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A Novel ZVS Step up Converter for Renewable Energy Generation Applications

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ABSTRACT: This paper introduces a novel ZVS step up converter especially for renewable energy generation applications. The proposed converter is consisting of single switch which operates in zero voltage and zero current. Resonant principles are opted for soft switching. High voltage gain is obtained by switched capacitor cell topology.Use of single switch will reduce the cost of conversion and complexity of control circuits. The circuit topology consisting of resonant inverter with zero voltage switching with an energy blocking diode having zero current switching. The energy blocking diode with DC output filter filters the output stage of converter.

KEYWORDS: Switched capacitor, Resonant power converter, zero-current switching, zero-voltage switching**,** pulsewidth modulation

I.INTRODUCTION

Now a days, global surface temperatures have increased drastically, because the global warming is taking place due to effluent gas emissions and increases in Carbon Monoxide. To prevent these effects, some potential solutions have evolved including energy conservation through improved energy efficiency, a reduction in fossil fuel use and an increase in environmental friendly energy sources. However, the output voltage of these sources is too low and which requires a voltage boost. In this stage, efficiency of conversion is a major concern. Efficiency in the sense minimizing the switching and conduction losses.

II.LITERATURE SURVEY

In transformer isolated dc-dc converters, by increasing the turns ratio, we can boost the voltage gain. But, when we increase the turns ratio, leakage inductance will also increase, which will lead to high voltage stress and poor efficiency [1].In case of non-isolated dc-dc converter topologies, boost converter is using for voltage boost up. But duty cycle limitation is the problem associated. As duty cycle increases, inductor current ripple and turn off current of the power device will increase, which leads to large conduction loss and degraded efficiency[2]. Cascaded boost converters can increase the voltage gain, however component count will increase hence size and cost of converter also [3]. Integrating coupled inductor into the non-isolated dc-dc converter by choosing a suitableturns ratio can increase the voltage gain effectively. In order to absorb the energy stored in leakage inductor, a snubber circuitry is needed which will increase circuit complexity and loss of efficiency [4]. Switched capacitor cell converters can obtain a very high voltage gain, however input current pulsation is a problem and poor load and line voltage regulation. Incorporating switched capacitor structure into switching mode dc-dc converter is a good remedy for this problems. Hence we can dramatically increase voltage gain with an appropriate duty cycle with good voltage regulation and minimum input current pulsation [5].

Pulse width modulationis the simplest method for controlling power semiconductor switches.PWM power converters can now operate at a much higher switching frequency hence reducing the size of passive components and the overall cost of the system. But, the converter switching loss also increases in proportion to the frequency. As switching frequency increases time derivative of voltage and current will also increase which will lead to increased stress on the deviceTo solve this problem, some soft-switching approaches must be used at high switching frequencies. Resonant converters can solve these high voltage and current stress problems and ensuring both high performance and supporting energy conservation applications in renewable energy generation systems.Two commonly used soft-switching

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methodsare Zero voltage switching and zero-current switching .i.e., either voltage or current is zero during the switching transition, substantially reducing the switching loss and increasing the reliability of resonant converters in renewable energy generation systems [6].

This work introduces a novel single-switch high step up converter with ZVS topology based on the traditional ZVS concept for renewable energy generation applications. Voltage step up is by adopting the principals of switched capacitor cell topology. The main features of this converter is that single switch operation, simple circuit, soft switching, ease of control, low switching losses and high voltage boost up. This circuit utilizes a capacitor across the active power switch to generate a freewheeling stage with a traditional ZVS power converter, enabling the novel converter to operate with a constant frequency and a markedly much reduced circulating energy. Main operating principal of switched capacitor cell is that, capacitor cells charges in parallel and discharges in series. As the number of capacitor cells increases, the output voltage will also increase. In this converter we are using single capacitor cell.This paper shows the operational analysis and simulation results of the proposed converter.

III.CIRCUIT DESCRIPTION

This work integrates a novel current-fed resonant converter with switched capacitor cell topology in order to increase the voltage level. Resonant converter with ZVS and ZCS operations of both the active power switch and the rectifying diode for energy conversion. Fig.1 shows a basic circuit diagram of the proposed novel ZVS and ZCS single-switch step up converter for renewable energy generation applications.

