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High Step-Up Two Inductor Boost Converter Integrated with Cascade Cockcroft-Walton Voltage Multiplier

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ABSTRACT: Photovoltaic (PV) array system is widely used as energy source in many electric power applications nowadays .The output voltage of PV panel is low if no extra arrangements are incorporated along with it. To boost the output voltage we should use high step-up DC-DC converters. This paper presents a high step-up Two Inductor Boost Converter (TIBC) integrated with Cockcroft-Walton voltage multiplier. The features like voltage gain and low input current ripple of conventional two inductor boost converter is further improved with the use of resonant circuit and voltage multiplier. The voltage stress across the switch is also reduced. For DC-AC conversion a three phase inverter with SPWM technique is used here. MATLAB/SIMULINK is used for the simulation of the system.

KEYWORDS: Two Inductor Boost Converter (TIBC), Cockcroft-Walton Voltage Multiplier, Photovoltaic (PV) systems.

I.INTRODUCTION

With increasing concern about environmental pollution, unavailability of electric power, the implementation of renewable energy sources in many of the applications is of having great importance. Among the renewable energy sources, photovoltaic (PV) energy is an efficient source due to the development of recent technological and efficient cells. Growth of the solar industry in recent years is rapid and it reveals the importance of PV system application for more efficient and reliable operation. When PV system is exposed to solar radiation, it can generate Direct Current (DC) without environmental impact and contamination. We can also increase the installed power by adding panels due to its simplicity. But we need a high voltage for most of the applications .So we have to boost the output voltage of the PV panel. Usually a single inductor, single switch boost converter topology and its variations can be applied in the majority of applications. But in high power applications, the performance of the boost converter can be improved by implementing boost converter with multiple switches or multiple boost inductors. Interleaved boost topology is also used in high power applications for eliminating reverse recovery losses of the boost rectifier. The Two Inductor Boost Converter (TIBC) is also beneficial in high power applications. In TIBC, the voltage stress of each switch is one half the voltage stress of the switches in the single inductor. Also the current ripple in the output capacitor is comparatively smaller because of the evenly distribution of input current through the boost inductors. Inability to regulate the load in a wide range with constant frequency control is a limitation of conventional TIBC .In order to overcome these limitations Cockcroft Walton voltage multiplier is used along with the resonance tank circuit and snubber circuit. The high step-up DC-DC converter used here is a modified TIBC integrated with Cockcroft-Walton voltage multiplier.

PV module converts solar energy to electric energy. DC-DC converter converts low DC voltages produced by the PV module to a high DC voltage. Inverter converts the high DC voltage to a three-phase AC voltage. . Two Inductor Boost Converter is a boost converter with two inductors and an isolation transformer. The input current is distributed through the two boost inductors having its current ripple amplitude halved at twice the PWM frequency. The use of resonant topologies able to utilize the component parasitic characteristics, such as the leakage inductance and winding capacitance of transformers, in a productive way to achieve Zero Current Switching (ZCS) or Zero Voltage Switching (ZVS) condition to the active switches and rectifying diodes. A snubber is connected in parallel with the whole system. The inverter is based on a classic topology (three legs, two switches per leg) and uses a Sinusoidal Pulse Width

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Modulation (SPWM) strategy. The use of this PWM strategy is to improve the output voltage level as compared to sinusoidal PWM modulation. During normal operation, a fixed duty cycle is used to control the TIBC MOSFETs, thus generating an unregulated high bus voltage for the inverter. MPP Tracking (MPPT) algorithm is used to track the maximum power from the PV panel.

II. LITERATURE SURVEY

A major limitation of the conventional TIBC is that the two inductor system has inability to regulate the load in a wide range with constant frequency control. The two inductors in the two inductor boost converter, generally hard switched overlapped, is having at least one of the switches ON at every instant. When there is no overlapping period between the two overlapping period of the switches, then the duty cycle of the switches, which is taken as the overlapping period to the half of switching period as zero. To reduce the stored energy and extend the load regulation range, it is necessary to shorten the conduction time of the switches. This can be accomplished by increasing the switching frequency. Thus it requires variable-frequency control to maintain the output voltage regulation in a wide load range.

