COMPARISON OF SINGLE BOOST CONVERTER AND HIGH STEP-UP CONVERTER FOR DISTRIBUTED GENERATION PHOTOVOLTAIC-INVERTER SYSTEM

1. R. Malathi, 2. A.S. Viswanathan, 3. Dr. M. Rathina Kumar,

Research Scholar, Sr. Asst. Professor, Professor and HOD,

Department of EEE, SCSVMV University, Kanchipuram, India.

malathinandhini@yahoo.co.in, Viswanathan.a.s@kanchiuniv.ac.in, rathinamari@yahoo.co.in

---

ABSTRACT

This paper deals with comparison of single boost converter and step-up DC-DC converters for PV module application. There is a growth in the area of PV generation connected to the grid. This paper proposes a high step-up DC-DC boost converter to boost the output voltage of PV cell. The output of high step up converter is converted into AC using a single phase inverter .A filter is introduced in the output to reduce the harmonics. High step up DC-DC converter for distributed generation employing photovoltaic inverter is modeled and simulated using Matlab/Simulink. The results of single boost converter system are compared with the results of high step up DC-DC converter system.

Keywords: *Photovoltaic. PV-cells, DC-DC converter. DC-AC inverter, Boost converter, High step-Up DC-DC converter, Voltage, Power, Current*

INTRODUCTION

The renewable energy based distributed generation systems are increasingly valued worldwide because of energy shortage and environmental contamination. These distributed generation systems are powered by multiple sources such as the fuel cells, Photovoltaic (PV) panels and batteries. Among these renewable energy systems photovoltaic power generation systems are expected to play an important role in future energy productions. Renewable energy systems generate low voltage output and thus high step-up DC-DC converters have been widely employed in many renewable energy applications [1]-[3].

A conventional centralized PV array is a serial connection of numerous panels to obtain higher dc-link voltage for main electricity through a DC-AC inverter .The output voltage of most of the PV-Cells are lower than 50 V, the power capacity of a single panel is about 100 Watts to 300 Watts. Also the PV light to electric energy conversion efficiency is degraded due to the panel mismatch and partial shading. However employing a high step-up DC-DC converter in front of the inverter improves power conversion efficiency and provides a stable DC link to the inverter [1]-[2].

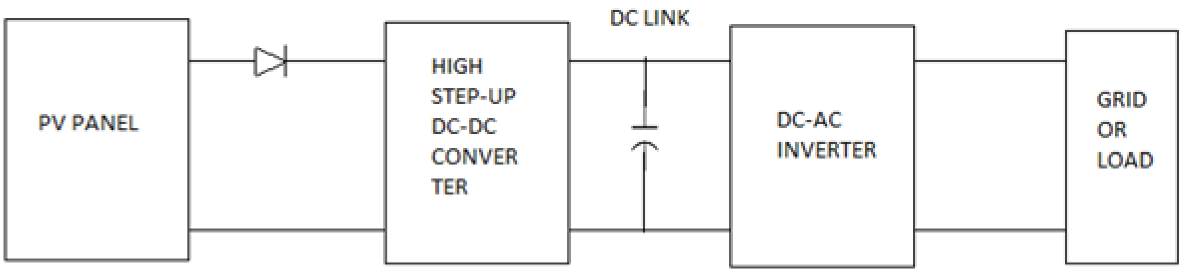

Figure: 1.General Configuration of Pv Based Distribution Generation System

The DC-DC converter requires large step-up conversion from PV Panels low voltage to the voltage level of application. To improve the conversion efficiency and achieve large voltage conversion ratio, various techniques have been adopted, switched-inductor and switched-capacitor types,transformerless switched-capacitor type [4], [5], [6]; the voltage lift type, the capacitor-diode voltage multiplier, and the boost type integrated with a coupled inductor, these converters obtain higher voltage gain than conventional boost converter by increasing turns ratio of coupled inductor. Some converters combined boost and flyback converters [7].Varios converter combinations are developed to obtain higher voltage gain by using coupled-inductor technique[8], [9], [10] . The voltage gain and efficiency of dc-dc converters constrained either by the parasitic effect of the power switches or the reverse recovery issue of the diodes [11], [12]. Active clamp technique used in dc-dc converter recycles the inductor energy but constrains the voltage stress across the active switch[13]. However the control circuit is complex and cost is higher. The zero voltage switching (ZVS) and zero current switching (ZCS) operation of the active switch in dc-dc converter improve the converter efficiency. However, when the leakage-inductor energy from the coupled inductor can be recycled, the voltage stress on the active switch is reduced[14], [15].

