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ORIGINAL PAPER

An Approach Design Of zero-voltage-transition Boost Converter With Coupled Inductors

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Extended Abstract

A novel isolated zero-voltage-transition (ZVT) boost converter with coupled inductors is proposed in this paper to satisfy the high power, high step-up and isolated requirements. In the proposed converter, the input-parallel configuration is adopted to share the large input current and to reduce the conduction losses, while the output-series structure is employed to double the output voltage gain. Consequently, a transformer with a low turns ratio can be applied, which makes the transformer design and optimize easily. Moreover, the active clamp circuits are employed to reduce the switch voltage stress and to recycle the energy stored in the leakage inductance. The ZVT is achieved during the whole switching transition for all the active switches, so the switching losses can be reduced greatly. Furthermore, the diode reverse-recovery problem is partly solved due to the leakage inductance. In addition, the magnetic integration technology is applied to improve the efficiency and to reduce the magnetic component size. Finally, a 12-V input 96-V output 1-kW prototype operating with 100-kHz switching frequency is built and tested to demonstrate the effectiveness of the proposed converter.

I. Introduction

Due to the environmental concerns about the global warming, the fossil fuel exhaustion and the carbon dioxide reduction requirements, many efforts have been made to investigate the clear and green renewable energy sources, such as the wind generation, the geothermal, the

Photovoltaic (PV), and the fuel cells. These renewable energy sources can generate electricity without increasing the environmental pollution to the Earth. Unfortunately, the output voltages of the PV arrays, the fuel cells, and the acid batteries employed in the renewable energy are relatively low and vary in a wide range, which calls for high-power and high-step-up dc–dc converters to boost the low voltage to a high one for the grid-connected power applications. Galvanic isolation is often employed to achieve the system reconfiguration flexibility and to meet the safety standards. Generally speaking, the isolated high

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power converters with high-voltage conversion ratio, low-input current ripple, and high efficiency are required in these applications.

A novel isolated ZVT boost converter with coupled inductors is proposed in this paper for the high power, high step-up applications. The input-parallel and output-series configuration is adopted to handle the large input current and to sustain the high output voltage. On the primary side of the converter, the input current is divided into two coupled inductors to cancel the current ripple and to reduce the switch conduction losses. Meanwhile, the active clamp circuits are introduced to depress the switch voltage stress and to recycle the energy stored in the leakage inductance. Both the main and the clamp switches operate with ZVT soft switching performance during the whole switching transition. Therefore, the switching losses are reduced significantly. On the secondary side, the windings of the coupled inductors are connected in series to get high voltage conversion. When one coupled inductor operates in the fly back mode, the other coupled inductor works in the forward mode due to the interleaved control.

II. Circuit Description

The proposed isolated ZVT boost converter with coupled inductors is illustrated in Fig.1 where S1 and S2 are the main switches, Sc1 and Sc2 are the clamp switches, Cc1 and Cc2 are the clamp capacitors, Cs is the switched capacitor, Ds is the regenerative diode, Do is the output diode, Cs1 and Cs2 are the parallel capacitors, Vin and Vout are the input and output voltages, and Ro is the load. There are two coupled inductors in the proposed converter, which are named by L1 and L2. The primary inductor L1a is coupled with its secondary inductor L1b, and another primary inductor L2a is coupled with its secondary inductor L2b. The coupling reference is marked by “*” and “◦”.

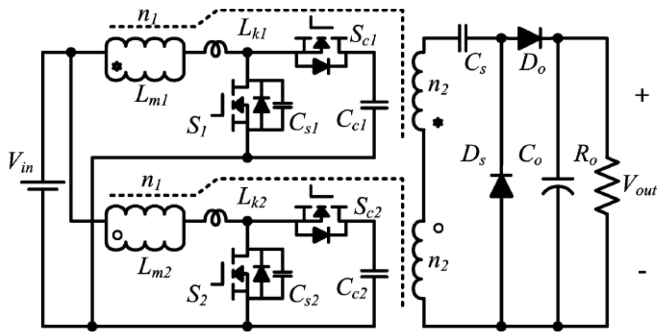

Fig.1:Equivalent circuit of proposed converter

The coupled inductor is modeled as an ideal transformer with the original turns ratio, which is in parallel with a magnetizing inductor and then in series with a leakage inductance.