All magnetic components are integrated into one magnetic core in isolated TIBC with one magnetic core. The circuit has the two inductor windings intrinsically coupled. This converter is implemented by using a single magnetic core with one gap in the centre leg. The advantage of this topology is the less magnetic components and at the same time keeps the coupling between the two inductor windings. Specifically the new circuit implements the isolated two-inductor boost converter with one transformer having two inductor windings intrinsically coupled. Under the condition that the output voltage is regulated, the input power is limited when the overlapping period of the two switches is close to zero. The limitation is that the coupling is only maintained when the output voltage is regulated.The voltage and current spikes, switching losses are reduced by using a current fed full bridge boost converter which can achieve ZCS by utilizing the leakage inductance and parasitic capacitance as the resonant tank. The leakage inductance in the transformer absorbs the energy of the inductance and feed it to the parasitic capacitance. Since the voltage stress on the active switches, diodes, and capacitors is not affected by the number of cascaded stages of the Cockcroft-Walton voltage multiplier, power components with the same voltage ratings can be selected.

III.PROPOSED CONVERTER

The commonly used isolated voltage-fed converters normally have a high input current ripple which forces the converter to have large input filter capacitors. These are normally electrolytic which are known to have a very small lifetime and thus affect the overall life span and mean time before failure of the converter. Furthermore the inherent step-down characteristic of the voltage-fed converters, the large transformer turns ratio needed to boost the output voltage, the high output diode voltage stress, and the need of an LC output filter are some disadvantages of voltage-fed converters .When compared to the voltage-fed topologies current-fed converters have some advantages. Usually they have an inductor at the input so the system can be sized to have input current ripple as low as needed, thus eliminating the need of the input capacitor at the panel voltage. Current-fed converters are normally derived from the boost converter having an inherent high step-up voltage ratio which helps to reduce the needed transformer turns ratio. The classical topologies of this kind are the current-fed push–pull converter, the current-fed full-bridge, and the dual half-bridge converter. Although the current-fed topologies have all the aforementioned advantages, they still have problems with high voltage spikes created due to the leakage inductance of the transformers and with high voltage stress on the rectifying diodes. One of the solutions to the current-fed PWM converters is the use of resonant topologies which is able to utilize the component parasitic characteristics such as the leakage inductance and winding capacitance of transformers in a productive way to achieve zero current switching (ZCS) or zero voltage switching (ZVS) condition to the active switches and rectifying diodes.

A modified TIBC for the first-stage DC/DC converter is used due to its very small number of components, simplicity, high efficiency, easy transformer flux balance and common ground gate driving for both switches. These features make it the ideal choice for achieving the system’s necessary characteristics. Aside from the high DC voltage gain of the TIBC, it also compares favourably with other current-fed converters concerning switch voltage stress, conduction losses, and transformer utilization. In addition the input current is distributed through the two boost inductors having its current ripple amplitude halved at twice the PWM frequency. This last feature minimizes the oscillations at the PV

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module operation point and makes it easier to achieve the MPP. In its classical implementation, the TIBC is a hard-switched overlapped pulse-modulated converter, this way; at least one of the switches is always closed, creating a conduction path for the input inductor current. Nevertheless the TIBC can be modified to a multiresonant converter by adding a capacitor at the transformer's secondary winding. A multiresonant tank is formed by the magnetizing inductance of the transformer, its leakage inductance, and the added capacitor. The intrinsic winding capacitance of the transformer is included in the resonant capacitor. By adding this capacitor and using the parasitic components of the transformer to create the resonant tank, it is possible to achieve ZCS condition for the input switches and output rectifying diodes, and this enables the converter to operate at high frequencies with greater efficiency.

Classically the TIBC have a minimum operation load to maintain an established output voltage. Below a certain load level, the energy transferred to the output capacitor is not completely transferred to the load and causes an increase in the output voltage. This happens because the inductors are charged even if there is no output current. As a result this converter has a drawback when used in motor drive systems. As a solution a non-dissipative regenerative snubber circuit is presented. The regenerative snubber is formed by two diodes and a capacitor connecting the input side directly to the output side of the converter. This makes it a non-isolated converter, which has no undesirable effect in the PV motor driver applications. The voltage over the MOSFETs is applied to a capacitor connected to the circuit ground and the voltage of this capacitor is coupled in series with the output of the rectifier. This modification allows part of the energy to be transferred from the input directly to the output through the snubber, without going through the transformer reducing its size and improving even more the efficiency of the converter.

The Cockcroft-Walton voltage multiplier produces a high DC voltage from a pulsating DC or low level input AC voltage. Here we are using a three stage voltage multiplier. It consists of a ladder network of capacitors and diodes having 6 capacitors and 6 diodes. Thus the cost is low and easy to implement. The voltage across each stage of this cascade is only equal to twice the peak input voltage is a great advantage of this circuit. From any stage we can tap the output, like a multi tapped transformer. This cascade network has some applications in CRT tubes, X-ray systems etc.