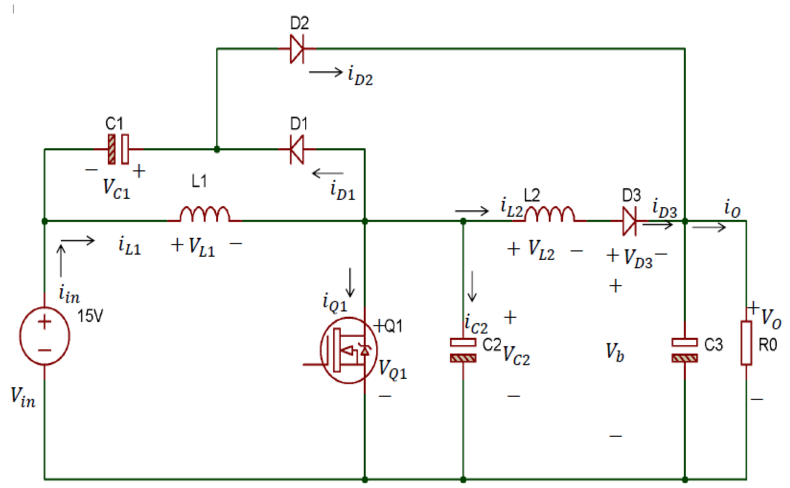

Fig. 1 Proposed circuit

The circuit consisting of a choke inductor L_1, a metal–oxide–semiconductor field-effect transistor (MOSFET) that operates as a power switch Q_1, The capacitor C_1 is connected in series to source voltage and load resistor through diode D_2 ,a shunt capacitor C_2, a resonant inductor L_2, an energy-blocking diode D_3, and a filter capacitor C_3. The capacitor C_3 and the load resistance R_0 together form a first-order low-pass output filter, which reduces the ripple voltage below a specified level. The MOSFET is thefavoured device because its body diode can be used as an antiparallel diodeD_E , for a bidirectional power switch. Notably, the shunt capacitanceC_2, includes the power switch parasitic capacitance and any other stray capacitances (such as the winding capacitance of the chokeL_1). Careful design of the circuit parameters guarantees that the power switch Q_1 is switched by ZVS and the energy-blocking diode D is switched by ZCS, optimizing the operation of the converter.

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IV.PRINCIPLE OF OPERATION

The novel ZVS single-switch step up converter for renewable energy generation applications is analysed using the following assumptions.

- The switching elements of the converter are ideal, such that the drop in forward voltage across the resistance of the power switch in the ON state is negligible.
- The equivalent series resistance of the capacitance and stray capacitances is negligible.
- The characteristics of the passive components are linear, time invariant, and independent of frequency.
- The filter capacitance C_3 at the output terminal is typically very large; the output voltage across capacitor C_3 can therefore be treated as an ideal dc voltage in each switching cycle.

The key waveforms for each mode of the proposed converter are shown in Fig. 2. One switching cycle is divided into six modes, which are described as follows.

