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Modern Z-Source Power Conversion Topologies: A Review

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Abstract— *Morden Z-source power conversion topologies are presents in this paper. The concept of the Z-source network introduced to overcome the limitations of the earlier developed V-source and I-source network. The V-source and I-source network either perform buck or boost operation but not both, hence extra additional network is required to achieve the desirable output. The Z-source network overcome all the barriers of the conventional V-source and I-source network by using the configuration of LC components. The ZS network have several benefits such as buck-boost functionality, power factor correction, reduced THD and reduced of passive components. Hence, this network become popular because of its specific features and its power conversion functionality such as ac-dc, dc-ac, dc-dc and ac-ac. Several modifications of Z-source network are introduced since it developed, with their unique feature in each and every modification as presented in this paper.*

Index Terms: *V-source, I-source, Z-Source, quasi-Z-source,* Embedded Z-source, Trans-Z-source and Γ-Z-source, LCCT Z-source.

1. INTRODUCTION

Electricity demand exponentially increases in the various field due to new technical invention in multiple sectors. During these upcoming days, the need of utilization of renewable energy source become a popular issue due to shortage of non-renewable resources, easy availability and low cost of renewable resources. The conventional source such as coal, diesel, water, fuel widely used in energy conversion, these sources are mutually coupled with various power converter such as rectifiers, inverters, choppers, voltage regulators and so on. In case of renewable energy, the output power generate is dc, hence it may be converted in ac or dc. Basically, there are two main traditionally converters; Current source converter and Voltage source converter [1]. These converters are very popular, in earlier days because of industrial application needs but have some common drawbacks such as V-source and I-source are either buck or boost converter, the main circuit of V-Source and I-source converter are not interchangeable due to their designing. Also, their reliability and efficiency is affected by EMI noise. To overcome these limitation, the concept of Z-source was introduced by a researcher in 2003 [2].

The Z-source converter has following benefits; reduced THD, inrush current, providing high gain, with improved switching scheme, and also provide buck and boost operational state as per the application. The Z-source network is popular due to its power conversion capabilities, it covers entire power conversion ac-dc, dc-ac, ac-ac and dc-dc. [3-6] The Z-source converter further be modified as quasi Z-source converter [7-9], embedded Z-source converter [10-11], Trans-Z-source [12], Γ-Z-source converter [13-14], and LCCT Z-source converter [15-16]. All the above Z-source converters are discussing in section III and IV.

2. CONVENTIONAL CONVERTERS

2.1 Voltage Source Converter

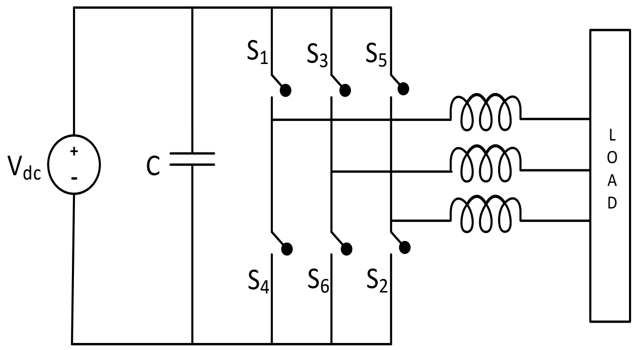

Fig-1: Conventional Voltage Source Topology

The Conventional V-source converter fed by dc-voltage source that may be battery, capacitor, renewable source, or diode rectifier. Fig-1 shows the traditional Voltage source topology; it consists of dc-voltage source linked with capacitor. The dc-link capacitor used in VSI act as a low impedance voltage source, and provide buck operation. The main purposed of designing voltage source converter is low power applications. However, the V-source converter has some drawbacks such as extra dc-dc network required to step up the output voltage, shoot-through problem due to EMI noises, which is harmful for reliability of converter and an output LC filter is also required for filtering the output which produced control complexity. It is also dangerous because of parallel capacitor feeds more powering to the fault.

2.2 Current Source Converter

The conventional I-source converter consists of large dc inductor fed by sources such as battery, fuel cell, and diode converter. The I-source converter acts as a boost converter for dc-ac conversion, since the input voltage is less than the output voltage. I-source converter is buck converter for ac-dc power conversion. The I-source converter produces EMI noise's due to open circuit problem. Fig-2: shows the conventional current source topology.

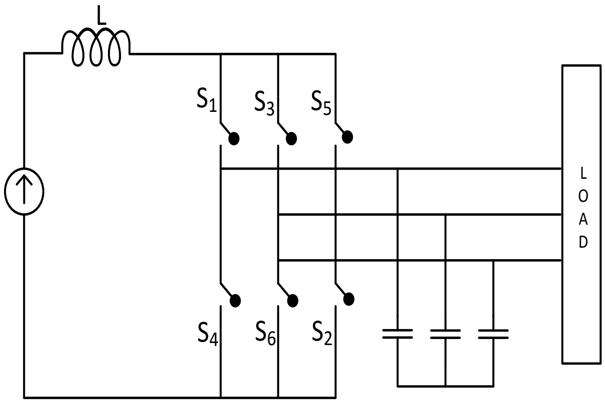

Fig-2: Conventional Current Source Topology

Overlap time for safe current commutation is needed in current source converter which also causes waveform distortion, etc. The main circuit of the converter is not interchangeable and mis-firing of switches are acceptable.