III. III.MODELING PROCEDURE

To obtain a nonlinear model for power electronic circuits, one needs to apply Kirchhoff’s circuit laws. To avoid the use of complex mathematics, the electrical and semiconductor devices must be represented as ideal components (zero ON voltages, zero OFF currents, zero switching times).

Therefore, auxiliary binary variables can be used to determine the state of the switches. It must be ensure that the equations obtained by the use of Kirchhoff’s laws should include all the permissible states due to power semiconductor devices being ON or OFF.

The steps to obtain a system-level modeling and simulation of power electronic converters are listed below.

1) Determine the state variables of the power circuit in order to write its switched state-space model, e.g., inductor current and capacitor voltage.

2) Assign integer variables to the power semiconductor (or to each switching cell) ON and OFF states.

3) Determine the conditions governing the states of the power semiconductors or the switching cell.

4) Assume the main operating modes of the converter (continuous or discontinuous conduction or both) or the modes needed to describe all the possible circuit operational modes. Then, apply Kirchhoff's laws and combine all the required stages into a switched state-space model, which is the desired system-level model.

5) Write this model in the integral form, or transform the differential form to include the semiconductors logical variables in the control vector: the converter will be represented by a set of nonlinear differential equations.

6) Implement the derived equations with "SIMULINK" blocks (open loop system simulation is then possible to check the obtained model).

7) Perform closed-loop simulations and evaluate converter performance.

8) The algorithm for solving the differential equations and the step size should be chosen before running any simulation. The two last steps are to obtain closed-loop simulations.

To verify the response of the converter a complete dynamic model of DC/DC converter scheme have been simulated by Matlab/Simulink software. The imulink block diagram of a boost converter and its controller is shown in Fig.2 The model's input is taken power from battery and the output of the model is fed to the load demand.

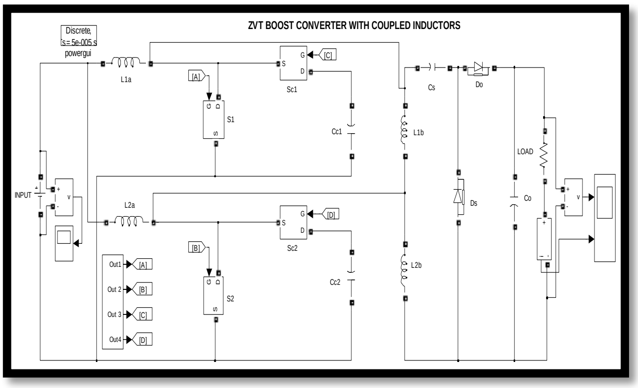

Fig.2 :Simulink Model

The experimental voltage and current waveforms of the secondary-side diodes are shown in Fig.3& Fig.4. It can be seen that the voltage stresses of both the diodes are equal to the output voltage. The reverse-recovery current is nearly reduced to zero, thus the reverse-recovery problem is alleviated.

