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DESIGN OF TWO INDUCTOR BOOST CONVERTER FOR PHOTOVOLTAIC APPLICATIONS

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ABSTRACT

A TIBC converter for photovoltaic applications is proposed in this paper. The proposed converter provides better solutions to the Renewable energy sources. The proposed system is mainly based on a current resonant converter which is also known as Two Inductor Boost Converter (TIBC).The classic topology of the TIBC features are increased voltage gain and reduced current ripple. And further it is improved with the use of a non-isolated snubber along with the snubber capacitor and transformer parasitic components. The proposed system is efficient and low cost. The analysis of TIBC with the pv array has been simulated using MATLAB Simulink. The developed system is utilized for photovoltaic applications.

Keywords— *Two Inductor Boost Converter, Non isolated snubber, Transformer Parasitic.*

I. INTRODUCTION

Solar energy is the most low cost, competition free, universal source of energy as sun shines throughout. This energy can be converted into useful electrical energy using photovoltaic technology. The steady state reduction of price per peak watt and simplicity with which the installed power can be increased by adding panels are attractive features of PV technology [23]. Among the many applications of PV energy, pumping is the most promising. In a PV pump storage system, solar energy is stored, when sunlight is available as potential energy in water reservoir and consumed according to demand. There are advantages in avoiding the use of large banks of lead acid batteries, which are heavy and expensive and have one fifth of the lifetime of a PV panel. A number of experimental DC motor driven PV pumps are already in use in several parts of the world, but they suffer from maintenance problems due to the presence of the commutator and brushes [25]. Hence a pumping system based on an induction motor can be an attractive proposal where reliability and maintenance-free operations with less cost are important [24]. The effective operation of Induction motor is based on the choice of suitable converter-inverter system that is fed to Induction Motor. Converters like Buck, Boost and Buck-Boost converters are popularly used for photovoltaic systems. But these converters are limited to low power applications. For PV applications like pumping these converters could do a good job as pumping is carried out at high power. Thus a new TIBC converter which is two switch topology can do justice by giving a high power throughout [2]. The Induction Motors are the AC motors and hence from converter, an inverter system is also required to obtain an AC voltage [26]. This inverter is chosen based on its advantages and it is fed to induction motor. It is important, however, that the absence of batteries does not compromise the efficiency of the end-to-end power conversion chain, from panels to mechanical pump.

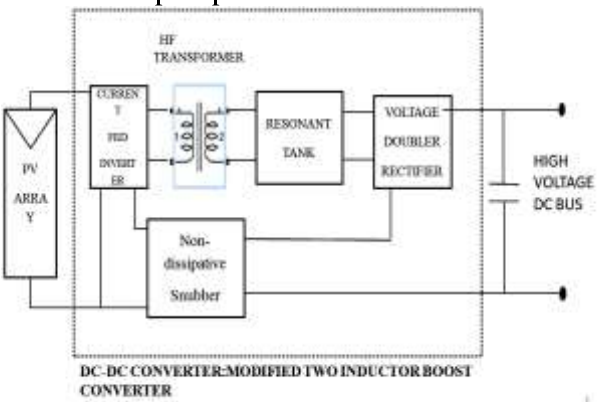

Fig 1. Proposed Two Inductor Boost Converter

Some of the renewable power sources, such as PV panels and fuel cells, are characterized by low-voltage high- current output and have strict current ripple requirement [3]. Consequently, a dc–dc converter with high step-up capability, galvanic isolation, low input current ripple, and high efficiency is required [27]. Current-fed converters attract more and more interests in such kind of applications, with their inherent properties of high boost capability and small input current ripple. Thus, the turn's ratio of the transformer reduced, and the bulk input filters can be shrunk as compared with the conventional voltage fed converters. However, the current-fed pulse width modulated converters still have the problems of high voltage and current spikes resulting from the leakage inductance and winding capacitance of the transformer [28], and high voltage stress on the rectifying diodes due to their reverse recovery. Hence, their operating frequency should be low, and the power conversion efficiency is also limited. Kinds of active clamping techniques have been proposed to recycle the energy in the leakage inductance and to alleviate the surge voltage on the switches. Nevertheless, the additional clamping circuits complicate the application, lower the reliability, increase the cost, and always result in triangular switch currents which increase the current RMS values.

Resonant techniques promise high-efficiency power conversion while operating at high switching frequency with their instinctive capability of well utilizing the circuit parasitic and achieving zero-voltage switching (ZVS) or zero-current switching (ZCS) for the active switches [6]. Moreover, the current-fed parallel resonant converters (CFPRCs) also have high step-up feature, with the introduced *LC* parallel resonating driven by a square wave current source. With such techniques, not only the parasitic of the transformer can be utilized, but also the turn's ratio can be further reduced.

