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IMPLEMENTATION OF Z SOURCE PUSH PULL DC/DC CONVERTER IN DC APPLICATIONS

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Abstract

The Z source push pull dc/dc converter is employed to reduce the switching losses by implementing zero current commutation (ZCC), zero voltage switching (ZVS), natural voltage clamping (NVC) to eliminate the need for active clamp circuits and passive snubbers required to absorb surge voltage in conventional current fed topologies. Soft switching and NVC are inherent and load independent. These merits make the converter good candidate for interfacing low voltage dc bus with voltage dc bus. Steady state, analysis, design, simulation and experimental results are presented.

Keywords: NVC(Natural Voltage Clamping), ZCC (Zero Current Commutation), ZVS(Zero Voltage Switching), ZCS (Zero Current switching), FCV (Fuel Cell Vehicle), EV (Electric Vehicles), ESS (Energy Storage System).

I. Introduction

A z source is a type of power inverter, a circuit that converts direct current to alternating current. It works as a buck-boost inverter. The source can be either a voltage source or a current source. The DC source of a Z source inverter can either be a battery, a diode rectifier or a fuel cell stack or a combination of these. It works as a buck-boost inverter. The load of a Z source network can either be inductive or capacitive or another Z-Source network. A DC/DC converter is employed to convert one voltage level to another voltage level. These are used everywhere in our day to day life in cellular chargers, laptop chargers etc.

Bi-directional converter with high boost ratio and high efficiency is required to connect the low voltage Energy Storage System (ESS), fuel cell vehicles (FCV) and high voltage dc-link bus. Compared with non-isolated topologies, high frequency (HF) transformer isolated converters are preferred with merits of high step up ratio, galvanic isolation and flexibility of system configuration. HF transformer isolated converters could be either voltage fed or current fed.

The voltage fed converters have low switch voltage ratings enabling the use of switches with low on-state resistance. This can significantly reduce the conduction loss of primary side switches. However voltage fed converters fed from several limitations, i.e. high pulsating current at input, limited soft switching range, rectifier diode ringing, duty cycle loss(if inductive output filter), high circulating current through devices and magnetics, relatively low efficiency for high voltage amplification and high input current applications.

II. Related Work

Emadi et al 2006 [1] developed power electronics intensive solutions for advanced electric, hybrid electric, and fuel cell vehicular power systems. They proposed to meet the future needs of the hybrid electric vehicles by increasing the input battery level from current 12v to 14v. The future load demand of the hybrid electric vehicles may increase up to 10k.w. In the current paper the current situations were reviewed and the future work of developing the advanced vehicular systems of hybrid electric vehicles are proposed for a fuel cell vehicles and hybrid electric vehicles. The rate of increase of the automotive load has been increasing at a rate of 4% per year. The dc converters are employed in these to meet all the auxiliary loads on the board. They proposed a 42 v input to the converters to meet the auxiliary loads such as air conditioners, compressors, power steering, antilock braking, and ride height adjustment. In practice there are series hybrid electric vehicle topology, parallel hybrid vehicle topology, series and practical hybrid electric vehicle topology. The classical trends of lead-acid, nickel metal hydride, nickel cadmium batteries are being plagued by the advanced hybrid electric vehicular systems. Regeneration principle is also worked out. The switches should handle a current of 300-500 amps/phase, so in order to handle such high currents advanced MOSFET switches should be employed. Trench IGBTs can also be employed. The precise electronic control can be achieved by the power electronic switches**. Kim et al 2014 [2]** developed a hybrid dual full bridge dc/dc converter with reduced circulating current, output filter and conduction losses of rectifier stage for RF power generation application. They implemented a RF power generator with three stages, variable frequency of 500 kHz-300 GHz. The conventional phase shift full bridge is implemented for high power transfer and wide output voltage applications. The circulating currents are reduced during the freewheeling period when a capacitor is connected in series with the primary of the transformer. The modes of operation are explained. **Wei Song et al 2007 [3]** developed buck type current fed push pull dc/dc converter with ZCS for high voltage applications. They proposed a converter with buck switches to reduce the start up in rush current. It is employed to operate at constant switching frequency. They implanted a laboratory model of input 200v and the output is 4kv with a power of 1kw and the efficiency of the proposed converter is 90%. The proposed converter has high frequency transformer. The magnetizing inductance of these transformer is very high so that the magnetizing current is negligible. The switches operate at a fixed duty ratio achieve zero current switching. The modes of operations are explained. **Su Jin Jang et al 2006 [4]** developed fuel cell generation system with a new active clamping current-fed half-bridge converter. They proposed a converter superior to the conventional dc/dc converters in terms of efficiency and utilization. The development of fuel cell generation systems has been rapidly increasing by considering global warming as they are renewable energy resources. In the fuel cell generation system they gave a varied dc voltage ranging from 28-43v. The high frequency dc/dc converter is connected to the primary of high frequency transformer with high boost ratio and the secondary is connected to a LC filter and supplied to the load. The modes of operations are explained. **Hung et al 2007 [5]** developed an active clamp push pull converter for battery sourcing applications. They have operated the primary and auxiliary switches at zero voltage switching in order to reduce the switching losses. The conversion efficiency can be improved significantly. By practicing these type converters the potential flux imbalance problems can be eliminated. Battery sourcing applications mostly need an uninterruptable power supply to the loads. The proposed converter will acts as one of those converters which reduce the voltage spike, high noise levels and improves the conversion efficiency. The resonant capacitors at the output terminals will store enough energy to achieve ZVS. To validate this, a 1 KW prototype of a discharger with active clamp circuits was built. The input voltage varies from 40-60Vdc and the output voltage is 400Vdc with output current of 2.5A, so voltage spike is suppressed effectively. It is feasible for high step up discharge applications. The modes of operation are explained.

