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Modified Hybrid Transformer ZVS/ZCS Dc–Dc Converter with Improved Utilization for Photovoltaic Module Applications

Supriya J
Dept. of Instrumentation and Electronics Engineering
Dayananda Sagar College Of Engineering
Bangalore, India

Meharunnisa Bhakshi
Dept. of Instrumentation and Electronics Engineering
Dayananda Sagar College Of Engineering
Bangalore, India

***Abstract*— Now-a-days due to the shortage of electric power and rising cost of non-renewable energy resources generating electric power from the renewable energy resources such as PV modules are increasing day to day. This paper presents a nonisolated, high boost ratio dc-dc converter with the application for PV modules. The proposed converter utilizes a hybrid transformer to incorporate the resonant operation mode into a traditional high boost ratio active clamp coupled-inductor pulse-width modulation dc-dc converter, achieving zero-voltage-switching (ZVS) to turn-on of active switches and zero-current-switching (ZCS) to turn-off of diodes/switches. For PV module converter, the high efficiency over a wide load range and input voltage range is extremely important. In this paper, a high boost ratio dc-dc converter with hybrid transformer is presented to achieve high system level efficiency over wide input voltage and output power ranges. The optimized Magnetic utilization(MU) reduces the dc-bias of magnetizing current in the magnetic core, leading to smaller sized magnetics. By adding a small resonant inductor and reducing the capacitance of the switched-capacitor in the energy transfer path, a hybrid operation mode can be achieved. The inductive and capacitive energy can be transferred simultaneously to the high voltage dc bus increasing the total power delivered decreasing the losses in the circuit. Since the magnetizing current has low dc-bias, the ripple magnetizing current can be utilized to assist ZVS of main switch, while maintaining low root-mean-square (RMS) conduction loss. In the proposed high boost ratio dc-dc converter. The inductive and capacitive energy can be transferred simultaneously to the high voltage dc bus increasing the total power delivered decreasing the losses in the circuit. The voltage stresses on the active switches and diodes are maintained at a low level and are independent of the wide changing PV voltages as a result of the resonant capacitor in series in the energy transfer loop. Due to the high efficiency over wide power range, the ability to operate with a wide variable input voltage and compact size, the proposed converter is an attractive design for PV module applications. As a result, the energy transferred through the hybrid transformer that combines the modes where the transformer operates under normal conditions and where it operates as a coupled-inductor, the magnetic core can be used more effectively and smaller magnetics can be used.**

Keywords—hybrid transforme(HT)r,optimized magnetics,power device utilization(PDU),high boost ratio dc-dc,high efficiency,photovoltaic(PV)module.

I. INTRODUCTION

Electrical energy demand is constantly increasing day by day due to the declining production and rising cost of nonrenewable energy supplies, leads to growing demand for the utilization of renewable energy sources. Among renewable energy sources, a PV module has experienced fast development in recent years. Power generated from sunlight is captured by dc PV modules. Integration of power from PV module and existing power distribution infrastructure can be achieved through power conditioning systems (PCS).PCS can be either single stage or double stage.

In two-stage PV power conditioners, isolated or non-isolated high boost ratio dc-dc converters are used to increase low PV voltage to a high dc voltage to interface with low power individual inverter or high power centralized grid-connected inverter. Another requirement for this high boost ratio dc-dc converter is to have high power density and low profile to integrate with the PV modules. Due to increasing cost of electronics and continuous drop of PV modules cost requires dc-dc converter to have simple structure and low electronic cost. A primary side active switch of transformer has coupled inductor and low voltage stress. Therefore circuit use low voltage MOSFET so that low Rds and hence it reduces the switching and conduction loss. A ZVS (zero voltage switching) high boost ratio active-clamp coupled-inductor (ACCI) converter, as shown in Fig.1 (b).This converter is derived from the active clamp flyback converter as shown in Fig.1(a).

