A T-Source Soft Switched High Step Up DC-DC Converter for Photovoltaic System

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Abstract- *A non-isolated T-source soft-switched high step up DC-DC Converter for photovoltaic system is presented in this paper. In the proposed converter, a coupled inductor accompanied with a capacitor which resembles T-shaped network known as T-source is used to reduce voltage stress, inrush current, poor transient response and more reactive components. Also, the duty ratio of proposed to converter is controlled by PI controller to achieve constant output. Furthermore, the proposed converter accomplishes the zero-voltage-zero-current switching to reduce reverse recovery loss and switching losses. The (ZVZCS) Soft-switching is applied to the switching device the entire time of operation, by these features together and the plainness of the proposed converter outcome will achieve high efficiency with a wide range of output . In order to verify the proposed the converter, proposed model is simulated by using MATLAB/SIMULINK software and hardware was implemented.*

Keywords- DC-DC Converter, High step up, PV system, Soft-Switching, T-Source network.

I. INTRODUCTION

In recent days the demand for the electrical power increasing day by day. Many conventional power generation topologies are pro-posed but they increase the environmental pollution and consumption of fossil fuels [1]. And now-a-days high step-up dc–dc converters are avital part of power electronics systems. They are widely employed in many applications such as distributed generation sources, renewable energy systems, DC micro grids, uninterruptible power supplies (UPSs), and wireless transceiver stations [2]. The power switches are switched with zero-voltage-switching (ZVS) characteristic while turn-on and turn-off the diodes occur under zero-voltage switching zero-current switching (ZCS) condition. ZVS turn-on of the power switches eliminates their turn-on capacitive losses caused by discharging their output capacitances into the switches when they turn on. This operation of the output diodes addresses their reverse-recovery issue which is severe in high step-up converters [2][3].

In the basic LC frame network, the topology arrangement of the connections doesn’t focus on either altering the basic network structure or improvising of the ZSI. In recent times, to exclude the inconvenience of the classical Z-source converter, there are few modifications prepared in its basic network, whose consisted mostly in change of primary source position. These unconventional LC networks have been known for many years from circuit theory. By developing those theory will open new possibilities for single-step energy conversion for high voltage boost converters [4].

The impedance source converter concept is used to the T-Shaped Z-source converters for photovoltaic system. The availability, effectiveness and cost is fulfilled the best output of photovoltaic system. The T-Source converter consists of one coupled inductor and a capacitor connected this forms a T-shaped network. Hence the name is T-Source [5]**.** However Z-source converter delivers suitable operation for buck-boost modes in this operating mode voltage stress across switching components and passive components is significantly high, therefore to reducing losses and achieve an efficient boosting of voltage levels.

This T-source converter employed in this converter fewer reactive components are establish to be effective in operating in buck-boost modes with significant reduction in voltage stress [6]. In the conventional methods of solar energy conversion systems boosting the voltage in a single stage has few drawbacks. To overcome these disadvantages of the Z-source converter T-source converter is applied. Normally Z-source converter requires more reactive component like two inductance and two capacitance. But T-source converter requires a coupled inductance which has very low leakage an it should be made with high accuracy.

In such a way, total volume of the system can be minimized because the number of passive elements is reduced it needs only the coupled inductance and a capacitor [7]. This type of Z-source converter has some limitations like more reactive components, which occupies more space and has high ripple contents. When comparing to Z-source converter, T-source converter has high voltage gain and less reactive losses because it has few reactive components. In T-network high voltage gain is possible by regulating the number of turns in coupled inductor[8].

In this paper proportional integral (PI) controller is used for the boost converter which is used for DC to DC conversion. This PI controller is a closed loop controller which used to maintain constant output voltage. It is used for some application which needs constant voltage like motor load it operates in constant voltage if that uninterrupted voltage needs then this paper is suitable one for those operation. The PI controller is a comparator which is comparing the output voltage and reference voltage and it will products the error signal that error signal is delivered to PI controller.

The PI controller is used for controlling the voltage signal after that it will send to PWM generator and the PWM generator is used to modify the K_p and K_i values from PI controller [9].The PI controller is most widely used for closed loop control. Defining its design methods is lead to the ideal operation of PI controllers, therefore of significant concern of simplicity, tuning as well asoptimality for this PI controller is important [10].