3. Z-SOURCE NETWORK WITHOUT MAGNETIC COUPLING

3.1 Traditional Z-source Network

Z-source converter based on LC network to couple the main converter circuit to power source for buck and boost operation which is not possible in V-source and I- source converter. The ZS network contains two inductor L_1 and L_2 and two capacitor C_1 and C_2 connected in X form as shown in Fig-3. The Z-source concept is new electronic circuit recently recognized because of its application and has following advantages; it provides large range of input current, high voltage gains, and also provide novel power conversion concept.

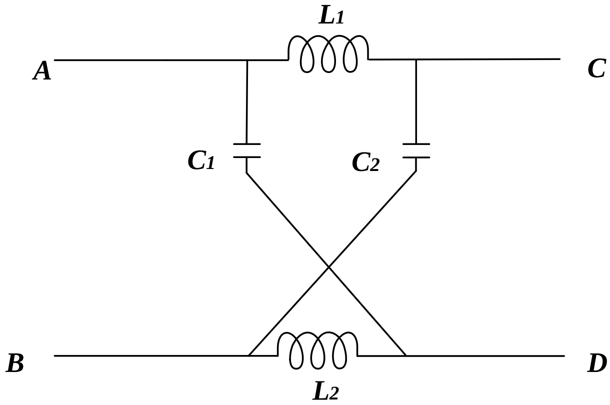

Fig-3: Basic Z-source Converter

3.2 Quasi-Z-source *Network*

Fig-4 shows the general quasi Z-source network. This is the first modification or the Z-source network, which eliminate the drawbacks of conventional Z-source network i.e. it provides continuous input current conduction path as well as reduces the switching stress of the switches. The construction of the q-Z-source network is done by connecting two inductor L_1 and L_2, two capacitor C_1 and C_2 and one diode D_1. Q-ZS network has several benefits such as it reduces the use of passive components reduce the inrush current in the system, enhance the efficiency and reliability of the converter.

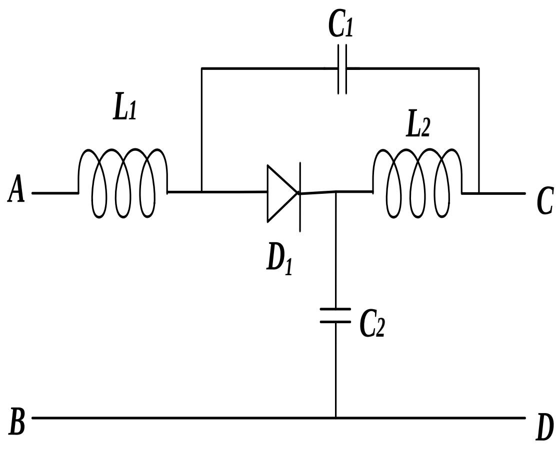

Fig-4: Quasi Z-source Network

3.3 Embedded Z-source Network

The embedded Z-source network is design to achieve continuous uninterrupted current and lower capacitor voltage rating, and multi-source feature especially suitable for PV power generation. The ZS network faces interrupted input current problem. To eliminate the ZS network problem, it needed another external LC network known as filter, which filter-out the chopping current and increases the cost of the network. To solve this problem of ZS network embedded Z-source network is introduced. This network embedded a voltage source in conventional ZS network. The operating principle and modes of the embedded network is similar to the conventional Z-source network. The main advantage of this network is to smooth the input current and eliminate the use of LC filter. However, the supply current is no longer sustained and provide asymmetrical structure which causes stress distribution among the components which is the main drawback of the embedded Z-source network. Fig-5 shows the embedded Z-source network.