In active clamp coupled inductor high boost ratio converter has single structure, low voltage stress and ZVS operation of active switches, increases the boost ratio of converter and reduces the primary side RMS conduction loss. To reduce voltage ringing across the output diode, a passive snubber was added which degraded the efficiency of the converter.High ripple current can be avoided by storing energy in magnetizing inductance instead of storing energy in leakage or external inductor to achieve ZVS of main switch. Converter transfers the energy to the secondary side during the interval when the main switch is off, causing poor magnetic utilization (MU), and high dc-bias magnetizing current.

The output diodes in the proposed converter can achieve ZCS turn-off because the resonant back to zero at the switching transitions. Due to continuous input current with combined sinusoidal resonant and linear PWM current leads to smaller current ripple and reduced RMS conduction losses.

Maintaining low level voltage stress on active switches and diodes and are independent of the wide changing input PV voltages as a result of the resonant capacitor in series in the energy transfer loop.

Reduced switching losses achieved by ZVS and ZCS operations and reduced RMS conduction losses leads to achieve high efficiency over wide input voltage and power range.

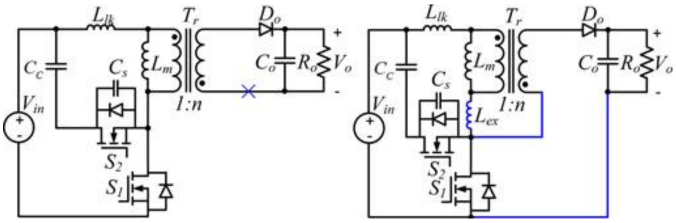


Fig.1. (a) Active-clamp flyback converter. (b)Active-clamp coupled-inductor high boost ratio converter

II. PROPOSED CONVERTER TOPOLOGY AND OPERATION ANALYSIS

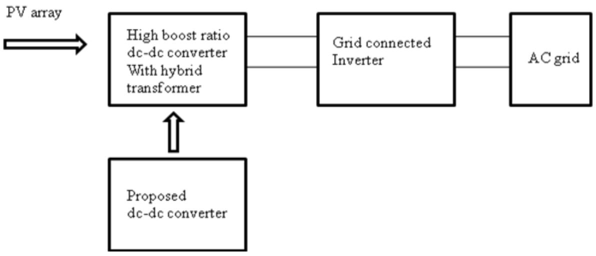
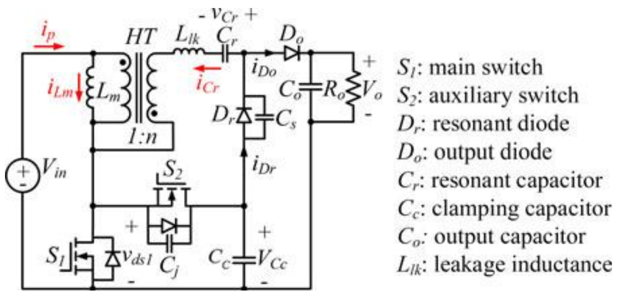


Fig.2.Single phase grid connected power system

In grid connected system as shown in Fig.2 there is a need to use of high voltage gain DC-DC converter .The prototype proposed in this work can be used for such applications. Also the prototype has source side application of renewable energy.



The above figure shows the circuit topology of proposed DC-DC converter. This converter consists of transformer, two MOSFET switch, five capacitors and diodes. Here HT is hybrid transformer, S1 is the active main MOSFET switch and S2 is the auxiliary active clamp switch. Cc is clamping capacitor. Cr is resonant capacitor. Lr is resonant inductor. Dr is resonant diode. Where Cc, Cr, Lr, and Dr forms the resonant part of the circuit. The leakage energy captured by Cc is transformed to Cr through the resonant part of the circuit. Dr provides a unidirectional current flow path for the operation of the resonant portion of the circuit. Cr has resonant charge and linear discharge, and it operates in the hybrid mode. Do is the output diode, Co is the output capacitor and Ro is the output resistive load. Cj represents the parasitic junction capacitors of MOSFETs, Cs is the equivalent capacitor of the diodes Do and Dr. The voltage across the switches can be clamped and adjusted by the turn's ratio of the transformer. For this reason, the voltage level of the switch is reduced significantly and low conducting resistance Rds (on) of the switch can be used. Thus, the efficiency of the proposed converter can be increased and high voltage gain can be achieved. To simplify the circuit analysis, the following conditions are assumed.

