Review on Impedance Network Converters

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ABSTRACT

This paper presents conventional inverters, voltage source inverter (VSI), current source inverter (CSI) and impedance source inverter (ZSI). The drawbacks of VSI and CSI during shooting through state, advantage of ZSI as booster during shooting through is presented. Different types of impedance sources and their output equations are also indicated. Step by step proofs of mathematical relations is presented for the proposed impedance source inverters.

Key words: VSI, CSI, ZSI, shooting through

INTRODUCTION

DC-AC converters /inverter is used to converter dc input into ac output. Different types of inverter topologies are used to convert dc into ac. However, the size of the converter, switching circuit, efficiency and the cost of the converters must be considered to design suitable converter. Voltage source inverters and current source inverters are ordinary inverters used either as buck or boost converter due to shooting through problem.

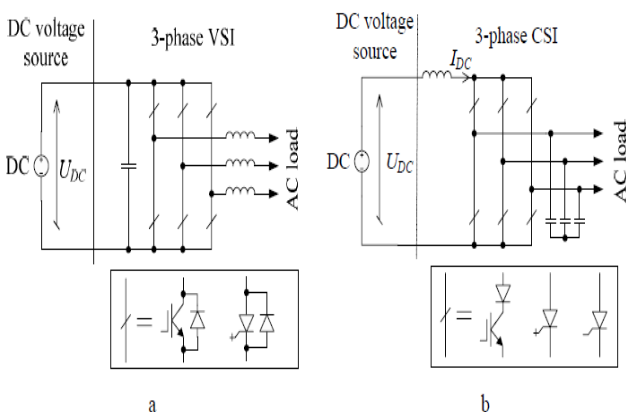


Figure 1: Conventional inverter systems: a) VSI; b) CSI

Impedance source inverters are designed to boost the output during shooting through. A - Source inverter is an impedance source inverter used auto transformer proposed to solve the drawbacks of other impedance source inverters. In this paper, different types of impedance source inverter, the comparisons of voltage source inverters, current source inverters and impedance source inverters is presented.

INVERTERS

Inverter circuits converts direct current in to alternating current (DC to AC) by the switching operations of electronic devices and components. Depending on the switching circuits and different topologies, inverters are available with increasing efficiency and compatibly to their industrial and commercial applications.

PWM DC-AC converters

The switching operation of PWM DC-AC depends on pulse width modulated signal fed to switching circuit. DC- AC converters broadly classified as voltage source converter and current source converter based on their specific characteristics [1]. Converter design improvements are continued with technology demand grows. Conventional inverters are as shown in Figure 1 (conventional voltage source in Figure 1a and conventional current source inverter in Figure 1b). According to the

Author, the main disadvantage in case of voltage source inverter is the output voltage is only decreasing (V≤VDC/1.73) and problems in short circuit branches. In case of current source inverter, the output voltage is only increasing (Um≥ UDC/1.73), this leads difficulty in using IGBT in module. Open circuit problemoccurs.EMI distortion damages inverters due to open circuit and short circuit in branches of conventional inverters.

The range of voltage regulation can be increased

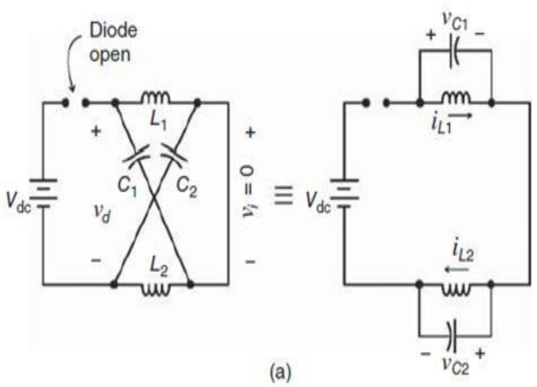


Fig 1.a:Conventional inverter systems: a) VSI

using output transformer or DC/DC converter to improve regulation problems of conventional converters. The addition of output transformer's problem is increased overall dimension; heavy weight and transformer's ratio limits range of regulation.

