Hybrid Full-Bridge–Half-Bridge Converter with Stability Network and Dual Outputs in Series

[1]Sowmya S, [2]Vanmathi K

1. PG Scholar, Department of EEE, Hindusthan College of Engineering and Technology, Coimbatore, Tamil Nadu.
2. Assistant Professor, Department of EEE, Hindusthan College of Engineering and Technology, Coimbatore, Tamil Nadu.

***Abstract*— A soft-switching hybrid converter combining the phase-shift full-bridge (FB) and half-bridge (HB) LLC resonant converters with zero-voltage switching (ZVS) lagging leg and stability network is presented and analysed. The stability network used here is a quasi Z source network. It regulates voltage and current. It acts as a filter and a voltage booster. The secondary side of the full-bridge converter composed of a resonant circuit which is used to reset the primary current during the freewheeling period. It helps to transfer input energy to the output and to clamp secondary rectifier voltage. The proposed converter composed of dual outputs which are connected in series and the dc voltage is regulated by the PWM phase shift control within the desired voltage range. To implement the converter without an additional inductor, leakage inductance of the transformer is utilized as the resonant inductance.**

Keywords*— *Zero voltage switching (ZVS), Full bridge converter, Half Bridge (HB) LLC resonant converter

I. INTRODUCTION

As generally recognized, electric vehicles can achieve higher energy conversion efficiency, motor-regenerative braking capability, fewer local exhaust emissions, and less acoustic noise and vibration, as compared to gas-engine vehicles. The battery has an important role in the development of electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs). For the recharging of hybrid (EVs), there are two solutions based on the Society of Automotive Engineers (SAE) charging configurations and ratings terminology.

a) Off board charger
b) On board charger

The most common on-board charger system architecture includes an active-front-end ac–dc converter, and an isolated dc–dc converter. First, an ac–dc converter converts ac power to dc power to maintain the intermediate dc bus. Then, the isolated dc–dc converter will recharge the EVs' battery pack within the output voltage range. This paper will focus on the isolated dc–dc converter. Based on the full bridge (FB) structure, there are three main types of converters, as follows.

a) *Phase-Shift FB (PSFB) Converter*
b) *Resonant Converters*
c) *Hybrid FB–HB Converters*

Recently, various hybrid FB–HB converters have been proposed for different applications; the common characteristic is that the input energy can be transferred to the output even in the freewheeling interval to the output inductor. Due to parallel power processing technique, high efficiency can be achieved by those soft-switching topologies. The fully ZVS range of the active switches in the lagging leg can be achieved by using additional transformer, while the circulating current problem also exists and produces severe conduction loss. The transformer auxiliary winding circuit is replaced by the output circuit of half-bridge *LLC* resonant converter using the leading leg, which can make the active switches in the leading leg get fully ZVS; the primary current is reset by the output voltage of *LLC* resonant converter during the freewheeling interval. This topology is attractive for HEV/EV on-board charger applications.

II. EXISTING SYSTEM

A. Circuit Description And Basic Operation Principles

The existing converter is shown in Fig and it composed of two parts:

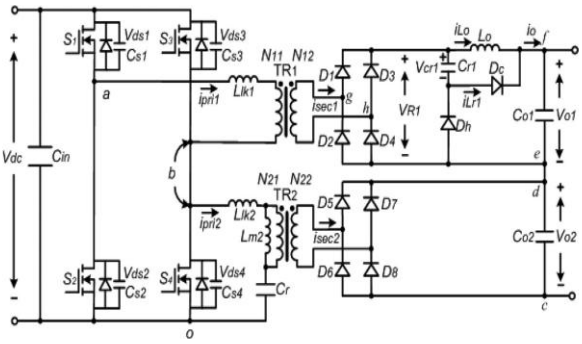

Fig 1. Circuit configuration of hybrid FB–HB shared lagging-leg converter

1) PSFB converter consists of two MOSFETs S_1 and S_2 in the leading leg, two MOSFETs S_3 and S_4 in the lagging leg, tightly coupled transformer TR_1 , second rectifier diodes (D_1–D_5), the LC output filter (L_o , C_{o1}), and the resonant circuit (C_{r1} , D_h , D_c).

2) Resonant HB circuit including two MOSFETs S_3 and S_4 in the lagging leg, loosely coupled transformer TR_2 , resonant capacitor C_r , the second rectifier diodes (D_5–D_8), and capacitor C_{o2}.

The proposed circuit combines the behaviors of two different converter topologies:

a) The constant frequency PSFB converter with a resonant circuit

b) HB LLC resonant converter operating, under the load-independent resonant frequency.

T_{on} is the on-time interval when (S_1, S_4) or (S_2, S_3) are turned ON by the phase-shift PWM control and T_s is the switching period, then we can derive $D = 2T_{on} /T_s$ as the duty cycle. For the resonant circuit, there are three operation modes depending on the simple quantitative criteria as shown in Table 3.1 to determine which mode of operation is actually taking place.

