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Application of High Boost Ratio Hybrid Transformer DC-DC Converter for PV Module

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ABSTRACT- *As per the present scenario the power from the conventional energy sources are becoming so less (coal, lignite, oil, and gases).So most of them looking in forward for the power from green or renewable based energies like solar, wind, tidal, biomass etc. which does not cause any pollution to the environment. There is an increasing demand for the utilization of renewable energy sources such as PV modules. Integrating the power from the photovoltaic (PV) module into the existing power distribution infrastructure is achieved using power conditioning systems (PCS). The dc–dc conversion stage of the PCS requires a high efficient and high boost ratio dc–dc converter to increase the low dc input voltage from the PV panel to a higher dc voltage. In this paper proposes a high boost ratio hybrid transformer DC-DC converter and simulation is also performed. Lot of necessary steps want to be taken one of the main important factor that high boost ratio DC-DC converter is needed. The proposed converter utilizes the inductive and capacitive energy simultaneously to achieve high boost ratio with the smaller sized magnetic component. This DC-DC converter utilizes hybrid switching technique. Hybrid switching consists of PWM and resonant power conversions to achieve high boost ratio while maintaining high efficiency. Hence resonant operation mode is incorporated into the traditional high boost ratio PWM converter; the switching losses (turn-off) are reduced, which increases the efficiency of the converter under all load conditions. The conduction losses and input current ripple are also reduced. The voltage stresses on the active switch and diodes are maintained at a low level.*

Keywords: *Energy sources with low dc voltage, high boost ratio dc-dc, high efficiency, hybrid transformer, IGBT, PV module.*

I. INTRODUCTION

In recent years, with fast emerging technological innovations, there is a growing demand for improved efficiency, reduced size, cost and weight. The demand for renewable energy sources, such as photovoltaic modules (PV), is increasing due to the rising costs and the limited quantity of non-renewable energy sources. In the high-power amplification ratio, the isolated inductor and switched capacitor are added to non-insulated DC to DC converter topologies due to the fact that only a single active low-voltage switch is required for the topologies. The primary-side active switches of the step-up converters have a low voltage load due to the transformer effect of the coupled inductors.
Since there is a low voltage load on the active switch, low voltage IGBTs can then be used in the circuits and smaller switching periods, thereby reducing both the line and switching losses. A high gain, non-insulated DC voltage converter was constructed using a clamp mode pair inductor buck-boost converter. The leakage energy of the converter from the coupled inductor was recycled, thereby reducing the losses of the system. However, the output diode voltage for this converter was higher than the output DC voltage bus voltage. Another disadvantage of the converter was that there was a high input current ripple.
By adding a switched capacitor in series with the power transformer path, a new improved step-up DC/DC converter with coupled inductor and switched capacitor has been introduced. With the switched capacitor inserted between the primary side and the secondary side of the coupled inductor, the gain ratio was increased and the output diode voltage load was decreased. However, the magnetic core was not fully utilized because it was more than one inductor than a transformer. A light load effect of the inverter is also reduced as the switching losses dominate under light load conditions.
This paper proposes a hybrid transformer DC-DC converter. The proposed transformer simultaneously uses the inductive and capacitive energy to achieve a high gain ratio with the smaller magnetic component. This converter uses a hybrid switching technique. Hybrid circuit is composed of PWM and resonant power converters to achieve a high gain ratio while maintaining a high efficiency.
Since the resonance operation mode is integrated into the conventional high-gain ratio pulse width conversion converter, the switching losses are reduced, thereby increasing the efficiency of the converter under all load conditions. The line losses of the input current ripple are also reduced. The voltage loads of the active switch and the diodes are maintained at a low level.

II. PROPOSED CONVERTER TOPOLOGY

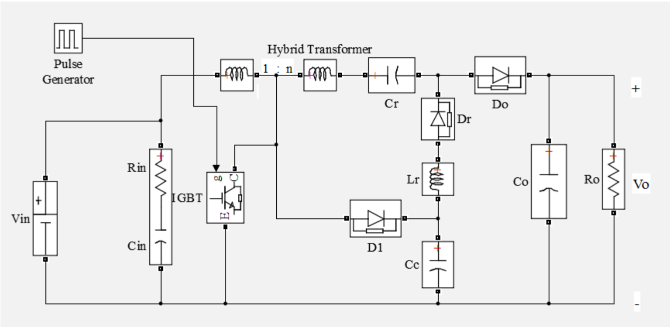

Fig.1 Proposed high step-up dc-dc converter with Hybrid transformer.