DC/DC converter used to increase the range of voltage regulation range additionally in conventional inverter has its own disadvantage: two stage of energy conversion, increased cost due

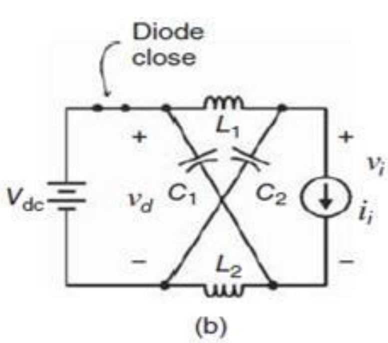


Fig 1.b:Conventional inverter systems: b) CSI

to two-stage conversion circuit and additional overall circuit, voltage source inverter and current source inverter cannot replace one another and vice versa. This leads to further adjustment.

Figure 2 below shows the topology of inverters with increased range of regulation [2].

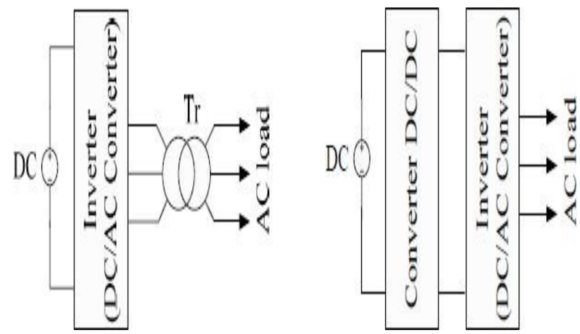


Figure 2: The inverter systems with increased range of regulation

Z-source inverters (ZSI)

Converters generally used as buck, boost or buck-boost converters. The impedance source inverters have various topologies. Z- Source inverters designed mainly for buck-boost DC-AC conversion [7][9].Z- Source inverter as shown in Figure 3 [2] inductors and capacitors connected in X-shape. According to the author, Z- source converter has higher efficiency when compared to other electronic converters in using less number of components. Considering shoot through zero state to increase boosting [2] is also important in improving the reliability. Another benefits of Z-source inverter is reduced number of components decreases cost and volume of the converter. Z-Source, buck-boost converter has operation mode with PWM of bucks and boost operation[2]

The fuel cells, wind turbines, photovoltaic (PV) arrays are the power generation topologies,plays a prominent

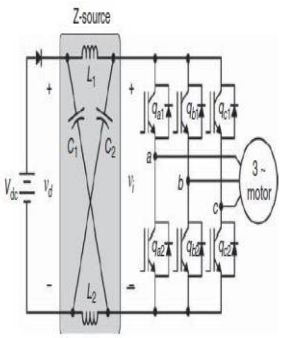


Figure 3: Equivalent circuit when short-circuited from dc point of view

role and hence its topologies had gained much importance[4][7].Z-Source circuit is a buck-boost and it operates as boost or conventional converters. When short circuit occurs on the same legs between two switches, the Z-source converter operates as boost converter since it boosts the input voltage Vdc. However, it operates as conventional converter or buck converter at the absence of short circuit.Using equivalent circuits shown in Figure 3 the author proved boost and buck operation of the Z-source converter. On the other hand, during the conventional operation (tN), yields the average inductor voltage will be increased.

The principles of operation, boosting or buck, efficiency depending on the connection and types of components , current source inverter (CSI), voltage source inverter (VSI) and Z-source inverters are summarize as shown in comparison table 1 below [6][9][11].

Current source inverter	Voltage source inverter	Z- source inverter
1.High source impedance due to the inductor used in DC link It behaves as constant current source	Low source impedance due to capacitor used in DC link. It behaves as low impedance voltage source	High impedance due both capacitor and inductor used in the DC link It behaves a constant high impedance VS
2. used only for buck or boost operation	used only for buck or boost operation	used in both buck and boost operation
3. high power loss due to filter in the circuit	High power loss	Low power loss
4. Low efficiency due to high loss	Efficiency should be low because of power loss is high	Higher efficiency
5.Momentary short circuit on load and mis- firing of switches are acceptable due to its capabilityof withstanding short circuit	Parallel capacitors feeding the fault makes more dangerous condition	Due to its combined effect mis-firing is sometimes acceptable in ZSI

Magnetically coupled impedance-sources (MCIS)

Impedance source converters with improved features are introduced with many functions. Magnetically coupled impedance source (MCIS) inverters are Z-source converters with simultaneous buck/boost operation. A magnetically coupled impedance source converter has the ability of withstanding disturbances. Magnetically coupled impedance source converter control is simple and seamless. Its voltage boost ability is higher and good in circuit integrity [5][7].There different types of MCIS such as Γ-source, T-source, and Y-source in which their voltage gains depends on the turns ratios and also have distinct voltage boost characteristics. By increasing or decreasing turns ratio the voltage gain of Y-source is increased. The voltage gain of Γ-source increases by decreasing turns ratio while T-source increases by increasing of the turn's ratio [3][7].