Most of the efforts for the CFPRCs were focused on achieving ZVS of the primary switches no matter if the active switches were controlled with dead time or overlapping [7]. However, in low-voltage high-current input applications, ZVS is not that much important, while ZCS is the key for switching loss elimination whereas the existing leakage inductance of the transformer still causes high voltage spikes on the switches.

II. PROPOSED CONVERTER

The requirements demand the use of a converter with the following features: high efficiency due to the low energy available;

less cost enables the deployment where it is needed; autonomous operation no specific training needed for operating the system; robust and less maintenance possible; and high life span comparable to the usable life of 20 years of a PV panel. This chapter proposes a new dc/dc converter and control suitable for PV water pumping and treatment that fulfill most of the aforementioned features [23].

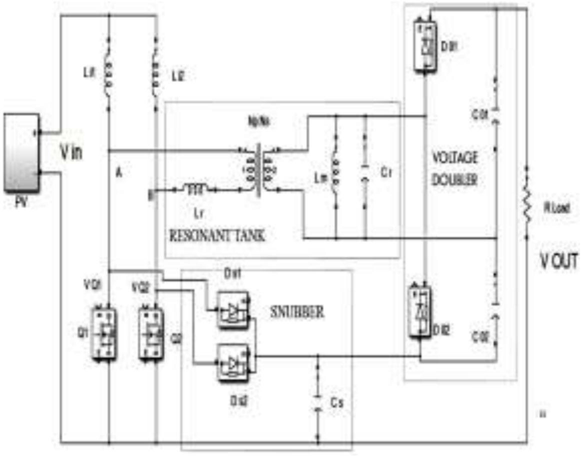

Fig 2. Proposed TIBC Converter

By using the redefined version of the two inductor boost converter, at the first stage that is dc-dc converter, due to the very less number of components, less complexity, flux balance of transformer and common gate ground driving for all the switches [2]. This facility makes it as ideal choice for achieving the system characteristics. From the high voltage gain of the proposed converter it also compares with the other current-fed converters like switching voltage stress, conduction losses and transformer utilization[28]. Also the input current is subdivided into the two inductors and the current ripple is reduced to half at double the PWM frequency [27].

This feature minimizes the oscillation at the input source and makes it very easy to obtain the maximum power point tracking. In its implemented version of the TIBC any one of the switch is always closed creating a path for inductor current [2]. The Proposed converter can also be modified as a multiresonant converter by using the capacitor at the secondary of the high frequency transformer winding.

The multi resonant tank circuit is formed by Leakage inductance, Magnetizing Inductance and the added capacitor. The parasitic capacitance of the transformer parasitic components it is easy to achieve the ZCS condition for the primary switches and voltage doubler diodes and it enables the converter to operate at maximum efficiency[8]. It is also possible to reduce the transformer winding ratio by using the voltage doubler at the output side.

A non-dissipative snubber is introduced with the two diode and capacitor connects the input side directly into the output side. This will make it as a non-isolated converter.

III. OPERATION PRINCIPLE

The following assumption are made before it is discussed, the input inductors are very large so the current is almost constant. The snubber and voltage doubler capacitors are also high to maintain the constant voltage, In order to achieve the ZCS operation overlapped duty cycle switching scheme to initiate the conduction path for the primary Inductors Current.

When both switches turned on the two input inductors are charged by the input current. When switch 1 is opened the energy stored in Inductor 1 is transferred to c1 through the high frequency transformer and the rectifier diode D1.If the multi resonant tank is formed two resonant condition occurs

1, when both switch closed Leakage inductance participates with the resonant capacitor.

2, during the conduction time interval.

3, Current resonant formed by the magnetizing inductance and the resonant capacitor.

The Key waveform for switching operation is presented in the figure 3.

In the figure VQ_1 and VQ_2 are the gate signals of the switches Q_1 &Q_2 .Drain to Source voltage of the switch Q_2 , transformer primary voltage, primary current and the input inductor current supplied by the source is also presented.

At the time of diode D_{01} is conducting, the voltage on resonant capacitor C_r is $+V_{out}/2$.At this time switch Q_1 is triggered by the V_{q1},and the Q_1 is turned on, voltage across the Q_1 is falls to zero and snubber diode D_{s1} is stop conducting. At this time resonant capacitor C_r transfer its energy to the L_r so that the combination of L_r and C_r starts the resonant process forcing the I_{q2} to decrease.so that rectifying diode D_{01} is forced off and C_r will resonant with the magnetizing inductor L_m .so that current of the switch Q_2 continues to decreases.