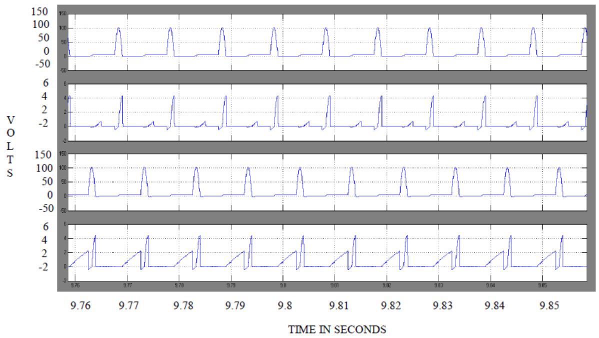

Fig.3 :Voltage And Current Wave Form Across Output Diode-1

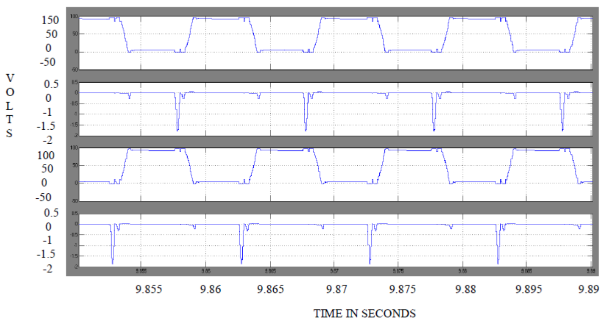

Fig.4: Voltage And Current Wave Form Across Output Diode-2

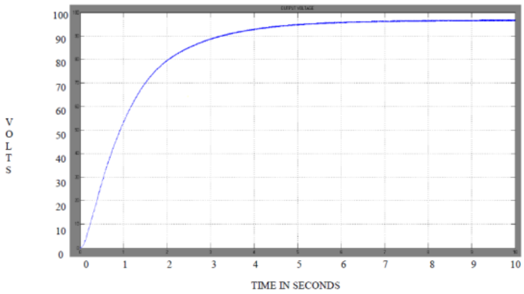

Fig.5: Output Voltage Wave Form Across Load

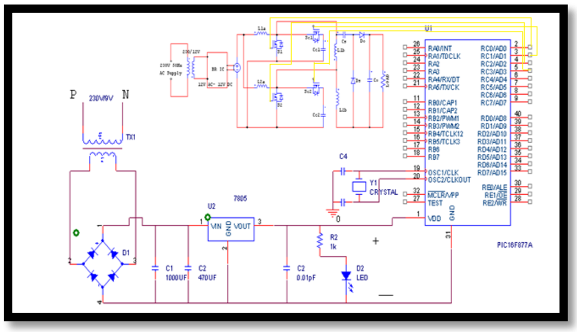

Fig.6: Hardware Circuit Diagram.

IV. *Hardware Description*

The driver circuit is supplied using a step down transformer 230V/12V AC .In this paper the driver circuit is mainly used to amplify the pulse output coming from the microcontroller circuit. The output from pin 1 and 2 of PIC16F877A is passed to the buffer IC CD4050 .The buffer IC acts as a NOT gate .the output from the buffer IC is passed to the two optocoupler respectively. The optocoupler is used to isolate the voltages between the main circuit and microcontroller circuit. This signal is passed to the transistors CK100 and 2N2222 which is connected in a Darlington pair model.

These are the classical and most widely used methods of pulse width modulation. They have as common characteristic subcycles of constant time duration, a subcycle being defined as the total duration Ts during which an active inverter leg assumes two consecutive switching states of opposite voltage polarity. Operation at subcycles of constant duration is reflected in the harmonic spectrum by two salient sidebands, centered around the carrier frequency, and additional frequency bands around integral multiples of the carrier. The multi carrier modulation technique is very suitable for a multilevel inverter circuit. By employing this technique along with the multilevel topology, the low THD output waveform without any filter circuit is possible. Switching devices, in addition, turn on and off only one time per cycle. That can overcome the switching loss problem, as well as EMI problem.