Fig. 1 shows the circuit diagram of the proposed converter. C_{in} is the input capacitor; Hybrid transformer is used; S_1 is the active IGBT switch; D_1 is the terminal diode which provides a current path for the leakage inductance of the hybrid transformer when S_1 is OFF, C_c detects the leakage energy from the hybrid transformer and transmits it to the resonance capacitor C_r by means of a resonant circuit consisting of C_r, C_c, L_r and D_r. L_r is a resonant inductor. And D_r is a diode used to provide a unidirectional current flow path for the operation of the resonance section of the circuit. C_r is a resonance capacitor operating in the hybrid mode by having a resonance charge and a linear discharge. The switching on of D_r is determined by the state of the active switch S1. D_o is the output diode similar to the conventional coupled inductor boost converter and C_o is the output capacitor and R_o is the equivalent resistive load.

III. TYPES OF OPERATION

The five operating modes of the proposed converter are described below.

Mode1: During this period the IGBT S_1 is switched on, the magnetization inductance of the hybrid transformer is charged by the input voltage, C_r is charged by C_c. The energy detected in C_c is transferred to C_r, which in turn is transferred to the load during the turn-off time of the IGBT. There are two advantages. The first advantage is that the energy is supplied from the source simultaneously during the capacitive mode and inductance. Compared to previous coupled inductor coil inductor dc-dc converters, the DC bias is greatly reduced, thereby reducing the size of the magnetic material. Secondly, the turn-off current is reduced, which reduces the turn-off switching losses.

Mode2: In this period, the IGBT S_1 is turned off, the clamp diode D_1 is turned on by the leakage energy stored in the hybrid transformer during the period of time the IGBT is turned on and the capacitor C_c is charged which cause the voltage on the IGBT to clamped.

Mode3: In this period, the capacitor C_c is charged to the point where the output diode D_o is biased. The energy stored in the magnetization inductor and the capacitor C_r is transferred to the load and the clamp diode D_1 is passed while C_c remains charged.

Mode4: In this period, the diode D_1 is reverse biased, and as a result, the energy stored in the magnetization inductance of the hybrid transformer and in the capacitor C_r is simultaneously transmitted to the load.

Mode5: During this time the IGBT S1 is switched on. Due to the leakage effect of the hybrid transformer, the output diode current will continue to flow for a short time and the output diode D_o is reverse biased. Then the next switching cycle starts.

IV. DESIGN CONSIDERATION OF PROPOSED CONVERTER

During the turn-off period,

Secondary reflected voltage of the transformer is equal to n V_{in}.

Therefore V_{cc} can be given as

$$V_{cc} = V_{in} + \frac{DV_{in}}{1-D}$$

$$V_{cc} = V_{in}\left[1 + \frac{D}{1-D}\right] = \frac{V_{in}}{1-D}$$

During the turn-on period with V_{cc} constant, V_{cr} can be given as

$$V_{cr} = V_{cc} + nV_{in}$$

$$V_{cr} = \frac{V_{in}}{1-D} + nV_{in} = V_{in}[\frac{1}{1-D} + n]$$

After calculating voltage across the capture capacitor and resonant capacitor, now we can calculate the output voltage V_o.

$$V_o = V_{cc} + V_{cr} + \frac{nV_{in}D}{1-D}$$

$$V_o = V_{in}[\frac{1}{1-D} + \frac{1}{1-D} + n + \frac{nD}{1-D}]$$

Boost converter output = $V_{in}\frac{1}{1-D}$

Flyback converter output = $V_{in}\frac{nD}{1-D}$

Voltage across the resonant capacitor

$$V_{in}(\frac{n}{1-D} + n)$$

Hence the output voltage of the proposed converter is the sum of outputs of Boost converter, Flyback converter and the voltage across the resonant capacitor.

$$V_o = V_{in}[\frac{2}{1-D} + + \frac{n - nD + nD}{1-D}]$$

$$V_o = \frac{2+n}{1-D}V_{in}$$

The output current can be calculated as,

$$I_o = \frac{V_o}{R_o}$$

The Boost conversion ratio can be calculated as,

$$M_b = \frac{V_o}{V_{in}} = \frac{2+n}{1-D}$$

V. TWO-PHASE INTERLEAVED EXTENSION

In order for the proposed converter to be used in higher power level conversion applications, the interleaving method applicable to the traditional high boost ratio PWM dc–dc converter can be employed.