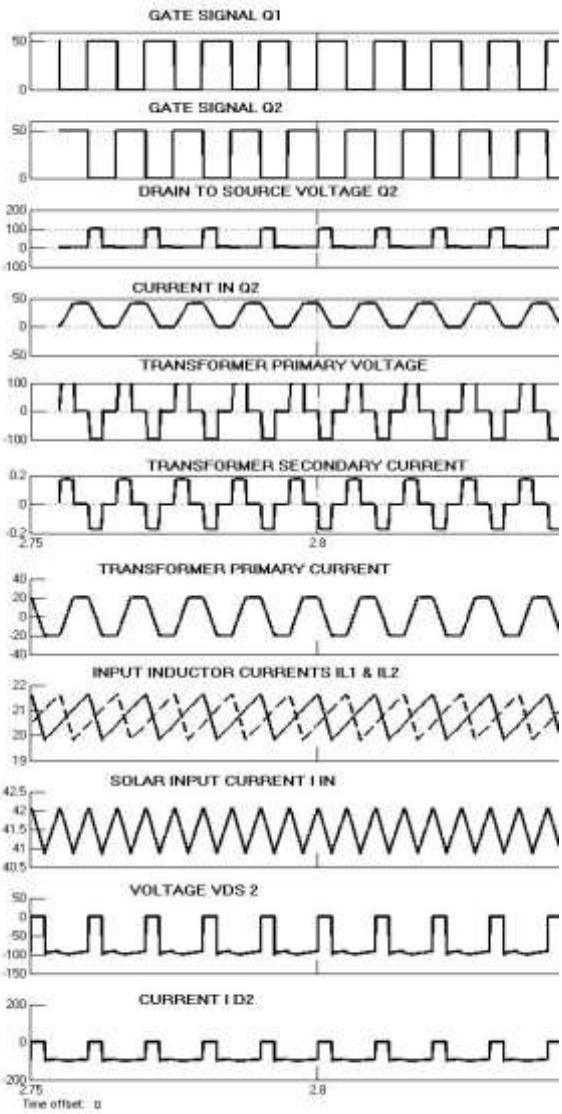

Fig 3. Key Waveform of the TIBC Converter

However the complete analysis is presented [1] and that resultant mathematical model is complex one for all the resonant process and this makes the design method depends on several dependent variables which makes the analysis to be difficult [9]-[20].

In this paper simplified methodology for the resonant process and resonant and switching frequency is proposed.Matlab simulation shows that, the current operation is guaranteed for soft switching operate of primary switches.

Although resonant affect the output voltage and the small effects neglected and the output voltage is derived on the block diagram model of the proposed converter.

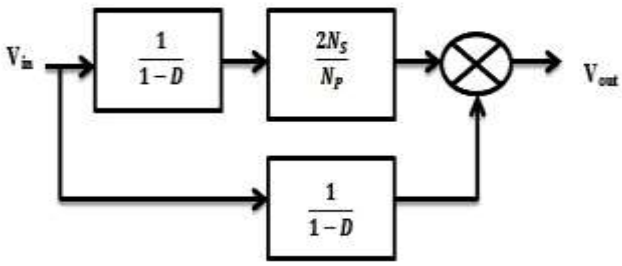

Fig 4.Block Diagrammatic representation of the control Equation

$$\frac{V_{out}}{V_{in}} = K_v = \frac{1}{1-D}\left(1 + 2\frac{N_s}{N_p}\right) \qquad (1)$$

Where D represents Duty cycle, N_s/N_p Transformer ratio, D≥0.5 i.e. for Boost converter ant overlapping. And F_{rs} resonant frequency,F_{sw} switching Frequency. Thus

$$F_{rs} = \frac{1}{2\pi\sqrt{L_m C_r}} \leq \frac{F_{sw}}{1.1} \qquad (2)$$

During primary current commutation Q_1 & Q_2 overlapping,L_r participates with L_m and C_r ,so the resonant frequency for this interval is,

$$F_{rp} = \frac{1}{2\pi\sqrt{\frac{L_m L_r}{L_m + L_r} C_r}} \qquad (3)$$

Considering L_m much larger than the L_r so that Eq (3) simplified as,

$$F_{rp} = \frac{1}{2\pi\sqrt{L_r C_r}} \quad (4)$$

Duration of commutation period is as,

$$T_{ov} = \frac{\pi}{w_r} \quad (5)$$

The energy stored in C_r should be transferred to the L_r so that

$$L_r \leq V_0^2 \frac{C_r}{2I_{in}^2} \quad (6)$$

IV.SIMULATION RESULTS

The proposed converter was simulated on Matlab R2014a

Fig. 5 shows the schematics used for the first-stage TIBC.All parasitic were included in the transformer and capacitors. The control of the switches was simulated using the fixed pulse width modulation and that is implemented with the PV panel.