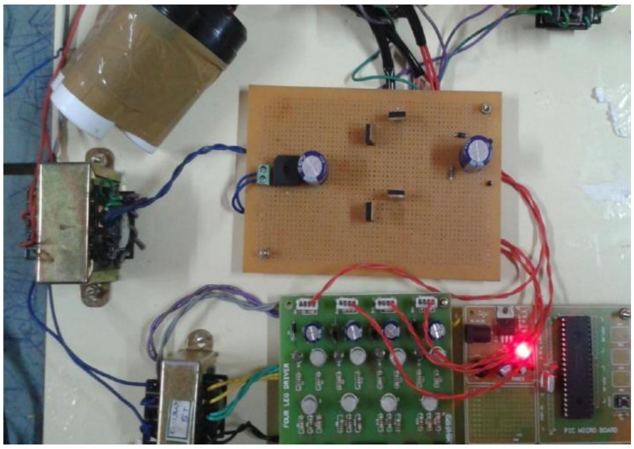

Fig.7 :Experimental setup

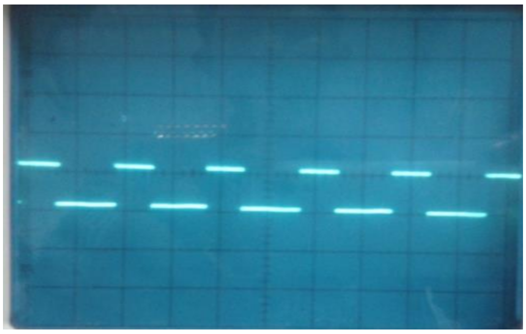

Fig.8: Gate Wave Form Across

The experimental results of the gate signals are shown in Fig.8. The duty cycle of the main switches is about 0.7, which shows that a proper duty cycle is obtained due to the reasonable turns ratio design of the coupled inductors. Interleaved control is realized in the proposed to improve the power level.

Fig.9: Output Voltage Wave Form Across Diode

The experimental voltage and current waveforms of the secondary-side diodes are shown in Fig. 9 It can be seen that the voltage stresses of both the diodes are equal to the output voltage.

Conclusion

A novel ZVT isolated converter with input-parallel and output-series configuration for the high step-up applications is introduced in this Paper. By adopting the input-parallel configuration, the large input current is shared by the two branches and the conduction losses are reduced. At the same time, the output-series configuration is helpful to get a high voltage gain the active clamp circuits are introduced to suppress the voltage spikes on the main switches and to recycle the energy stored in the leakage inductance.

Furthermore, ZVS soft switching performance of both the main and the clamp switches is achieved. The diode reverse-recovery problem is alleviated by the leakage inductance of the coupled inductors. In addition, the magnetic integration technology is employed to reduce the core losses and to simplify the structure of the converter. At last, a 500W, 12-V to 96-V high-efficiency prototype converter is built to verify the analysis, and the experimental results illustrate that the proposed converter is a competitive candidate for the high power and high step-up applications with isolation requirements.

References

[1] Q. Li and P. Wolfs, "A review of the single phase photovoltaic module integrated converter topologies with three different DC link configurations," IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1320–1333, May 2008.

[2] R. J.Wai and R. Y. Duan, "High step-up converter with coupled-inductor," IEEE Trans. Power Electron., vol. 20, no. 5, pp. 1025–1035, Sep. 2005.

[3] Q. Zhao and F. C. Lee, "High-efficiency, high step-up DC-DC converters,"IEEE Trans. Power Electron., vol. 18, no. 1, pp. 65–73, Jan. 2003.

[4] R. J.Wai andR.Y.Duan, "High-efficiency power conversion for lowpower fuel cell generation system," IEEE Trans. Power Electron., vol. 20, no. 4, pp. 847–856, Jul. 2005.

[5] B. Yang, W. Li, J. Wu, Y. Zhao, and X. He, "A grid-connected PV power system with high step-up ZVT interleaved boost converter," in Proc. IEEE APEC 2008, pp. 2082–2087.

[6] H. Kim, C. Yoon, and S. Choi, ""An improved current-fed ZVS isolated boost converter for fuel cell applications," in Proc. IEEE APEC 2008,pp. 593–599.

[7] H. D. Thai, J. Barbaroux, H. Chazal, Y. Lembeye, J. C. Crebier, and G. Gruffat, "Implementation and analysis of large winding ratio transformers,"in Proc. IEEE APEC 2009, pp. 1039–1045.

[8] J. M. Kwon, E. H. Kim, B. H. Kwon, and K. H. Nam, "High-efficiency fuel cell power conditioning system with input current ripple reduction," IEEE Trans. Ind. Appl., vol. 56, no. 3, pp. 826–834, Mar. 2009.