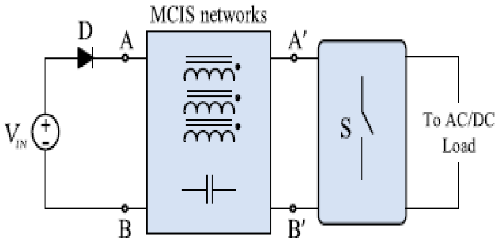


Figure 4: Generic structure of MCIS converters

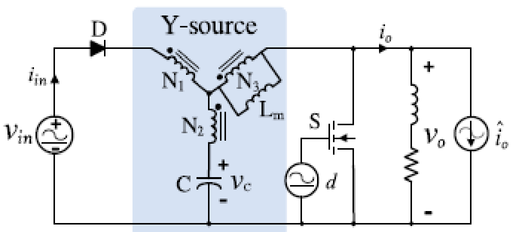
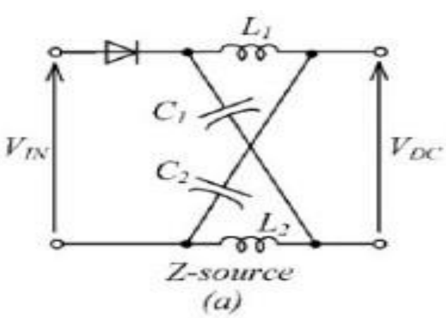


Figure 5: PWM Y- source converter with perturbation in the input voltage duty cycle and the load current

According to [4] there are different types of magnetically coupled impedance source networks.

Z-Source and Quasi Z-Source Network:

Z-source network (ZSN) and Q- Z-source network constructed (qZSN) with single and coupled magnetic components. In ZSN and qZSN core losses and winding losses are reduced and winding sizes are minimized in the number of turns as well. Fig 7a and Fig 7b present ZSN and qZSN topologies. The arrangements of capacitors and inductors are different inbothaforementioned topologies and the boost factor (B) and voltage at each component is shown in equations (2) - (5) below.



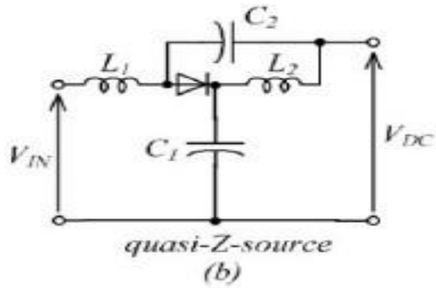


Figure 6: Z- source and quasi Z- source

The boost factor (B) of ZSN and qZSN schemes:

$$B = \frac{V_{DC}}{V_{IN}} = \frac{1}{1-2D} \quad (2)$$

Voltage stress on Z-source inverter $C1$ and $C2$ can be:

$$V_{C1} = V_{C2} = V_{IN}\frac{1-D}{1-2D} = V_C \quad (3)$$

Voltage stress in q-Z-source inverter C_1 is as (3) and C_2 is as:

$$V_{C2} = V_{IN}\frac{D}{1-2D} = V_C - V_{IN} \quad (4)$$

Voltage stress on the semi-conductors:

$$V = V \frac{D}{\quad} \quad (5)$$

A. EZ-SourceNetwork

Embedded impedance source network topology shown in Fig 7c has no magnetic component instead it featured with a multiple independent-voltage source. It is applicable for photovoltaic panels and fuel cells. It also can be used as energy storage however its demerit is asymmetrical working with asymmetrical input voltage.