1. Ideal MOSFET switches S1 and S2 with body diodes.
2. D is the steady-state duty ratio based on S1.
3. The voltage ripples on Co and Cc are negligibly small.

There are eight distinctive steady state modes for this proposed DC-DC converter.

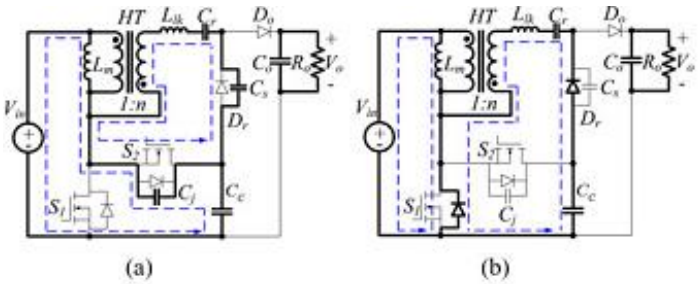


Fig. 4. Topological stages: (a) t0-t1, (b) t1-t2, (c) t2-t3, (d) t3-t4, (e) t4-t5, (f) t5-t6, (g) t6-t7, and (h) t7-t8.

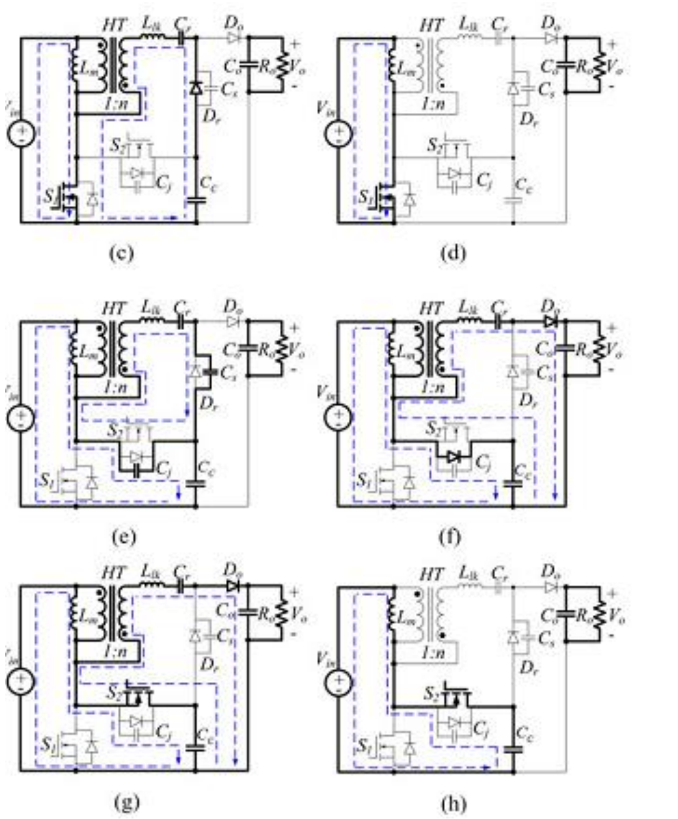


Fig. 4. Topological stages: (a) t0-t1, (b) t1-t2, (c) t2-t3, (d) t3-t4, (e) t4-t5, (f) t5-t6, (g) t6-t7, and (h) t7-t8.