The major contribution of this paper is to introduce a novel technique to simultaneously achieve both ZVS performance for the power switches and reduced conduction loss and constant output voltage. In summary, merits of the proposed high step-up converter include simple structure, sufficiently high voltage gain, PI controlled operation with a non-isolated T-source soft-switched high step up DC-DC Converter for photovoltaic system, with reduced conduction loss, reduce voltage stress, inrush current, poor transient response and more reactive components. All these factors together with the simplicity of the proposed converter structure result in high efficiency over a wide range of output power.The block diagram of T-source soft-switched high step-up dc-dc converter for photovoltaic system is shown in the fig 1.

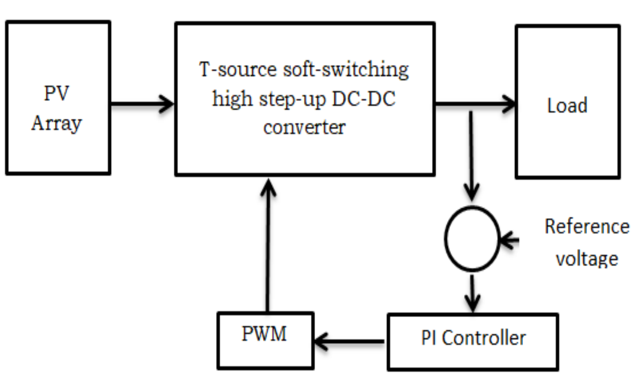


Fig.1 Block diagram of proposed system

The main blocks of the proposed converter are, PV array, Proposed DC-DC converter, PWM and PI controller, load, reference voltage. Input DC supply is taken from the PV array the proposed DC-DC converter is a closed loop system. The step-up voltage is given to the output and feedback to the PI controller. PI controller is used to compare reference voltage and feedback voltage and gives the signal to PWM generation. If any error is presented PI controller gives signal to the PWM generation and the switching operation is operated under this closed loop control. And also, soft-switching (ZVZCS) is applied by using resonant switching.

II. PRINCIPLE OF OPERATION

Fig.2 shows the power circuitry of T-source soft-switched high step-up dc-dc converter is proposed for photovoltaic system. This configuration has capable to reduced switching voltage stress and also provide high voltage gain. Moreover, the proposed converter is designed without using voltage multiplier or isolated transformer. The main benefits of the proposed configuration are less reactive component, single switch, coupled inductor reduces inrush current and harmonics and lesser component then Z-source.

And the energy from input is transfer to output without any transfer loops or using multiple conversions this increases the performance and efficiency. The power circuit is designed with the help of coupled inductor L_1, L_2 which is accompanied with a capacitor C, one MOSFET switch S, a unidirectional diode D. Across to the capacitor C_o the output voltage is taken and it is carried to load (*R*).

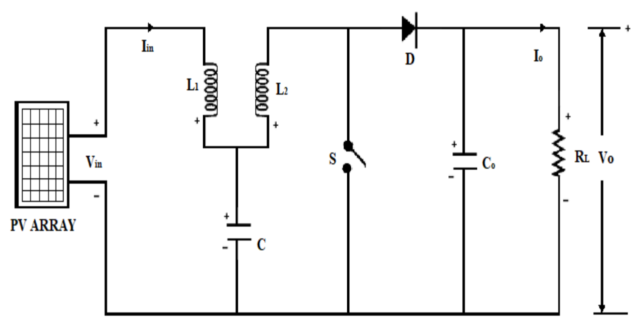


Fig.2 Power circuitry of proposed converter

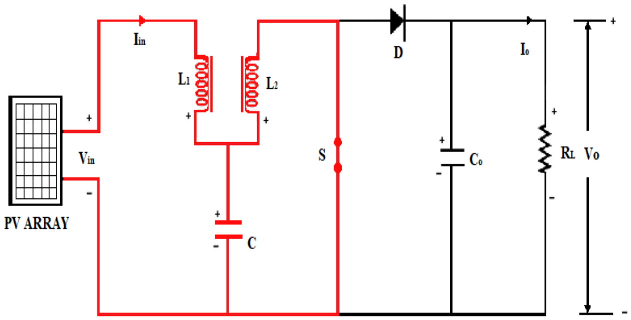
Based on the operation, coupled inductor $L_1$and L_2 considered as identical inductors ($L_1 = L_2$). Therefore, T-source (impedance) network and semiconductor device are considered in order to explain operating principle and the characteristics.