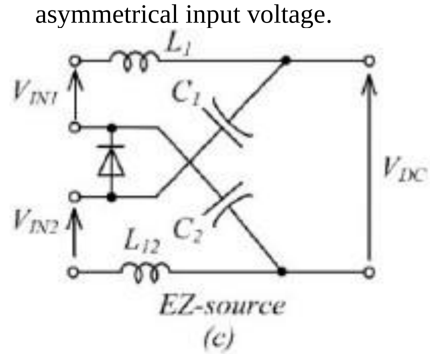
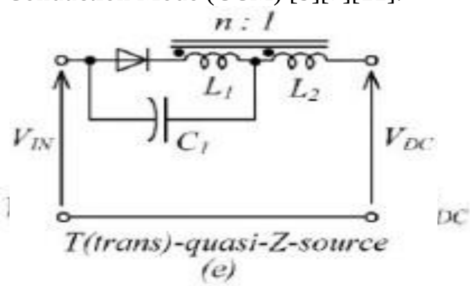
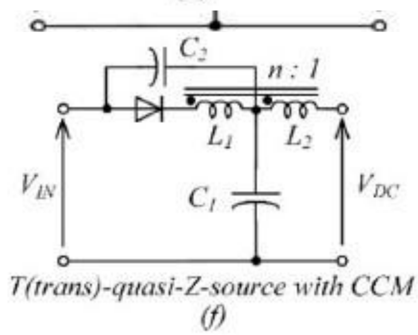


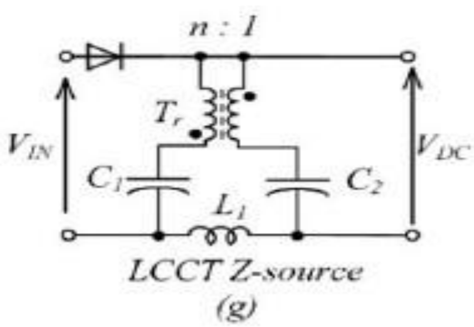
Figure 7: EZ- Source circuit

C.T (trans)-Z-Source, T (trans) - qZSN and T(trans) - qZSN withCCM

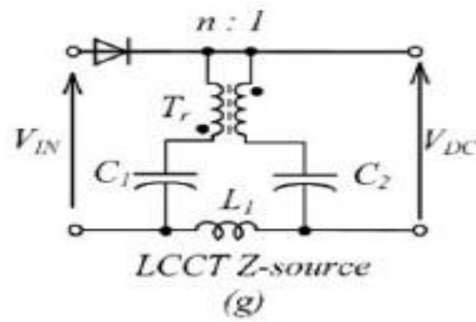
Impedance source networks shown in Fig 8d, Fig 8e and Fig 8f below are T(trans)–Z-source, T(trans)-quasi-Z-source network, and T(trans)-quasi-Z-source respectively. The topologies are Continuous Conduction Mode (CCM) [5][7][11].







D.LCCT Z-Source and LCCT Quasi-Z-SourceNetworks



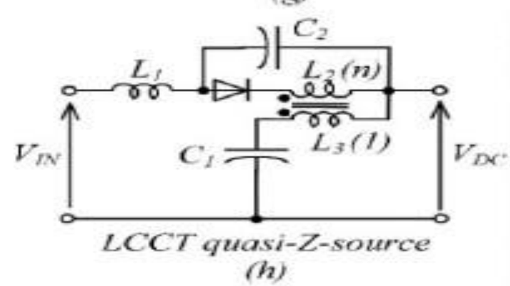


Figure
Fig.9: LCCTZ – Source and LCCT Quasi – Z- source Networks

E. Γ-Z-SourceNetwork

Impedance network shown in Fig 10 below is another topology called Γ-Z-source network, which contains transformer instead of inductors[5][7].