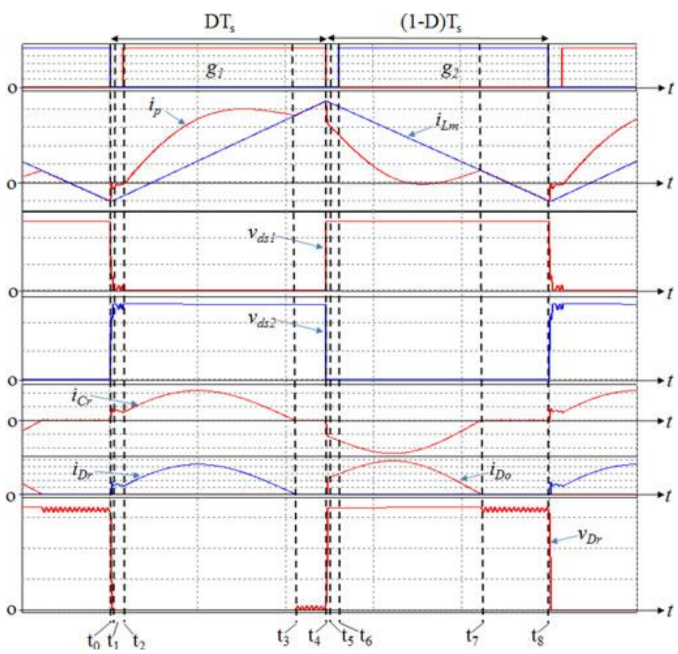


Fig. 5. Steady-state waveforms.

A. Mode 1:t0-t1: During this mode at the time to, switch S2 is turned off. The negative magnetizing current iLm starts to charge Cj. Change in voltage potential of the drain mode of S1 causes secondary side of HT, Llk, Cr,Cs,and Cj starts to resonate until Dr is forward-biased.

B. Mode 2: t1-t2: At time t1, Vds1 is reduced to zero. Sum of ip and nicr, flows through the body diode of S1 and this provides a ZVS condition for S1.Vin is applied on Lm and iLm is linearly increased. At the same time, the secondary-reflected input voltage nVin along with Vcc charge Cr in a resonant manner through the resonant loop including secondary side of HT,Llk,Cr,Dr,Cc and body diode of S1.

C. Mode 3: t2-t3: At the time t2, switch S1 is turned on with ZVS.

D. Mode 4: t3-t4: At the time t3, iDr resonates back to zero so Dr turns off with ZCS. Vin continues to linearly charge Lm and from t1 to t4,iLm is linearly charged by Vin.

E. Mode 5: t4-t5: At the time t4, switch S1 is turned off. iLm starts to discharge Cj. Change in voltage potential of the drain mode of S1 causes secondary side of HT,Llk,Cr,Cs,and Cj starts to resonate.

F. Mode 6: t5-t6: At the time t5, Cs is discharged to the point where the antiparallel diode of S2 starts to conduct and this provides ZVS turn-on S2.Voltage potential of anode of Do increases causes high enough leading Do to be forward-biased

G. Mode 7: t6-t7: At the time t6, switch S2 turned on with ZVS. Since S2 takes a long time interval before iLm reduces to zero, so that ZVS of S2 is easily achieved and the energy transferred to the output with the resonant current iDo.

H. Mode 8: t7-t8: At the time t8,iDo resonates to zero, Do turns off with ZCS. From t5 to t8,the voltage applied on Lm is Vin-Vcc, which decreases iLm to a negative valley to provide a ZVS turn-on condition of S1.

III. CONCLUSION

The proposed high boost ratio ZVS/ZCS PV module DC-DC converter with hybrid transformer which combines both resonant and linear mode is suitable for low input voltage such as photovoltaic module. The proposed converter is compared with coupled inductor and coupled inductor-switched capacitor converters. The resonant mode incorporated into the linear PWM converter has the following advantages

1) ZCS turn-off of diodes and ZVS turn-on of active switches, reducing the switching losses and EMI noises.
2) Low voltage stresses for all power devices and independent of wide changing input PVmodule voltage.
3) Due to optimized MU(Magnetic Utilization) allowing utilization of smaller-size magnetics and low profile design.
4) RMS conduction losses reduces due to continuous input current combined with resonant and PWM waveforms.
5) PDU(Power Device Utilization) is improved due to additional resonant diode and small resonant capacitor.

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