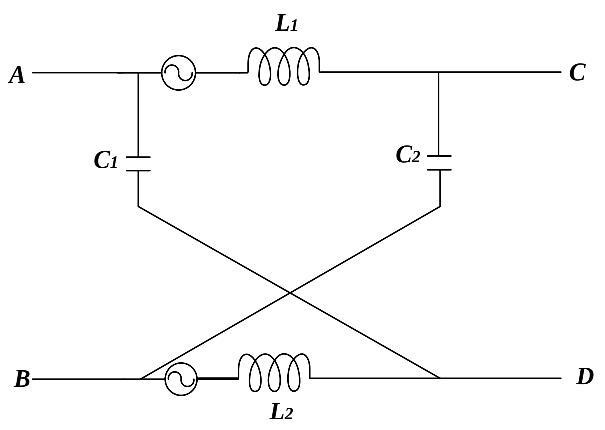

Fig-5: Embedded Z-source Network

4. Z-SOURCE NETWORK WITH MAGNETIC COUPLING

4.1 Trans-Z-source Network

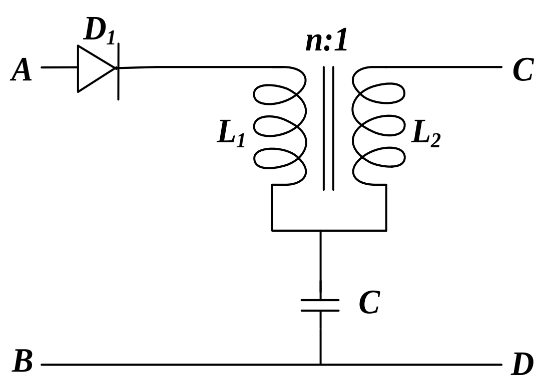

Fig-6: Trans- Z-source Network

Trans- Z-source network contain, the two-winding coupled transformer of n:1 turns and one capacitor C as shown in Fig-6. This network is designed to achieve high gain compared to conventional Z-source and q-Z-source network by adjusting the turn ratio of the transformer winding. The working principle of the Trans-ZS network is very similar to the conventional Z-source network, it also eliminates the shoot-through barriers. The trans-Z-source network has additional merits such as; able to operate on very low supply voltage, voltage stress is reduced, and the voltage gain is maximum.

4.2 Γ-Z-source Network

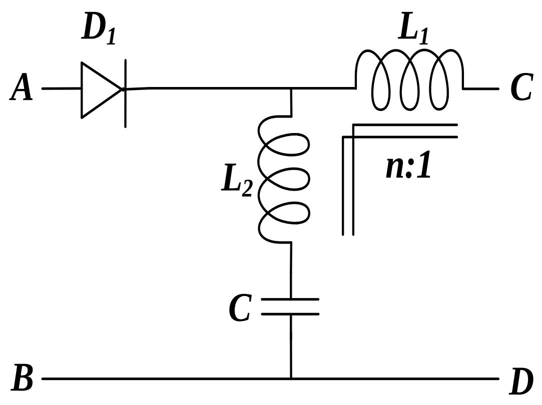

Fig-7: Γ-Z-source Network

The Γ-Z-source Network designed by unique Γ shaped, which consists one capacitor and two windings coupled transformer which also implementing in impedance network. This unique design increases the gain and modulation ratio simultaneously and reducing the number of component. In the other Z-source network such as Trance-Z-source and LCCT Z-source, the gain is increases by increasing *the turn ratio. Whereas, the Γ-Z-source* network turn increases by decreasing turn ratio. Fig.7 shows the Γ-Z-source Network.

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4.3 LCCT Z-source Network

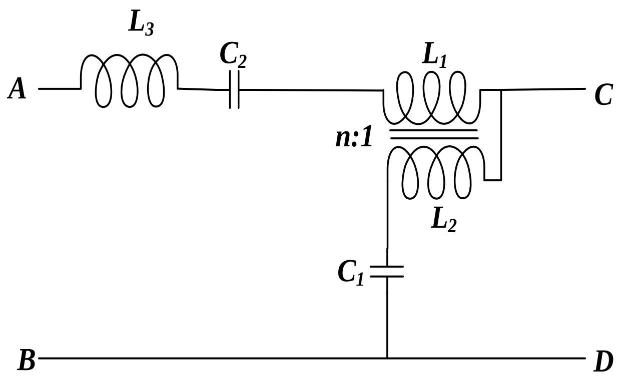

Fig-8: LCCT Z-source Network

The LCCT network stands for inductor-capacitor-capacitor transformer as shown in Fig-8, it designs by integrating inductor and transformer into a common core and achieve high voltage gains and modulation index. This topology maintains continuous current even in light load and also filter out HF ripples from the input current. The unique feature of this topology is that the transformer does not store any energy and the core of the transformer free from saturation because of the capacitor C_1 and C_2.

TABLE-1: Analysis of Z-Source Network

Z-source Network	No. of semi-conductors	No. of passive component	Features
Z-source	-	Two capacitor and two inductor	• Overcome the VS and CS barriers • Discontinuous input current • Inductor of ZS network sustain high current
Quasi-Z-source	One diode	Two capacitor and two inductor	• First modification of ZS network • Continuous input current • Reduce passive component ratting
Embedded Z-source	-	Two capacitor and two inductor	• Draw smooth current from source without adding extra component
Trans-Z-source	One diode	One capacitor and two integrated winding	• Increase voltage gain compared to ZS and q-ZS network • Reduced component stress
Γ-Z-source Network	One diode	one Integrated two winding	• High gain can achieve by lowering turn ratio • Better performance of converter
LCCT Z-source	-	one inductor and 2 winding coupled inductor	• Continuous current during even light load • Filter out HF ripple from source current

5. CONCLUSION

This paper presents the concept of modern power conversion topologies of Z-source network, which is designed to overcome the traditional voltage source and current source limitations. The modified Z-source network has high reliability and efficiency, buck boost functionality, inverting and non-inverting phase delay, unity power factor and also reduced total harmonic distortions. This network become popular because of its specific features and its attractive power conversion functionality such as ac-dc, dc-ac, dc-dc and ac-ac.

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