Table 1: Mode Selection Criteria

Mode 1	Mode 2	Mode 3
$T_{on}>t_{r1H}$	$T_{on}=t_{r1H}$	$T_{on}<t_{r1H}$

1) Resonant-mode 1: Half-cycle of the sinusoidal resonant current i_{Lr1} change is completed before the end of the on time interval T_{on}. The diode D_c turns OFF at zero-current level; further negative resonant current flow is prevented because of the diode D_c.

2) Resonant-mode 2: The half-resonant cycle t_{r1H} is equal to on-time interval T_{on}, so that turn OFF of D_c coincides with the turn OFF controlling switch S_1 or S_2.

3) Resonant-mode 3: the half-resonant cycle t_{r1H} is bigger than Ton so that the switch S_1 or S_2 is turned OFF before the resonant current is reduced to zero. The voltage $(V_{o1}+V_{cr1})/_{n1}$ is applied across resonant inductor L_{lk1}, introducing a linear decrease of the resonant current i_{Lr1} until zero current level is reached resulting in turn OFF of diode D_c.

III. PROPOSED SYSTEM

A hybrid resonant and PWM converter with stability network is presented here. The block diagram of proposed system is shown in figure 2.

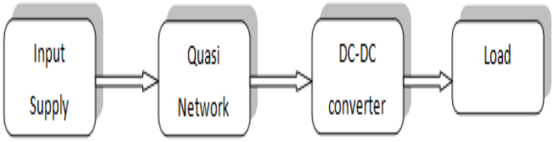

Fig 2. Block diagram of proposed system

The block diagram composed of Z source network, dc-dc converter and is connected to the load. Input supply is from dc source and is then given to stability network. After filtering and boosting, it is fed to dc-dc converter. The output is connected to load.

A. Quasi-Z-Source Inverter

The quasi z-source inverter (QZSI) is a single stage power converter derived from the Z-source inverter topology, employing a unique impedance network. The conventional VSI and CSI suffer from the limitation that triggering two switches in the same leg or phase leads to a source short and in addition, the maximum obtainable output voltage cannot exceed the dc input, since they are buck converters and can produce a voltage lower than the dc input voltage. Both Z-source inverters and quasi-Z-source inverters overcome these drawbacks; by utilizing several shoot-through zero states.

A zero state is produced when the upper three or lower three switches are fired simultaneously to boost the output voltage. Sustaining the six permissible active switching states of a VSI, the zero states can be partially or completely replaced by the shoot through states depending upon the voltage boost requirement. Quasi-Z-source inverters (QZSI) acquire all the advantages of traditional Z source inverter. The impedance network couples the source and the inverter to achieve voltage boost and inversion in a single stage. By using this new topology, the inverter draws a constant current from the PV array and is capable of handling a wide input voltage range. It also features lower component ratings, reduces switching ripples to the PV panels, causes less EMI problems and reduced source stress compared to the traditional ZSI.

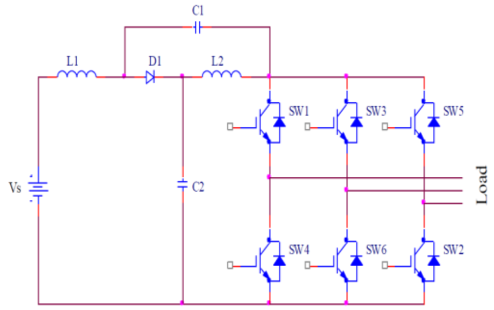

Fig 3 QZSI Network Topology

The impedance network of QZSI is a two port network .It consists of inductors and capacitors connected as shown in Fig.4.2. This network is employed to provide an impedance source, coupling the converter to the load. The dc source can be a battery, diode rectifier, thyristor converter or PV array. The QZSI topology is shown in the Fig 3.

The input to the system is dc voltage. The quasi Z source network will filter this input voltage and also regulates it. So voltage fluctuation of the input is also controlled. This regulated voltage is fed to an inverter. So dc voltage is converted into ac voltage. The primary of the transformer is given this ac voltage and step up of ac voltage takes place in the secondary side of the transformer. After this, voltage is rectified and output voltages are obtained. The operation principles of the circuit after the stability network is similar to that of the existing system as explained earlier.