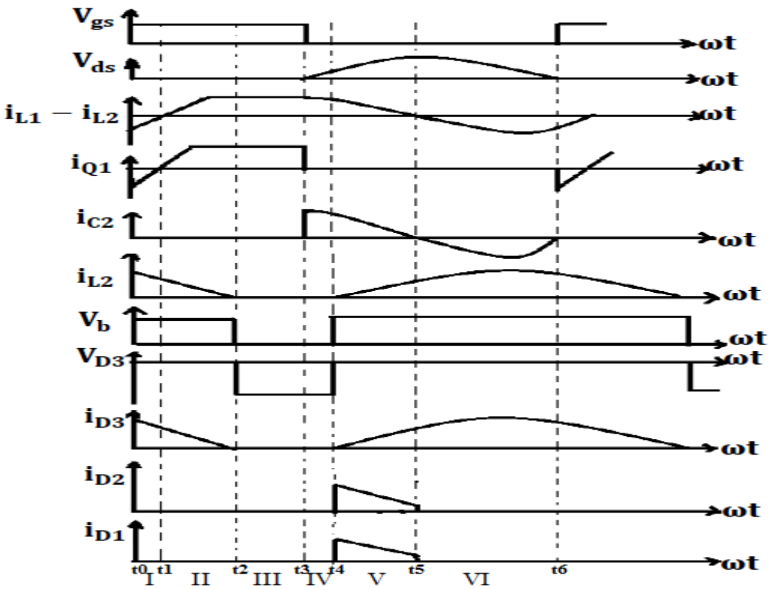

Fig. 2 Switching waveforms

Mode 1 —Between$t_0$and t_1: Prior to Mode 1 operation, power switch Q_1 is off. The resonant tank current i_{L2} is positive and higher than the dc input current i_{L1}. The switch must be turned on only at zero voltage. Otherwise, the energy stored in the capacitor C_2 will be dissipated in the active power switch Q_1. To prevent this situation, the antiparallel diode D_E must conduct before the power switch is turned on. Since the capacitor current i_{C2} is negative, it flows through capacitor C_2. When the capacitor voltage V_{C2} falls to zero, a turn-on signal is applied to the gate of the active power switch Q_1. Therefore, the active power switch Q_1 turns on under ZCS and ZVS conditions. At the beginning of this mode, since the difference between currents $i_{L1} - i_{L2}$ isnegative,the antiparallel diode D_E conducts. The energy-blocking diode D_3 is turnedon because the resonant tank current i_{L2} is positive. Diodes D_1 and D_2 is reverse biased. Fig. 3 represents the equivalent circuit of this mode. Mode 1 ends as soon as the antiparallel diode D_E is reverse biased by a positive current $i_{L1} - i_{L2}$.

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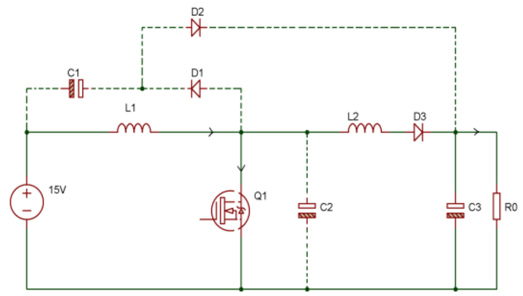

Fig. 3 Mode 1 Operation

Mode 2 —Between $t_1$and t_2: In this mode, the active power switch Q_1 remains in the ON state. Fig. 4 shows the equivalent circuit. The input line voltage is applied to the choke inductor L_1, and i_{L1} increases continuously. In this mode, the current $i_{L1} - i_{L2}$ commutates the antiparallel diode D_E and turn on active power switch Q_1. Hence, the voltage across the capacitor C_2 is clamped at zero.The resonant current i_{L2} passes through the energy-blocking diode D_3 .The circuit operation enters Mode 3 when the inductor current i_{L2} falls to zero.

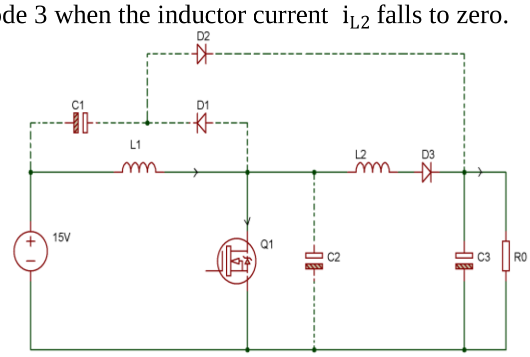

Fig. 4 Mode 2 Operation

Mode 3 —Between $t_2$and t_3: In this mode, the switch Q_1 remains in the ON state, and the input dc current i_{L1}continuously rises. The input inductor current i_{L1} flows through the power switch Q_1. The resonant inductor current i_{L2} falls until it reaches zero and is prevented from going negative by the energy-blocking diode D_3. Energy is stored in the choke inductor L_1 when the active power switch is turned on and is transferred to the output load when the active power switch is turned off. Fig. 5 displays the equivalent circuit of this mode. Mode 3 is exited at the time when the power switch $Q_1$is turned off.