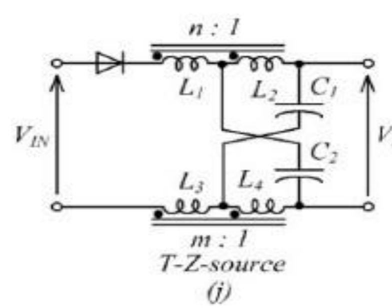


Figure 10: Γ-Z-Source Network

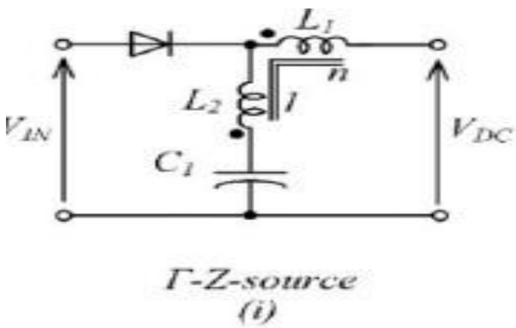
Leakage inductance in this scheme influences the voltage and current stress. This is the demerits of the scheme [3][5][7].

F. FY-Source Network

Y-source network schemes are magnetically coupled network with three winding inductors as shown in Fig 13. The boost factor (B4), voltage stresses on capacitors (Vc1) and voltage stress on semiconductor are given in equations (13), (14) and (15)respectively[5][9][11].

B. T-Z-SourceNetwork

T-Z-source network scheme is a topology containing two winding dual inductor magnetic components. It has higher boost factor due to the turn's ratio of the coupled inductor. Fig 11 below shows the network[5][7][11].



Z- Source Impedance network

Impedance network is new type of topology constructed with autotransformer. The presence of filter has its own function in filtering the harmonics during ac-dc conversion. A- Source impedance network is used for dc-ac (inverter), ac-dc (rectifier), dc-dc (chopper) and ac- ac (cyclo-converter). Fig. 12(a) shows the circuit of the A-Source impedance network. In reviewing the source [5-7], the mathematical proves shown step by step besides to the equations given reference paper [3][7][9].

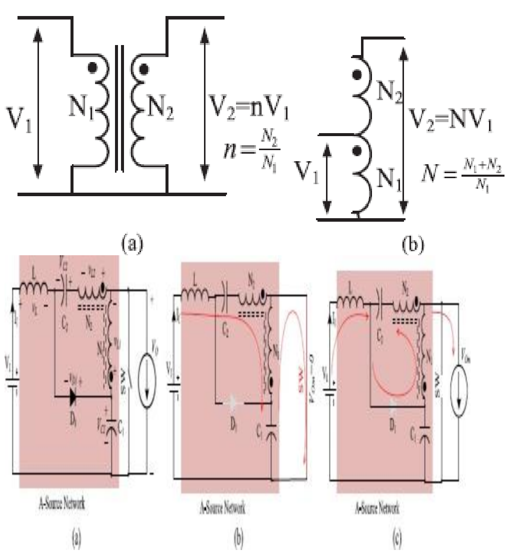


Figure 12: Illustration of (a) A – source impedance network and its equivalent circuits during

A. shoot through state:

The analytical parts of shooting state of Z- source inverter is done using the circuit indicated below. Switch is ON, Diode D is off, Vom= 0 (short circuited)

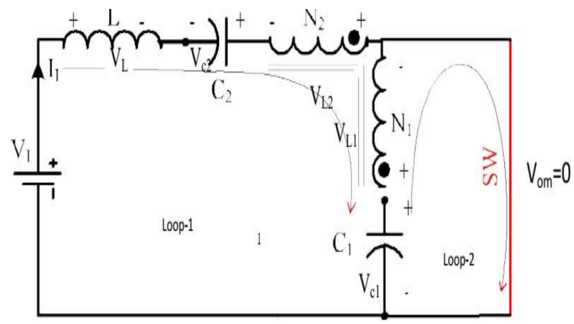


Figure 13: (a)-Shoot-through state- for the A-source converter

B. Shoot through state:

The analytical parts of shooting state of Z- source inverter is done using the circuit indicated below. Switch is ON, Diode D is off, Vom= 0 (short circuited)

C.Shoot through state:

The analytical parts of shooting state of Z- source inverter is done using the circuit indicated below. Switch is ON, Diode D is off, Vom= 0 (short circuited).