III. Methodology

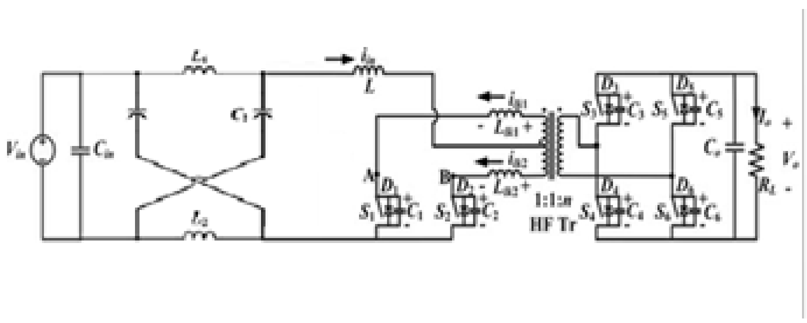

Fig. 1. Circuit diagram of Z- source push pull DC-DC converter.

Figure 1 shows the circuit diagram of Z-Source push pull DC – DC converter R load. In this project, z source circuit is added in the DC source side, which boosts the input voltage values. Also naturally clamped soft-switching bidirectional snubber less current-fed push–pull converter is proposed. Here zero current commutation (ZCC) is implemented in primary side of the transformer and in the secondary side Zero voltage switching is implemented. The proposed z source network will be acting as an all pass filter. An input of 12v is given to the Z source network to boost the input voltage and by ZCC the switches on the primary side are operated at regular intervals and the switches on the secondary side is operated by ZVS.

Mode1: In this interval, secondary side switches pair S_3–S_6 and body diode D_2 of primary-side switch are conducting.

Mode2: Secondary side switch pair S_3–S_6 is turned-off. i_{lk} charges the snubber capacitor voltage C_3 and C_6 and discharges the snubber capacitor voltage C_4 and C_5 in a short period of time.

Mode3: Now output voltage appears across inductors L_{lk} , causing current to reduce linearly.

Mode4: In this interval, S4 and S5 are turned-on with ZVS. Currents through all the switching devices continue increasing or decreasing with the same slope as mode 3.