Let's consider, time period of one switching cycle is T_S and switching frequency of a switch is f_S.S is controlled by the PI controller, the gate pulse with duty ratio *d* is given by the PI controller. Using the feedback voltage across the output, switching pulses are given to the S. MOSFET is switched under resonant switching, for the (ZVS and ZCS) soft-switching.

The converter is operates in two modes.

MODE 1:

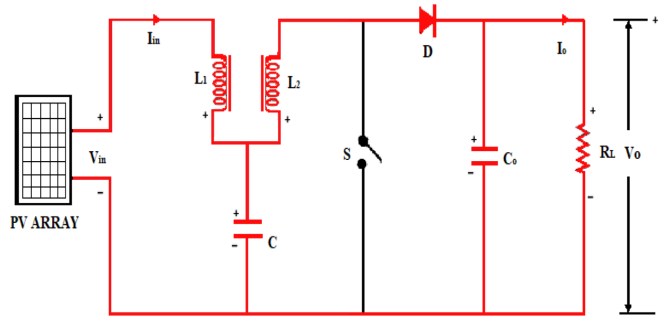
In this mode equivalent power circuit of T-source soft-switched high step-up dc-dc converter, MOSFET is turned ON under ZVZCS switching (resonant switching) and the coupled inductors L_1 and L_2 are magnetized and capacitor C gets energized by input voltage respectively. After mode 2 Capacitor C_0 gets energized and discharged during when MOSFET is in off state. After mode 2 Capacitor C_0 gets energized and discharged during when MOSFET is in off state.



(a)

MODE 2:

In this mode, equivalent power circuitry of T-source soft-switched high step-up dc-dc converter in which switch S is turned OFF under (ZVZCS) soft-switching and, coupled inductors L_1 and L_2 and capacitor C gets are de-energized in series with input voltage and boost the input voltage. And the diode D forward biased and capacitor C_o is energized across with the load (R), respectively.



(b)

Fig.3 Equivalent circuit for proposed converter in each mode (a) Mode 1 (b) Mode 2.

During the design of T-source converter the estimation of values for the reactive components of impedance network are the most stimulating part. Calculation for the average current for an inductor.

Assumption made are:

- For proposed T-network
  - $L_1 = L_2$;
  - $V_{L1} = V_{L2} = V_L$;
- The ripple current is ΔI_L.
- The maximum current through the inductor is I_{LMAX}.
- Total switching period (T) = Ton+Toff .

$$I_{LMAX} = I_L + \Delta I_L ..... \quad ...(1)$$
$$I_{LMAX} = I_L - \Delta I_L ..... \quad ...(2)$$
$$\Delta I_L = I_{LMAX} + I_{LMIN} ..... \quad ...(3)$$

Calculation of required inductance of T-source inductors:

$$L = T * V_C / \Delta I_L ..... \quad ...(4)$$

Where, T - is the switching period.

Calculation of required capacitance of T-source capacitors:

$$C = T * I_L / \Delta V_C ..... \quad ...(5)$$

Thus the formula used in the T-source high step-up dc-dc converter.

III. SIMULATION PARAMETERS

The parameters used in the proposed system with its specifications, input range, output ranges are represented in the following Table I.

Table I Experimental parameters and values

PARAMETERS	VALUES
Input voltage	35V-50V
Coupled Inductor ($L_1 = L_2$)	500Mh
Capacitor C_1	100μF
Capacitor C_2	100μF
Diode	IN4007
Output voltage	300V

IV. SIMULATION OF PROPOSED CONVERTER

The Simulation for T-source soft-switched high step-up dc-dc converter for photovoltaic system is shown in the Fig.4. The proposed converter has capable to reduced switching voltage stress and also provide high voltage gain. The main features of the proposed configuration are closed loop control with PI controller, less reactive component, single switch, coupled inductor reduces inrush current and harmonics and lesser component than Z-source.The simulation is done using the MATLAB/SIMULINK software. The blocks are the main elements which are connected as per the circuit diagram of T-source soft-switched high step-up dc-dc converter for photovoltaic system shown in fig3.1. we use, to build models by using the Simulink Library Browser to browse and search the block libraries.