Fig. 6 shows the overlapped pulses to control the switches and the input current flowing through the inductors and pv array.

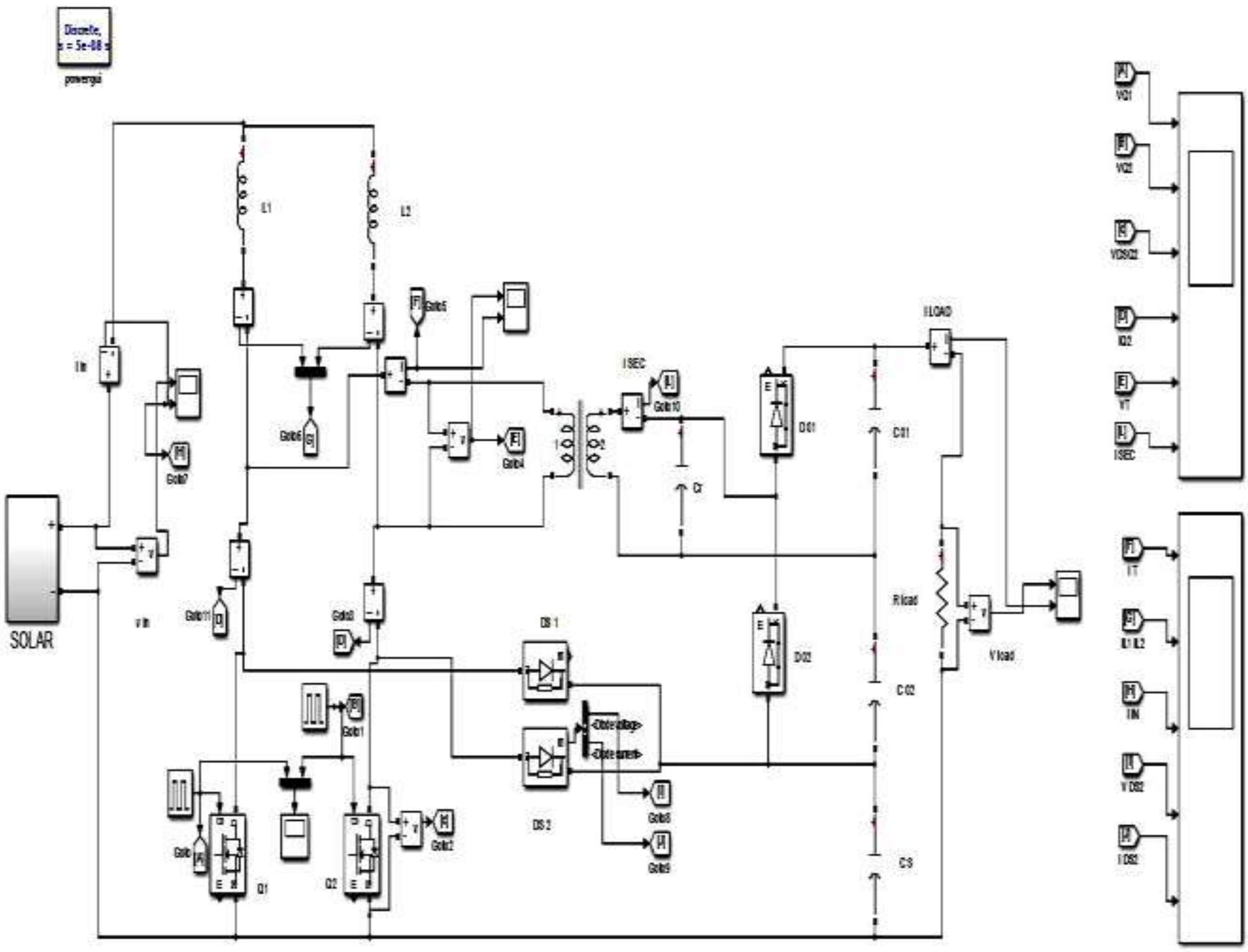

Fig 5.Circuit used in the simulation.