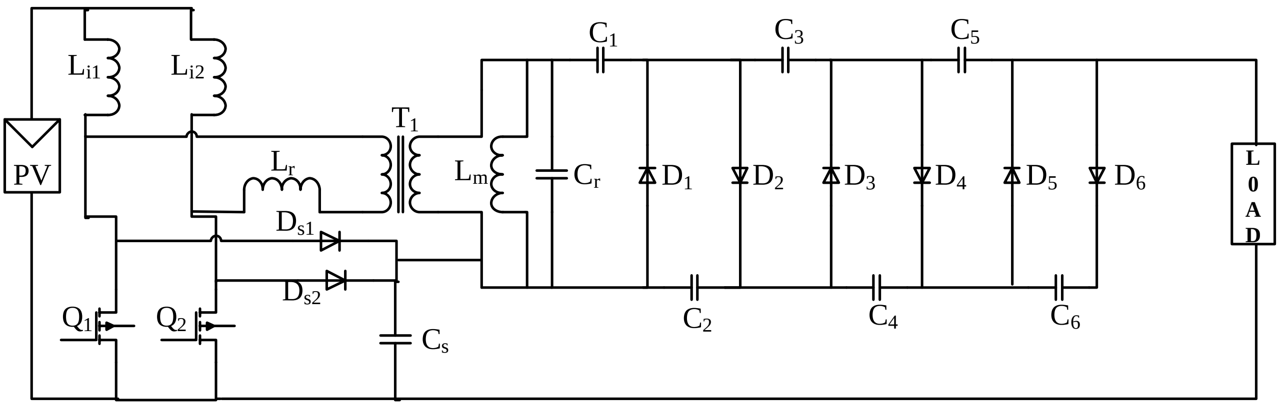

Fig.1.Circuit Diagram of the Proposed Converter

The converter circuit is shown in fig 1.L_{i1} and L_{i2} are the two inductors, L_r, L_m and C_r forms the resonant tank circuit. The snubber circuit is formed by D_{s1} ,D_{s2} and C_s. C_1 ,C_2 ,C_3 ,C_4 ,C_5 ,C_6 ,D_1 ,D_2 ,D_3 ,D_4 ,D_5 ,D_6 form the three cascade structure of Cockcroft-Walton voltage multiplier.The two primary switches Q_1 and Q_2 of the proposed converter operate at an overlapped duty cycle switching scheme to guarantee a conduction path for the primary inductor current. When both Q_1 and Q_2 are turned on, L_{i1} and L_{i2} are charged by the input energy. When Q_1 (Q_2) is opened, the energy stored in L_{i1} (L_{i2}) is transferred to C_{o1} (C_{o2}) through the transformer and the rectifier diode D_{o1} (D_{o2}). To simplify the analysis of the proposed converter, it is assumed that the input inductors L_{i1} and L_{i2} are sufficiently large so that their current is almost constant. The converter has six modes of operation during first half switching cycle. This can be explained as 3 stages of operation.During stage 1 switch Q_1 is on and Q_2 is in off position.L_{i2} feeds the resonant tank which is formed by L_m and C_r while L_r is absorbed into L_{i2}.D_{s1} of the snubber circuit conducts through the load. During

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stage 2,Q_1 is off and Q_2 is on condition. Diode D_{s2} will conducts through the load. L_r is absorbed into L_{i1}.Current flowing through L_{i1} formed by L_m and C_m while L_{i2} is charged by the input voltage. In stage 3 both the switches Q_1 and Q_2 conduct the current. L_r participates in the resonance. Current flowing through Q_2 increases while current flowing through Q_1 decreases.

IV.SIMULATION AND ITS RESULTS

To ensure low cost and accessibility of the system energy from PV panel is used. Output AC voltage is obtained from PV through the proposed converter. The PV panel simulation diagram is shown in fig.2.The output voltage obtained from PV panel is 29.7V as shown in fig.3.MPPT technique is used to track the maximum power from PV.

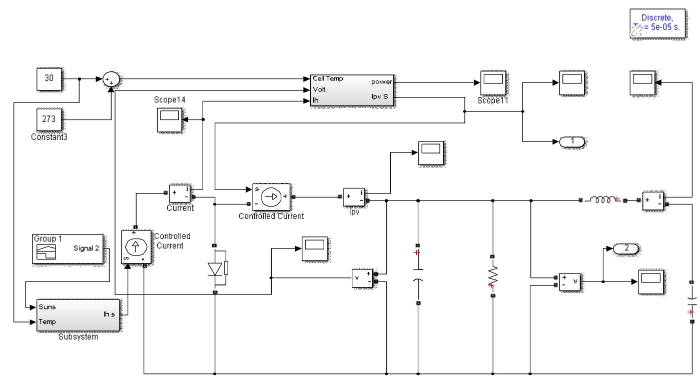

Fig.2. Simulation Diagram of PV System

The simulink model of the proposed converter is shown in fig.4 .The output voltage is measured using voltage measurement block and output current is measured using current measurement block