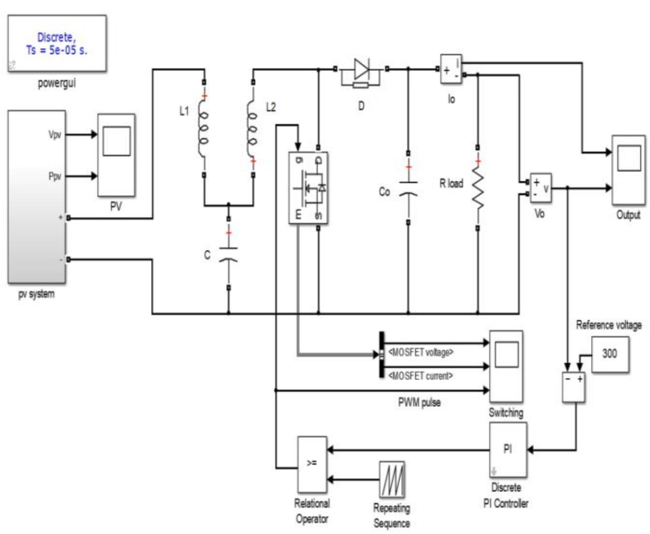


Fig.4 Simulation Diagram of proposed converter

When we find the block we want to use, we can add it to our model as per proper circuit connections. In this simulation diagram we use Dc source, four MOSFET switches, pulse generator for triggering purpose, Scope, Discrete, inductance, Capacitance, Current measurement, Voltage measurement, Diode, PI controller, saturator, PV array.After connecting all these blocks as per the circuit, we should save it and then run it. If we found any errors, then the particular should be solved and then again we should run the simulation. It would produce the waveform of the output voltage. By using that waveform we can assume the performance of the proposed system by comparing the simulated output voltage value with the input value and then it is verified by using the theoretical value.

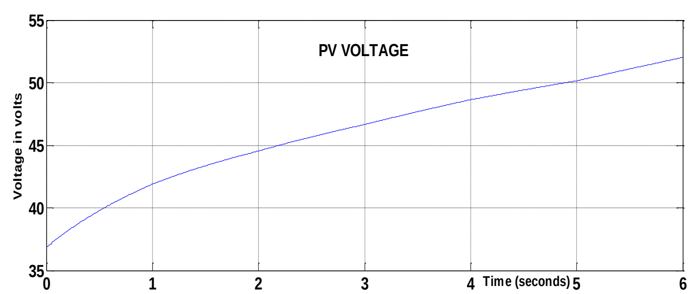
V. EXPERIMENTAL RESULTS

AT-source soft-switched high step-up dc-dc converter for photovoltaic system is proposed in this system. The simulated input and output of the proposed system is shown below.

A. Input Waveform

The input supply voltage is shown in the fig.5(a). Here we have set an input voltage as 35-50V.

The input power from the PV array is 140-280W along with respect to the input Voltage. The input power is shown in the fig.5(b)



(a)

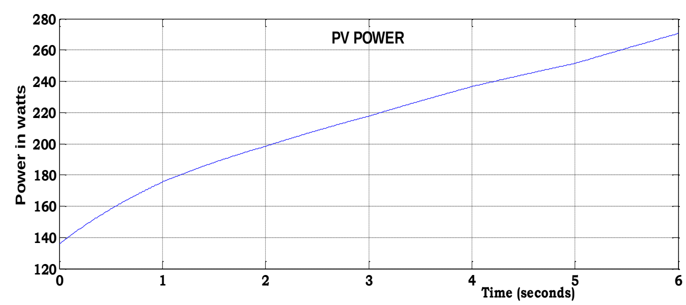


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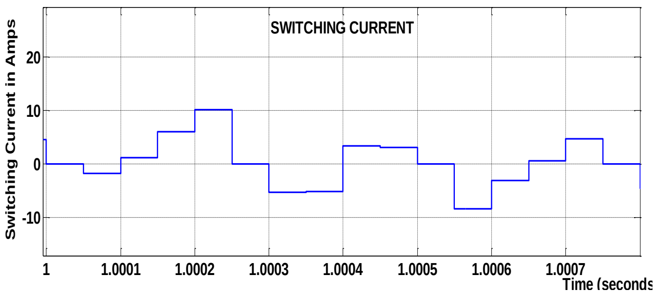
Fig.5 (a) Input voltage waveform (b) Input power waveform

B. Switching Waveform

The switching waveform is shown in the below fig.6. Here the waveform is plotted across time vs voltage and current. The soft-switching (ZVZCS) is shown with PWM triggering pulses.