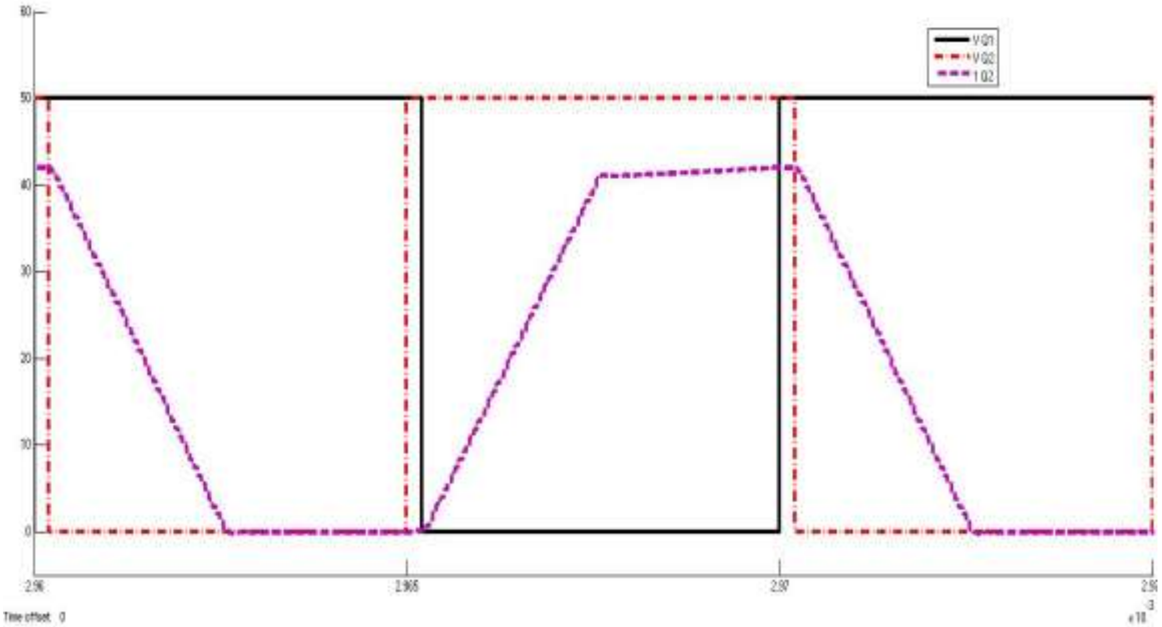

Fig 6.ZCS condition of the input switch Q_2.

PV array input current with the highest ripples and output voltage waveform of the modified TIBC converter is presented in the Fig 7.shows the reduced amount of the ripples is presented.

The parameters used for the simulation is tabulated in the TABLE I

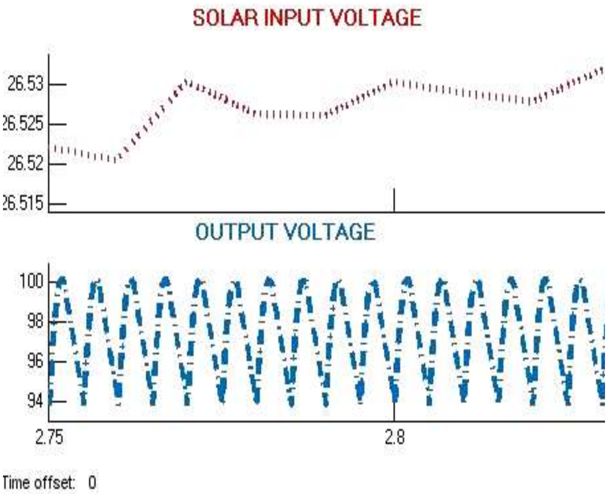

Fig 7.Solar Input and Output voltage of the converter.

TABLE I

Parameters	**Specifications**
Input inductor L1, L2	96µ henry
Switching Frequency	100 KHz
Resonant Frequency	37 KHz
Leakage Inductance L_r	5.7µ henry
Magnetizing inductance	3098µ henry
Resonant Capacitance	5.8n farads
Output Filter Capacitor c_{01}, c_{02}	1.5µ farads
Snubber Capacitor C_s	4.5µ farads

V. CONCLUSION

In this paper, a TIBC converter for Photovoltaic applications has presented. The converter has designed to operate a photovoltaic system directly. This paper presented the system block diagram and its design. The simulations result shows the response of the proposed TIBC converter under the variation of solar energy and the reduced voltage ripple in the output of the converter. And also the resonant condition shows the reduced losses in the switching devices by using the transformer parasitic component [27].

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