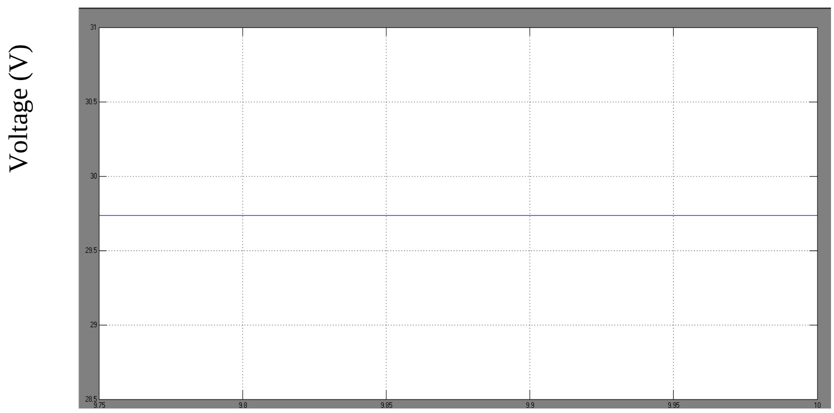

Fig.3.Waveform of PV Output Voltage

Time (sec)

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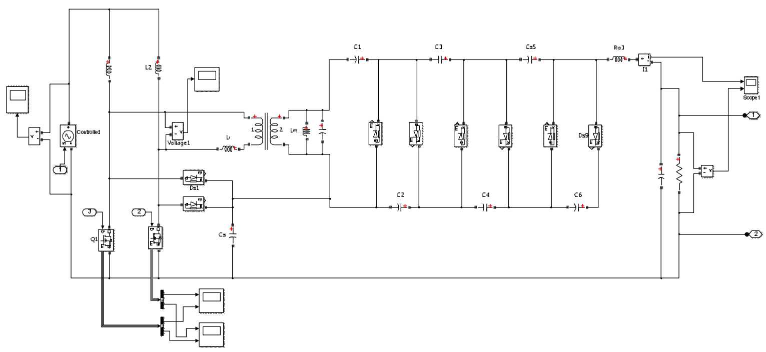

Fig.4.Simulation Diagram of Proposed Converter

The output from PV is the input to the converter and 440 DC voltage is obtained as output of the converter. The converter output current is 5A.The output voltage waveform is shown in fig.5 and output current waveform in fig.6.

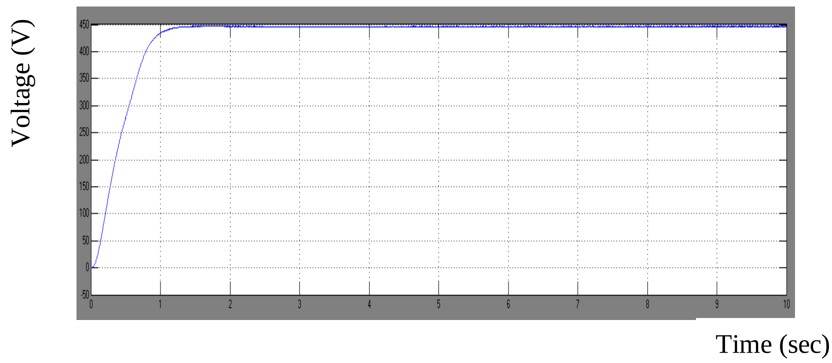

Fig.5.Waveform of Converter Output Voltage

The simulink model of three phase inverter circuit is shown in fig.7 .SPWM technique is used to generate pulses for the switches.6 pulses are generated for the six switches.