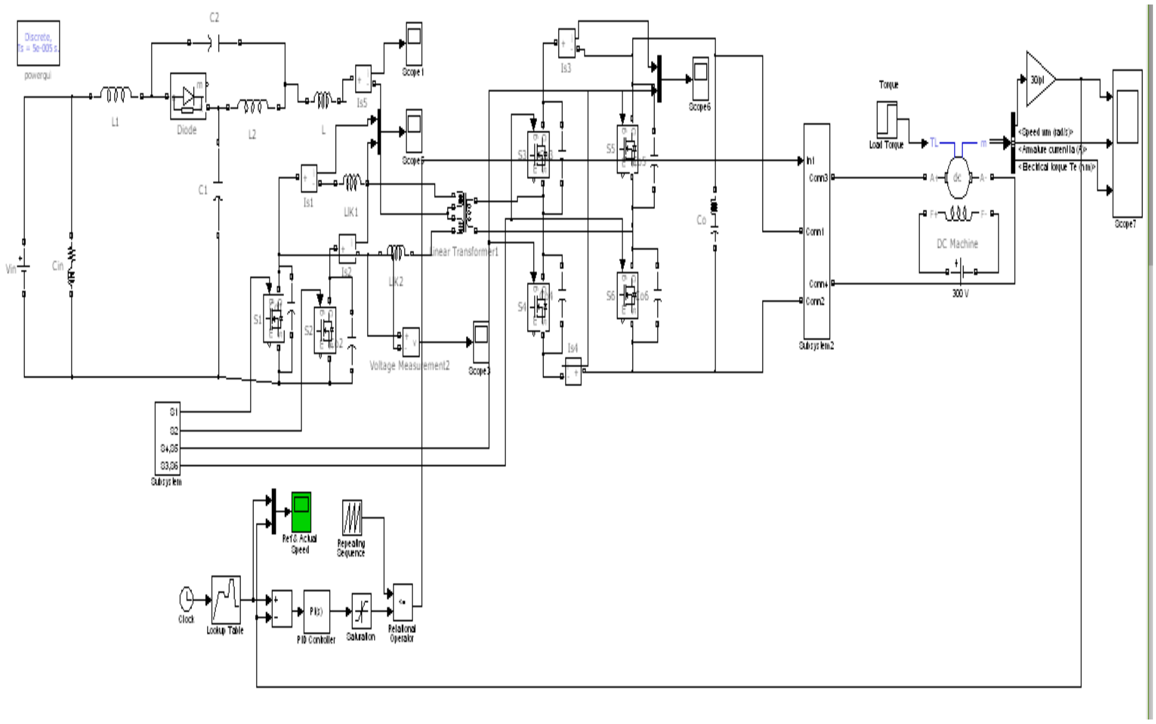

Fig. 2. Simulation diagram of z-source push-pull DC/DC converter.

The simulation diagram of Z source push pull dc/dc converter is shown in figure 2. A subsystem is used in order to give the trigger pulses to the all six switches present on the primary and secondary side switches. The two inductors on the primary side transformer are connected to the two switches on the primary side. The current is measured at the multiplexer end. At the secondary side the final voltage is measured across the motor. The output speed at the motor is sensed and given back to rotor position sensor in which already a defined set of speed is determined. A comparator is used to compare both the speeds and the error signal is fed back to the switches for adjusting the triggering. The PID controller is used to maintain the stability and the desired output response.

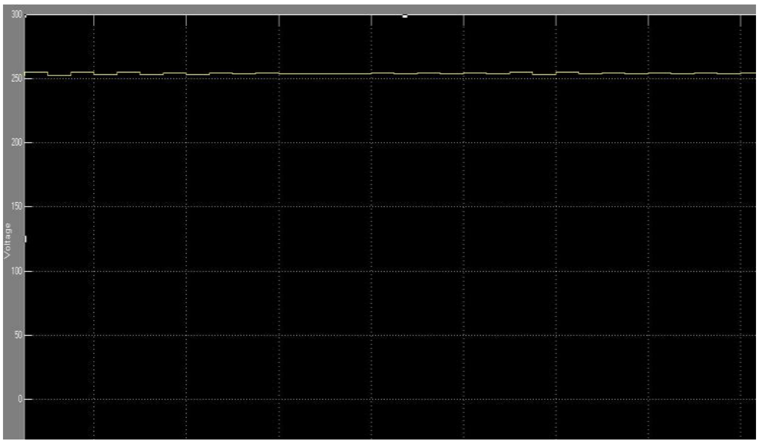

Fig. 3. Output of Z source push pull DC/DC converter.

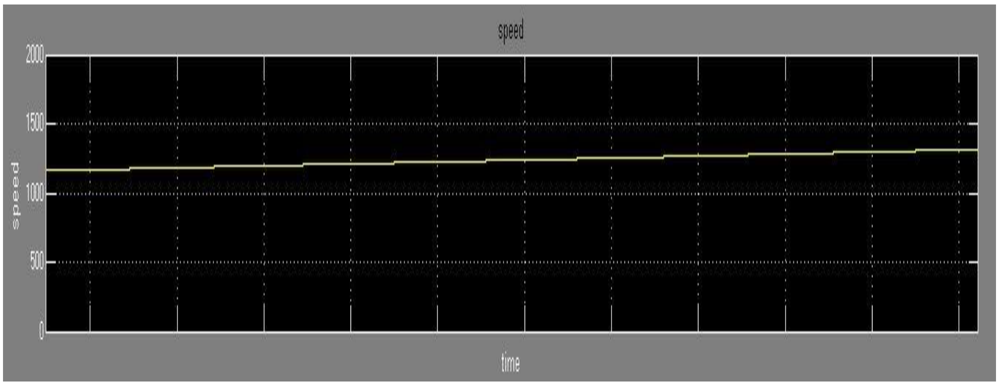

Fig. 4. Speed f Z source push pull DC/DC converter.