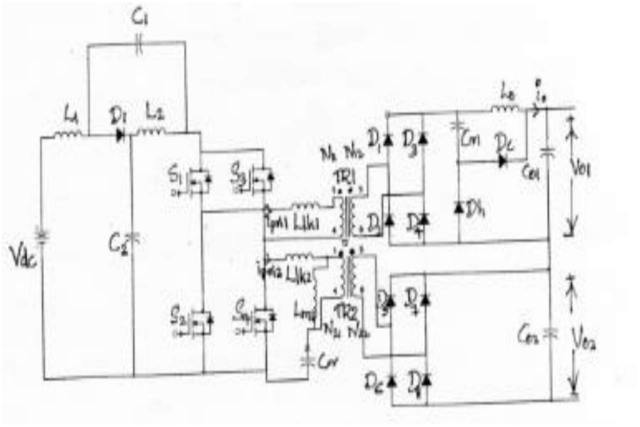

Fig.4.Circuit diagram of proposed system

With the parallel LLC resonant half-bridge configuration, zero-voltage switching of MOSFETs in the leading-leg can be ensured from true zero to full load, and thus, the super-junction MOSFET with slow reverse recovery body diode can be reliably used. Duty cycle loss is negligible since the leakage inductance of the main transformer can be minimized without losing ZVS operation, thus, the current stresses through the primary-side semiconductors are minimized by the optimized turns ratio of the main transformer.

IV. SIMULATION

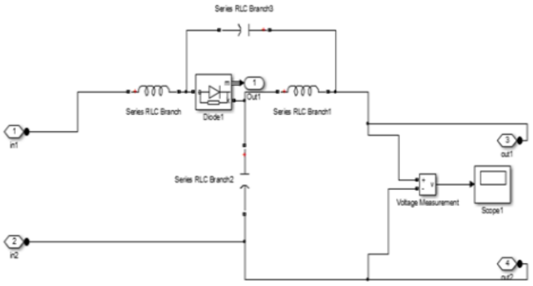

Fig 4. Simulation Model Diagram of Subsystem

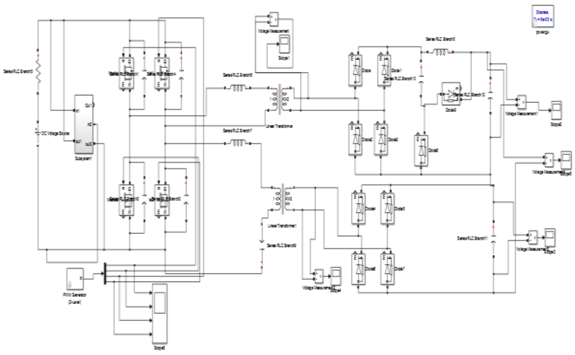

Fig 5. Simulation Diagram of Proposed System

The dc input is given to the quasic network, which helps in filtering the supply. It acts as a power factor controller also. The front end is single phase inverter which converts dc to ac. Then the converted dc is given to the linear transformers which steps up the output voltage. The high voltage is given to the diode rectifiers which converts the produced ac to dc. Resonant condition is maintained by the resonant circuit after the rectifier circuit. The two dc outputs it is given to separate filters which is connected in series. The output can either be taken from single bridge or we can combine two bridges and connect load in series.

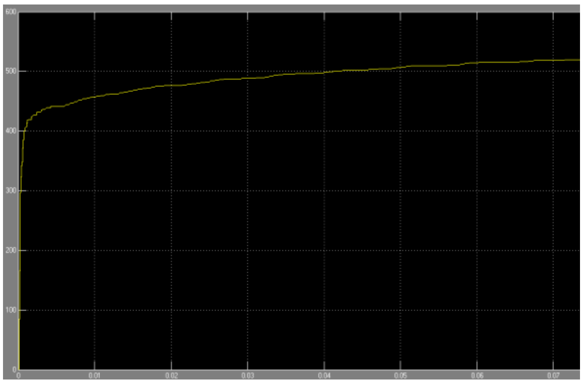

Fig 6. Output waveform when bridges are in series.

The overall output voltage when bridges are in series is 520V. We can observe that the output voltage of the proposed system is greater than the existing system by 80V. By introducing quasi Z source, the overall output voltage is increased to 200V.

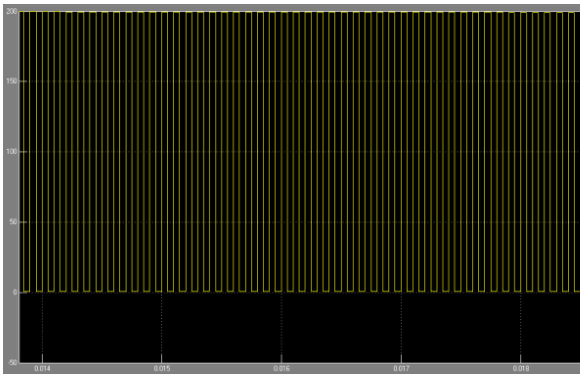

Fig 7. Output waveform of subsystem.

V. CONCLUSION

The main features of the proposed circuit are summarized as follows:

ZVS of MOSFETS in the lagging leg can be ensured from by using the HB *LLC* resonant converter. Using the resonant circuit, more input energy can be transferred to the output. Dual outputs are obtained in series The resonant circuit used in the secondary side of the FB converter can effectively reset the primary current during the freewheeling period to decrease circulating conduction loss, as well as clamp secondary rectifier voltage. Voltage fluctuations in the input is reduced due the stability network and it acts as a filter circuit. Output voltage of the proposed system is greater than the existing system by 80V.

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