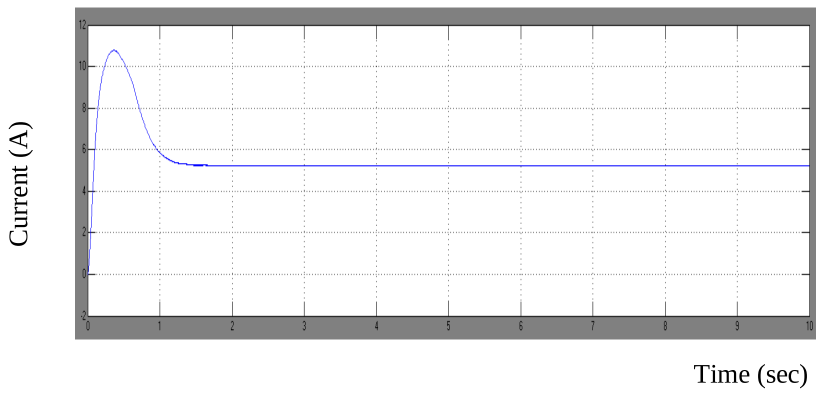

Fig.6.Waveform of Converter Output Current

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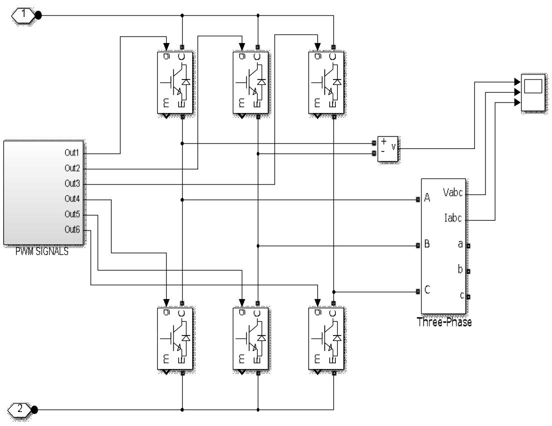

Fig.7.Simulation Diagram of Three Phase Inverter

The inverter output voltage, output current and voltage across two arms is shown in fig.8. The peak magnitude of output voltage is about 400V.

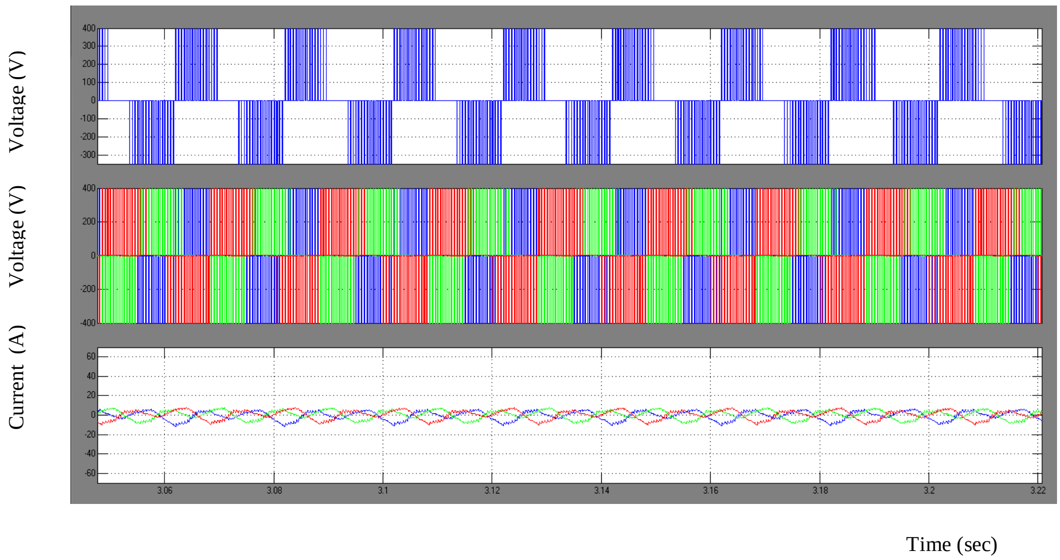

Fig.8. Inverter Output Waveforms

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Sl.No.	Parameter	Value
01	L_{i1} ,L_{i1}	100uH
02	L_m	52.8mH
03	Cockcroft Walton Voltage Multiplier Capacitors	470uH
04	Filter capacitor	10mH
05	Converter Switching Frequency	100kHz
06	Inverter Switching Frequency	7.7kHz
07	Resonant Capacitor, C_r	5.8uH

Table.1.Simulation Parameters

V.CONCLUSION

The Two Inductor Boost Converter integrated with cascade Cockcroft-Walton voltage multiplier is described in this paper. The multi-resonant tank provides high voltage gain and absorbs the parasitic parameters of the transformer. Snubber circuit makes it a non-isolated converter. A part of the energy is allowed to be transferred from the input directly to the output through the snubber, without going through the transformer reducing its size and improving the efficiency of the converter. The voltage stress across the switch is also reduced. Since the voltage stress on the active switches, diodes, and capacitors is not affected by the number of cascaded stages, power components with the same voltage ratings can be selected for the voltage multiplier.Low input current ripple, low cost and high step-up characteristics are some advantages of this converter. The output of the converter system is given to the inverter system. Here SPWM control is used and MPPT control is provided to operate the PV cell in maximum power.

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