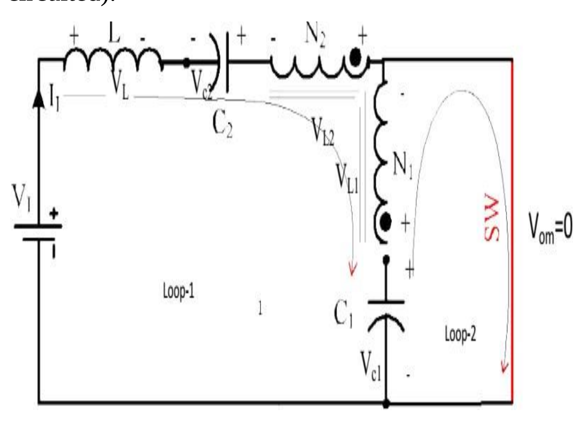
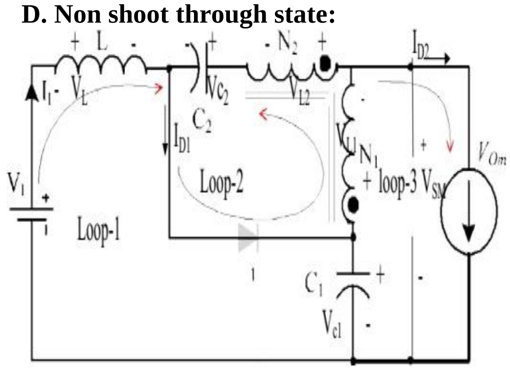
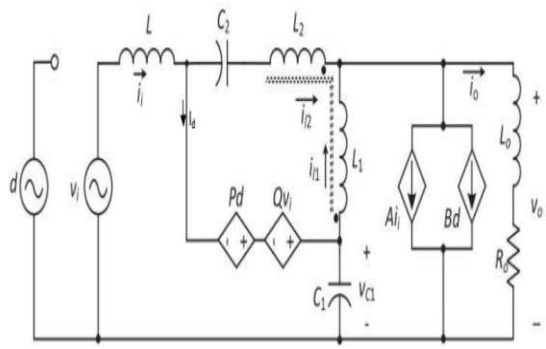


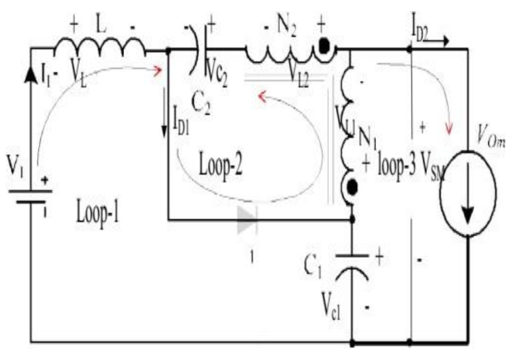
Figure 14: (a)-Shoot-through state- for the A-source onverter

D. Non shoot through state:





Switch is off, diode D is on, Vom¹ 0:



E. CONTROL TRANSFER FUNCTION

The controllable switch MOSFET in A-source impedance network indicated in small signal analysis unsing frequency domain and its control transfer function is given by replacing MOSFET by dependent current source and diode with dependent voltage source. The derivation for the quantities is shown using a series of equation below using period and duty cycles of the circuit[5][7][9].

The fundamental state equations, which are applicable to the complete small-signal model, are as follows. Applying KCL at the node connecting the diode branch, capacitor C1, and winding L1 gives,

CONCLUSION

According to the proposed converter, A- source impedance network is a type of impedance source converter using an autotransformer to realize a high voltage gain with minimum number of turn for DC-DC converter. Detail steady state analysis and the proofs for the derived equations for A – impedance network is solved and discussed in detail for shooting through state and Non- shooting through state. AC small-signal modeling of the power stage of the A-source converter is alsoanalyzed.In addition, the corresponding expressions describing, input and output components, input-to- output and input-to-capacitor dc voltage transfer functions, the expressions for the semiconductor devices and switch stresses required to ensure the continuous operation of the desired converter are derived and explained in detail. To analyze the advantages and importance of the proposed A-source converter, different types of converter VSI, CSI, and Z-source converters are reviewed and the required parameters, designing system, controlling scheme, operation system, drawbacks and converters efficiency are presented. It is concluded that A – source impedance network solves the problem of other impedance source topologies in boosting the output during shooting through state and it helps to buck and boost in both shooting through and non-shooting through states. Finally this paper is very helpful to understand principles of operation A – source impedance network and observe the functionalities and working principles of different ordinary and impedance source converters.

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