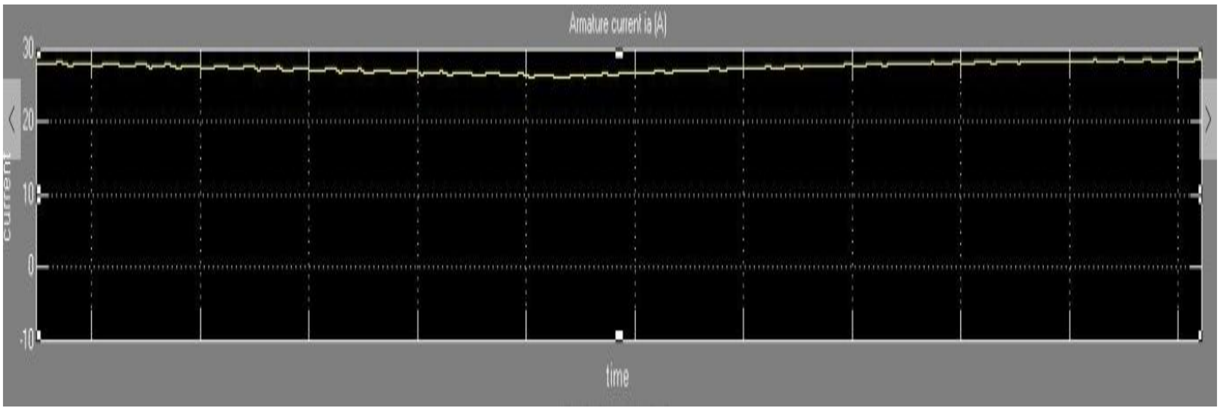

Fig.5. Current Z source push pull DC/DC converter.

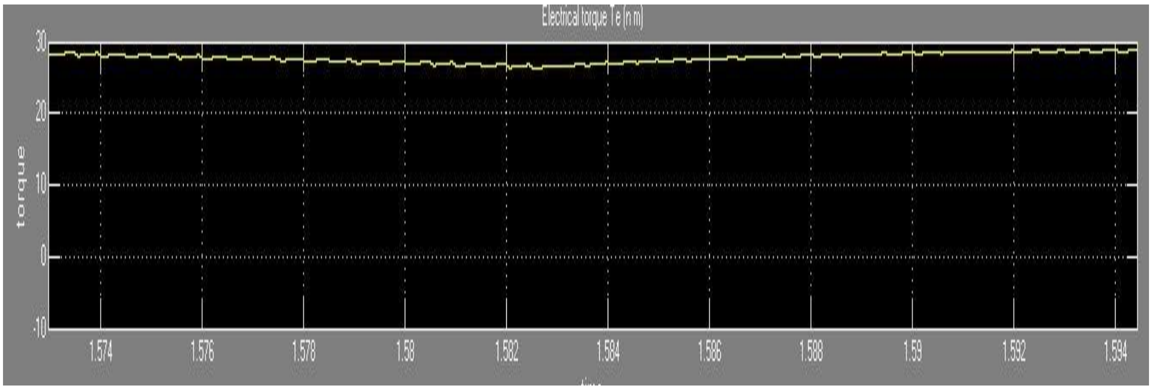

Fig.6. Torque of z source push pull DC/DC converter.

Table-1: Comparisoon of R and RL Load in the Source push pull DC/DC Converter.

Parameters	With R-load	With Dc shunt motor
Output voltage (v)	40	250
Duty cycle	0.85	0.8
Speed (RPM)	NIL	1500
Armature Current (A)	NIL	30
Torque (NM)	NIL	30

Table 1 represents the comparison of the measuring parameters across R and RL load. The output voltage obtained in the R load is less when compared to RL load and the duty cycle ratio is less with R load and the speed is high in RL when compared to R load. There is no current and torque obtained in R load.

VI. Conclusion

This paper presents a Z source push pull dc/dc converter for applications of the ESS in FCVs. A Z source is proposed to eliminate the problem of low voltage. The above claimed ZCC and NVC of primary side switches without any snubber are demonstrated and confirmed by the simulation and experimental results. ZCS of primary side devices and ZVS of secondary side devices are achieved which reduces the switching losses significantly. Soft switching is inherent and maintained independent of the load. Maintaining soft switching of all devices substantially reduces the switching losses and allows higher switching frequency operation for the converter to achieve a more compact and higher power density system. The proposed modulation method is simple and easy to implement. These merits make the converter promising for interfacing low voltage dc bus with high voltage dc bus for higher current applications such as FCVs, front end dc/dc power conversion for renewable (fuel cells/PV) inverters, ups and energy storage.

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