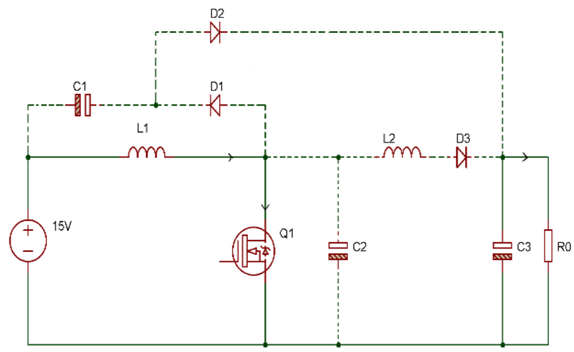

Fig. 5 Mode 3 Operation

Mode 4 —Between $t_3$and t_4: At the beginning of this mode, switch Q_1 is switched off. The resonant capacitor current i_{C2}becomes i_{L1}. Then, the capacitor voltage v_{C2} rises from zero to a finite positive value. For ZVS operation, Q_1 is switched off at zero voltage, and the capacitor voltage v_{C2} increases linearly from zero at a rate that is proportional toinput inductor current i_{L1}. The capacitor current i_{C2} flows through capacitor C_2 to charge C_2 , transferring the energy

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from the dc input source to capacitor C_2. During this mode, the output power of load resistor R_0 is supplied by the output capacitor C_3. Fig.2 reveals that the active power switch Q_1 is turned off under the ZVS condition. Fig.6 presents the equivalent circuit. Mode 4 ends when the energy-blocking diode $D_3$is forward biased ($v_{C2} > V_0$). Then, the circuit operation enters next mode.

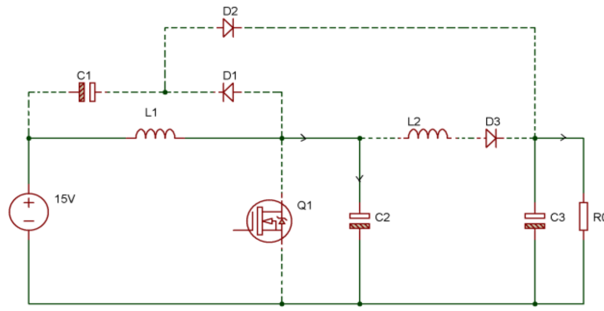

Fig. 6 Mode 4 Operation

Mode 5 —Between $t_4$and t_5: In this mode, the active power switch Q_1remains in the OFF state. The resonant inductor current $i_{L2}$is positive, and the energy-blocking diode D_3 is turned on, yielding a resonant stage between inductor L_2 and capacitor C_2. In this time, the capacitor current i_{C2} is still positive. Hence, the capacitor voltage v_C continues to increase to its peak value. Diodes D_1 and D_2 in the conducting state. The capacitor C_1 discharges it's energy to the load via diode D_2 .Fig. 7 presents the equivalent circuit. Mode 5 ends when capacitor current i_{C2} resonates to zero at t_5, and next operating begins.

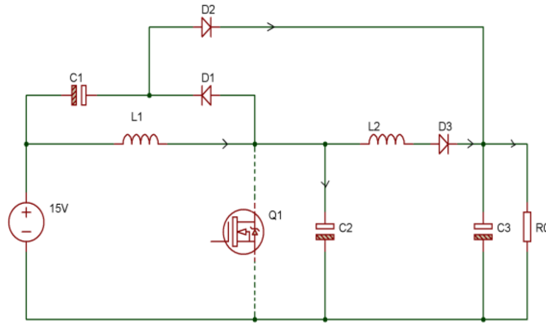

Fig. 7 Mode 5 Operation

Mode 6 —Betweent_5 and 2π: This mode begins at t_5 when capacitor voltage v_{C2}resonates from negative values to zero. The active power switch Q_1 is turned on when $\omega t = 2\pi$ to eliminate switching losses. Fig. 8 illustrates the equivalent circuit.

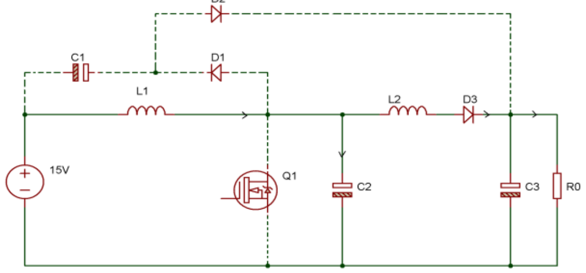

Fig. 8 Mode 6 Operation

Before the cycle of the resonant inductor current i_{L2} oscillation ends, the active power switch Q_1 is kept off condition, constraining the positive current to flow continuously through the energy-blocking diode D_3 . In addition to the active power switch, the energy-blocking diode in the novel converter is also commutated under soft switching. When the

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driving signal Vgs again excites the active power switch Q_1 , this mode ends, and the operation returns to Mode I in the following cycle.