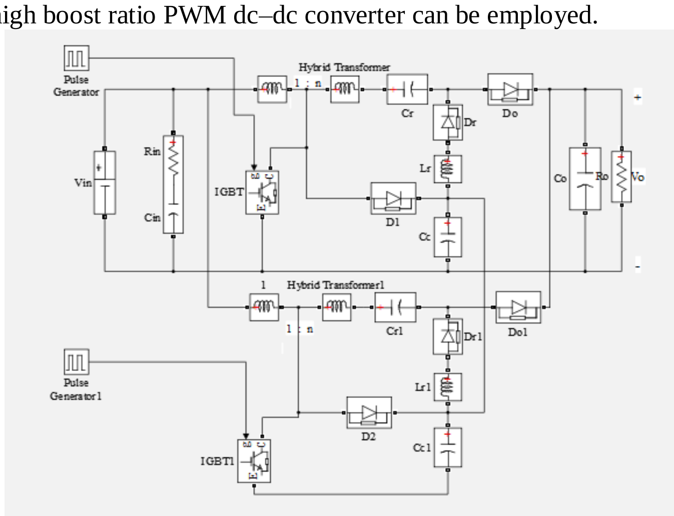

Fig.2 Two phase extension for proposed high step-up dc-dc converter with Hybrid transformer.

This gives the advantages of standard interleaved converter systems such as low-input current ripple, reduced output voltage ripple, and lower conduction losses. Fig.2 represents two-phase extension of proposed converter. The difference between standard interleaved converters and the proposed interleaved converter is that the clamping capacitor C_c can also be shared by the interleaved units reducing the total number of components in the system.

VI. SIMULATION MODEL AND RESULTS

In order to verify the effectiveness of the proposed converter, the converter was designed in MATLAB/SIMULINK environment.

The parameters values is shown below:-

V_{in} =40 V, R_{in}=10 ohms, C_{in} =5 μF, C_r =0.5 μF,
L_r =2.2 mH, C_c =20 μF, C_o =2 μF, R_o =50 ohms.

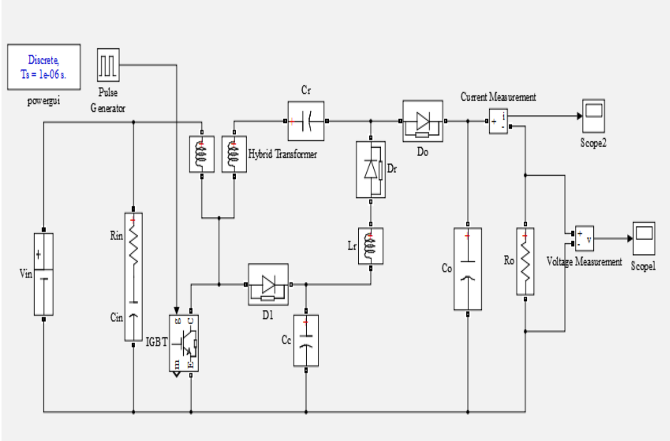

Fig.3. Simulation diagram of proposed high boost ratio hybrid transformer dc-dc converter (single stage)

Fig.3 represents Simulink model of proposed high boost ratio hybrid transformer dc to dc converter. In this input voltage=40V given to this converter. The voltage is stepped up using a hybrid transformer and due to the capacitance Co the ripples will be reduced and the fine DC voltage is obtained at the output side of the circuit.

