make a closed loop formation. For six active vectors and three zero vectors, there are nine switches to use. Improved performance of ZS-DMC using a different PWM modulation method. have the appropriate PWM schema that is capable of achieving the maximum susceptible output voltage. Minimize harmonics at the output and input currents, providing maximum efficiency [29]. ZS-DMC is the distribution of shoot through the traditional PWM modulation concept. In this section the carrier PWM and space vector based on pulse width modulation schema (SVPWM) [30]. By comparing the two modulations, the THD input current and THD voltage from the SVPWM scheme is 1.2% and 8% lower than PWM, so it shows that SVPWM is suitable for ZS-DMC.

Both of the topologies, ZS-IMC and ZS-DMC in each configuration and control using SVPWM modulation are presented in Table I.

TABLE I. Comparison between ZS-IMC and ZS-DMC of topologies using SVPWM modulation

Type	Configuration	Control
ZS-DMC	by two modes, Shoot through zero state and Non-shoot through state	ZS-DMC has nine bidirectional switches that convert voltage and current in one step
ZS-IMC	two stage rectifier and inverter	Each ZS-IMC requires an 18 ac switch, which makes it difficult to use directly

V. CONCLUSION

This manuscript outlines a literature review on different Z-source matrix converter (ZS-MC) topologies, including Z-source indirect matrix converter (ZS-IMC) and Z-source direct matrix converter (ZS-DMC). ZS-IMC topology overcomes the limitations of traditional MC voltage reinforcement and makes the operation of buck and boost by decreasing the number of switches to obtain high efficiency, reliability and low cost. ZS-IMC topology is very suitable for research and applied in industry.

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