V.SIMULINK MODEL

To verify the feasibility and validity of the proposed converter, MATLAB/Simulink software is applied for the simulation of the converter. The input of the proposed novel ZVS single-switch step up power converter can be connected to a small-scaled solar energy generation system that consisting of a dc source with an output voltage of 15 V. Fig. 9 shows the Simulink model of the proposed converter.The following parameters are used in this simulation model. DC input voltage of 15V. $L_1 = 25\mu H$, $L_2 = 19\mu H$, $C_1 = 0.82\mu F$, $C_2 = 0.1\mu F$, $C_3 = 220\mu F$, $P_0 = 16W$, $V_0 = 55V$, $f_s = 70kHz$.

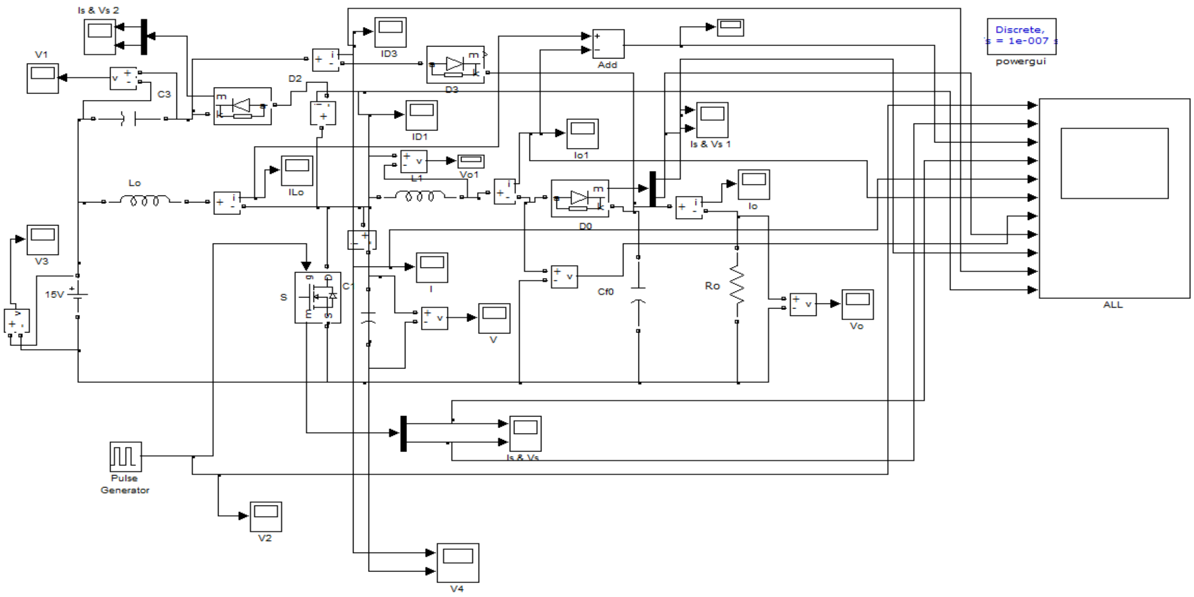

Fig. 9 Simulink Model

VI. RESULT AND DISCUSSION

The gating pulses are generated at 0.36 duty ratio by pulse generator. This pulse is given to the gate of power switch. Gating pulses are shown in Fig. 10.

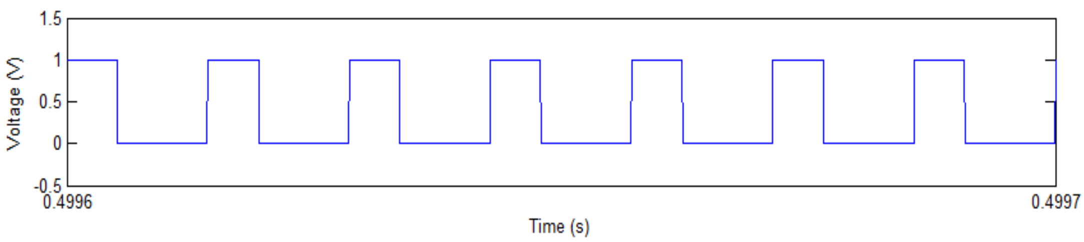

Fig. 10 Gating Pulse

The input to the converter is 15 V which is shown in Fig. 11. The input is steady and ripple free. The input source can be renewable energy sources or battery.