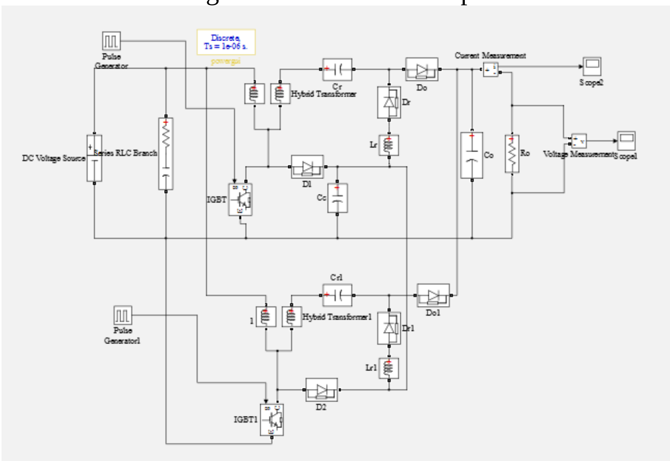

Fig.4 Simulation diagram of proposed high boost ratio hybrid transformer dc-dc converter (Two stage).

Fig.4 represents Simulink model of proposed high boost ratio hybrid transformer dc to dc converter with two stage. In this input voltage=40V given to this converter. Here also, the same process will be done. The additional part we are adding another proposed converters. The outputs of these two converters are being connected in series.

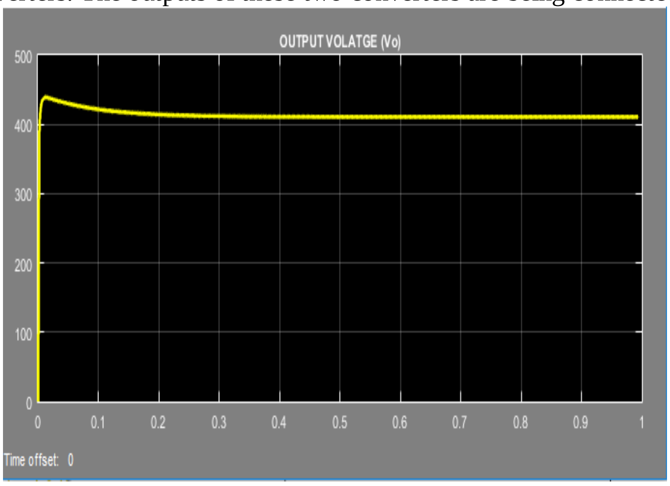

Fig.5. output voltage at input voltage=40V (single stage)

Fig.5 shows the output voltage waveform of proposed high boost ratio hybrid transformer dc to dc converter with single stage which is seen that the voltage gradually increasing from 0V to 410V, for IGBT.

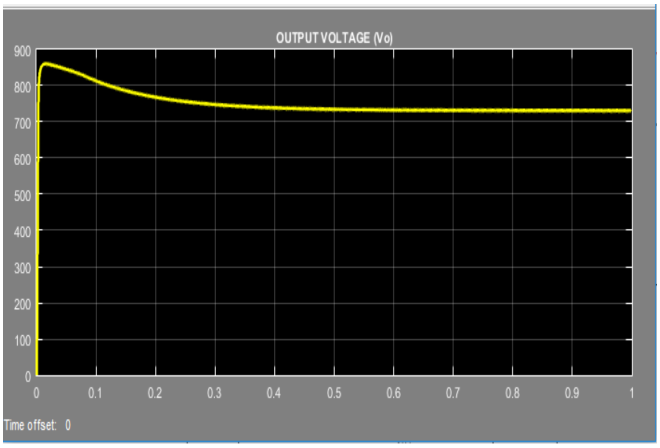

Fig.6. output voltage at input voltage= 40V (Two stage).

Fig.6 shows the output voltage waveform of proposed high boost ratio hybrid transformer dc to dc converter with two stage which is seen that the voltage gradually increasing from 0V to 740V, for IGBT.