The power switch is switched with zero-voltage-switching (ZVS) characteristic while turn-on and turn-off the diodes occur under zero-voltage switching zero-current switching (ZCS) condition.



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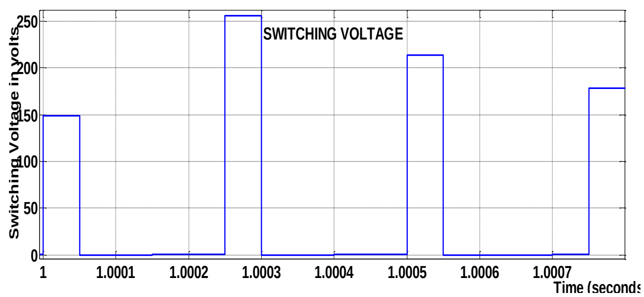

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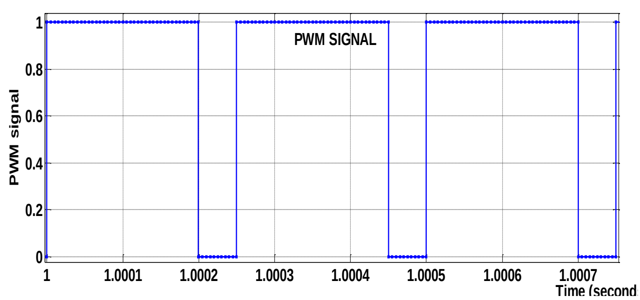
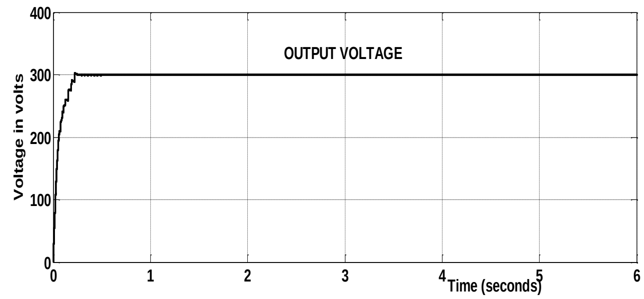


(c)

Fig.6 Switching waveform (a) ZCS waveform (b) ZVS waveform (c) PWM signal

C. Output Waveform

The simulated output voltage and current is represented in the fig.7 for output voltage is given for the T-source soft-switched high step-up DC-DC converter. Input voltage 35-50V is fed, the proposed converter will provide the output value which will be boosted while comparing with the input value.So, here we have set input voltage value as 35-50V, the resulted output voltage value is obtained as 300V.



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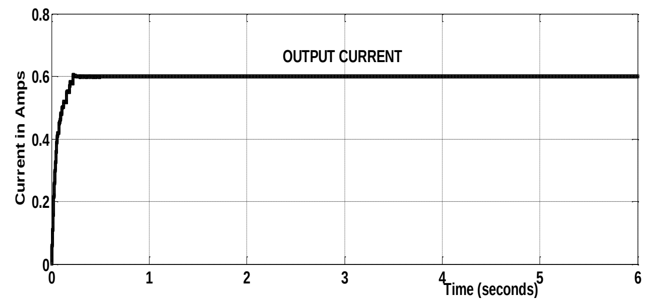

(b)

Fig.7 (a) Output voltage waveform (b) output current waveform

Thus the simulated results is shown in the above for the T-source soft-switched high step up DC-DC converter for photovoltaic system.

VI. CONCLUSION

A non-isolated T-source soft-switched high step up DC-DC Converter for photovoltaic system is presented in this paper. In the proposed converter, a coupled inductor accompanied with a capacitor which resembles T-shaped network known as T-source is used to reduce voltage stress, inrush current, poor transient response and more reactive components. Also, the duty ratio of proposed to converter is controlled by PI controller to achieve constant output. Furthermore, (ZVS) (ZCS) switching is accomplished to reduce switching loss and reverse recovery losses. The T-source soft-switched high step up DC-DC converter is compared with existing topologies and this proposed converter significantly a good choice to accomplish reduced voltage stress on switching device and converter component to attain high voltage gain. The analysis and experimental results are presented which validate the simulation results and performance of the proposed converter.

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(a)