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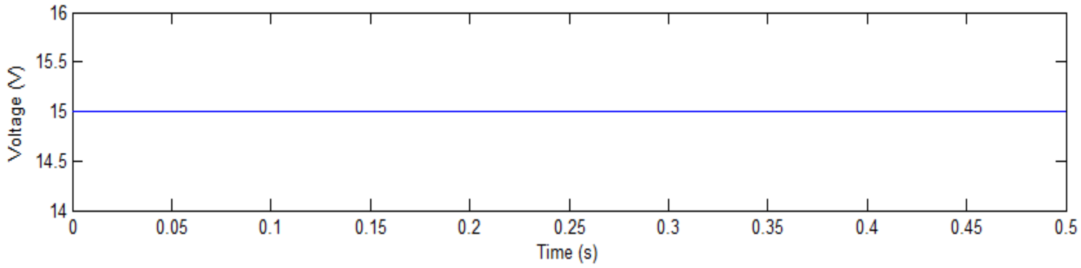

Fig. 11 Input Voltage

Fig. 12 shows the voltage across the switch. From the figure, it is clear that the switch transition occurs at zero voltage. Hence we can say that lossless switching is achieved .

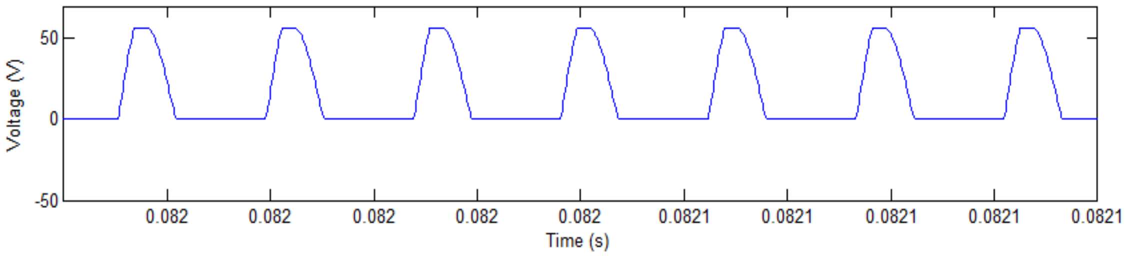

Fig. 12 Voltage across switch

Fig. 13 shows the current through the switch. From the figure, it is clear that the switch transition occurs at zero current. Maximum current through the switch is limited below 5A.

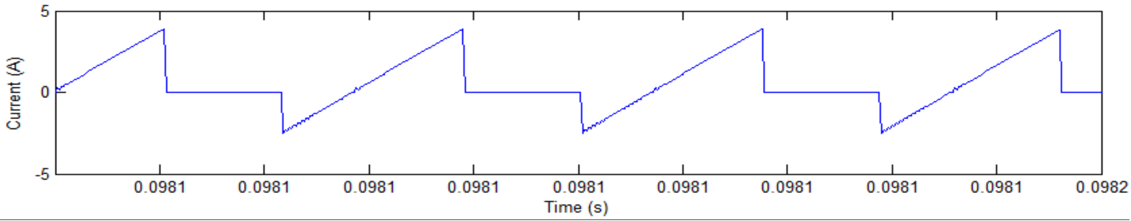

Fig. 13 Current through the switch

Fig. 14 shows the resonant capacitor current. Resonant transition of inductor capacitor pair is clear from this current waveform.

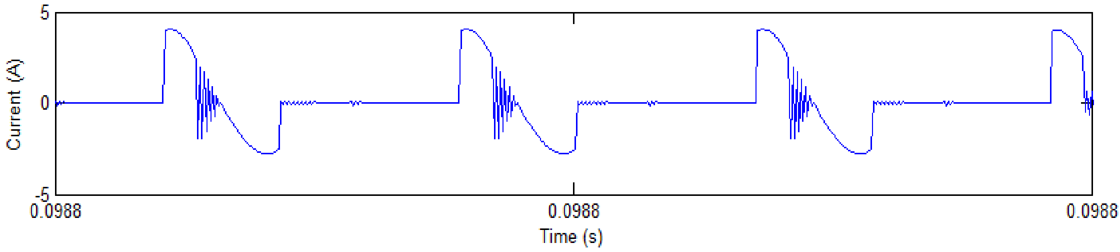

Fig. 14 Resonant capacitor current waveform

Fig. 15 shows the current through energy blocking diode.This figure reveals that this diode is operating under the ZCS condition, which can reduce the switching loss and increase the energy conversion efficiency.