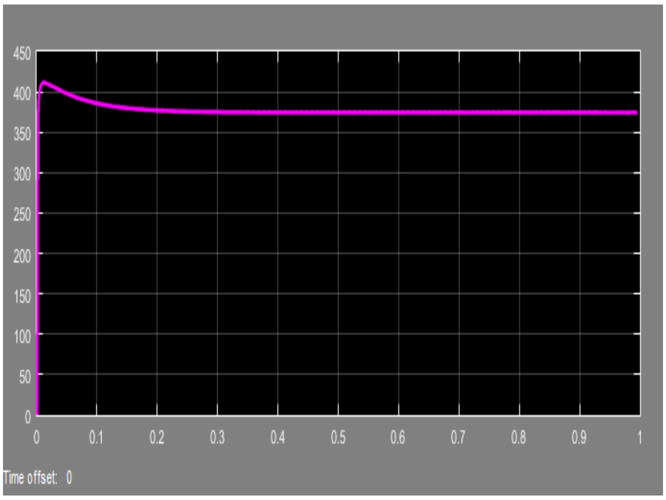

Fig.7. output voltage at input voltage=40V (single stage)

Fig.7 shows the output voltage waveform of proposed high boost ratio hybrid transformer dc to dc converter with single stage which is seen that the voltage gradually increasing from 0V to 375V, for MOSFET.

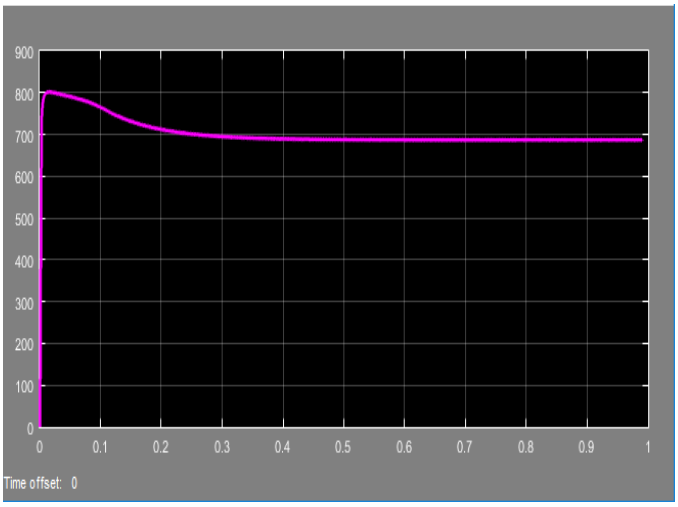

Fig.8. output voltage at input voltage= 40V (Two stage).

Fig.8 shows the output voltage waveform of proposed high boost ratio hybrid transformer dc to dc converter with two stage which is seen that the voltage gradually increasing from 0V to 685V, for MOSFET.

TABLE 1: SPECIFICATION OF PARAMETERS AND COMPARISION

Single Stage Proposed Converter								
Parameter	V_{in} (V)	R_{in} (Ω)	C_{in} (μF)	C_r (μF)	L_r (μH)	C_c (μF)	C_0 (μF)	V_0 (V)
MOSFET	40	10	5	0.5	2.2	20	2	375
IGBT	40	10	5	0.5	2.2	20	2	410
Two Stage Proposed Converter								
Parameter	V_{in} (V)	R_{in} (Ω)	C_{in} (μF)	C_r (μF)	L_r (μH)	C_c (μF)	C_0 (μF)	V_0 (V)
MOSFET	40	10	5	0.5	2.2	20	2	685
IGBT	40	10	5	0.5	2.2	20	2	740

VII. CONCLUSION

This work presents "A High-Boost Ratio Hybrid Transformer DC-DC Converter for Photovoltaic Applications with low DC input voltage" with following features and benifites:-

1. The concept of achieving high efficiency due to reduction in voltage stresses on switch and compactness in the size is the main paradigm in the present day Power Electronic Industries.
2. The main feature of this converter, transfers the capacitive and inductive energy simultaneously to increase the total power delivery to the load by reducing losses in the system.
3. From simulation results it is clear that, the conversion ratio is approximately 10, with the output voltage 410V for single stage along with IGBT used as a switcing device.
4. Two stage of proposed DC to DC converter, the conversion ratio is approximately 18.5, with output voltage 740V (IGBT).
5. Similarly the simulation results of DC to DC converter using MOSFET as a switch, output voltages are 375V & 685V for single stage and two stage respectively.
6. In this DC-DC converter, use IGBT in place of MOSFET because the distinct results comparision between IGBT & MOSFET which is shown in the simulation results.
7. Since using IGBT as a switch in converter, it gives better performance, less distortion in output which causes low harmonics injects into the power system.
8. With these improved performance, the converter can maitain high efficiency under low power and low input voltage condition.

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