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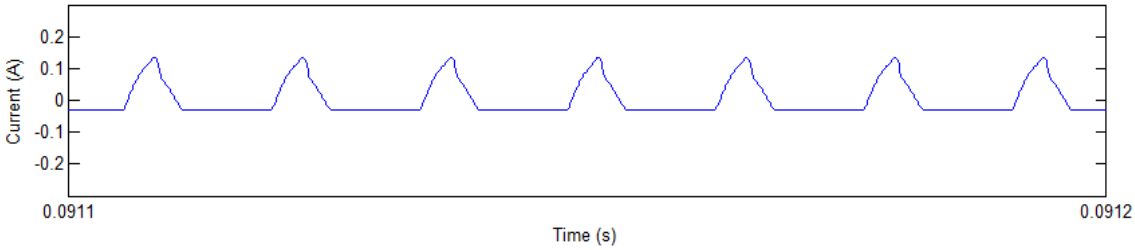

Fig. 15 Current through energy blocking diode

For an input voltage of 15V, the output voltage is boosted to 55V with a single switch converter which operated in zero voltage and zero current conditions. Fig. 16 shows the output voltage waveform.

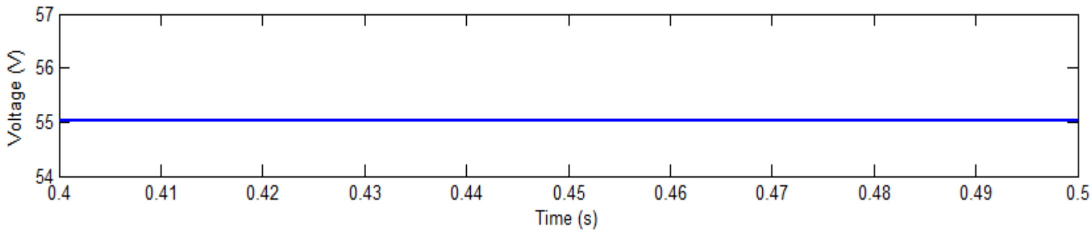

Fig. 16 Output Voltage

VII.CONCLUSION

A novel ZVS step up converter has been designed for application in renewable energy generation systems. The main advantages of this converter includes soft switching, single switch operation, high voltage gain, less component count, low cost, minimum switching loss. The operation of circuit is analysed, and simulated the performance characteristics.The simulation results reveals the effectiveness of the developed novel ZVS step up converter in solar energy generation. For an input voltage of 15V, the output is 55V. ZVS and ZCS operation of switch is achieved. When the high-frequency converter is applied to a resistive load, high energy conversion efficiency is obtained.

REFERENCES

[1] J. Lee, T. Liang, and J. Chen, "Isolated coupled-inductor-integrated dc–dc converter with non-dissipative snubber for solar energy applications," IEEE Trans. Ind. Electron., vol. 61, no. 7, pp. 3337–3348, Jul. 2014.

[2] Y. Hsieh, J. Chen, T. Liang, and L. Yang, "Novel high step-up dc–dc converter for distributed generation system," IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1473–1482, Apr. 2013.

[3] K. Park, G. Moon, and M. Youn, "Non isolated high step-up stacked converter based on boost-integrated isolated converter," IEEE Trans. PowerElectron., vol. 26, no. 2, pp. 577–587, Feb. 2011.

[4] T. Wu, Y. Lai, J. Hung, and Y. Chen, "Boost converter with coupled inductors and buck–boost type of active clamp," IEEE Trans. Ind. Electron., vol. 55, no. 1, pp. 154–162, Jan. 2008.

[5] Gang Wu et.al," Non isolated High Step-Up DC–DC Converters Adopting Switched-Capacitor Cell", IEEE Transactions On Industrial Electronics, VOL. 62, NO. 1, January 2015

[6] Ying-Chun Chuang et.al, "A Novel Single-Switch Resonant Power Converter for Renewable Energy Generation Applications ",IEEE Transactions On Industry Applications, Vol. 50, No. 2, March/April 2014

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