This paper proposes a coupled-inductor based high step-up converter. This work compares the output powers of conventional boost converter and high step-up converter.

PROPOSED HIGH STEP-UP BOOST CONVERTER

This paper proposes high step-up DC-DC converter and it is compared with conventional boost converter. Figure. 2 shows the circuit topology of the proposed converter. The proposed converter comprised of a coupled inductor T_1 with the floating active switch S_1.The primary winding $N_1$of a coupled inductor T_1 is similar to the input inductor of the conventional boost converter. The capacitor C_1 and diode D_1 receive leakage inductor energy from N_1.The secondary winding N_2, of the coupled inductor T_1 is connected with another pair of capacitors C_2 and diode D_2, which are in series with N_1 in order to further enlarge the boost voltage. The rectifier diode D_3 connects to its output capacitor C_3.

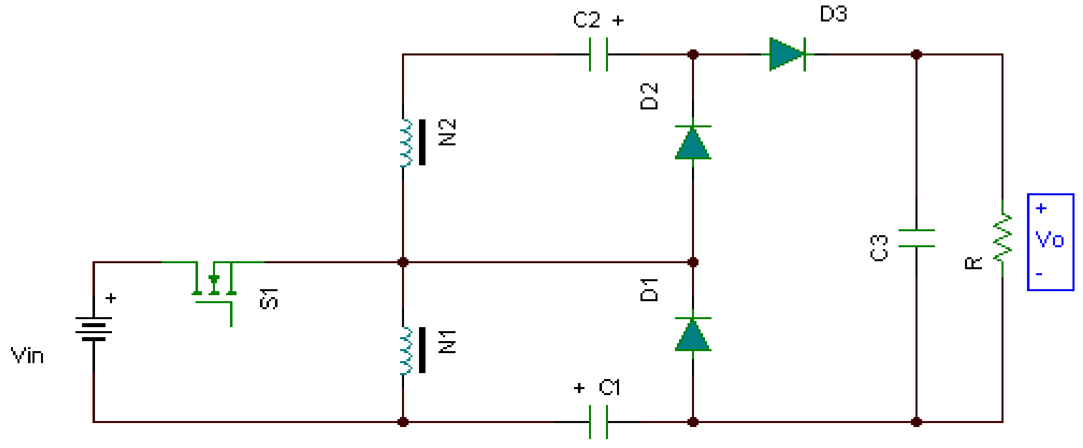

Figure: 2. Circuit Configuration of Proposed Converter
. The rectifier

The proposed converter has several features:
1. The two pairs of inductors, capacitors and diode gives a large step-up.
2. The leakage inductor energy of the coupled inductor can be recycled, thus increasing the efficiency and restraining the voltage across active switch.
3. The floating active switch efficiently isolates the PV Panel energy during non-operating conditions, which enhances safety.

CONVENTIONAL BOOST CONVERTER

Figure: 3 shows the conventional boost converter .it consists of a DC input voltage source Vs, a large inductor L is in series with source voltage, switch S, diode D, filter capacitance C and the load resistance R.

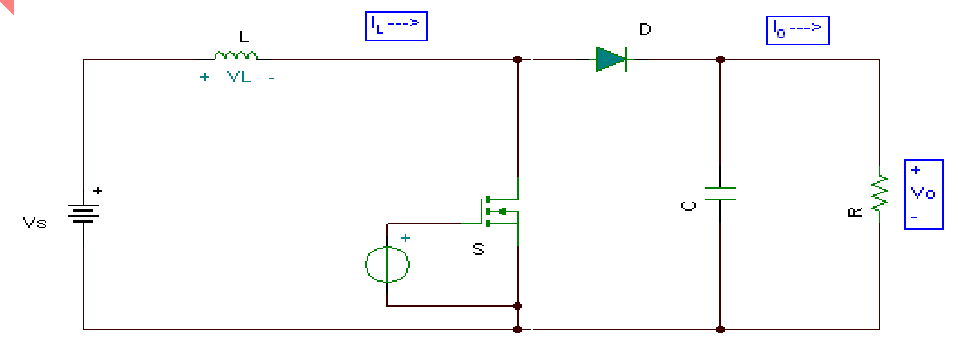

Figure: 3. Conventional Boost Converter

When the switch S is ON, the current through the inductor L, increases. The diode D is in the OFF state at that time inductor stores energy during the ON period of the switch S. when the switch S is turned OFF, the energy stored in the inductor is released through the diode D, to the output RC circuit.

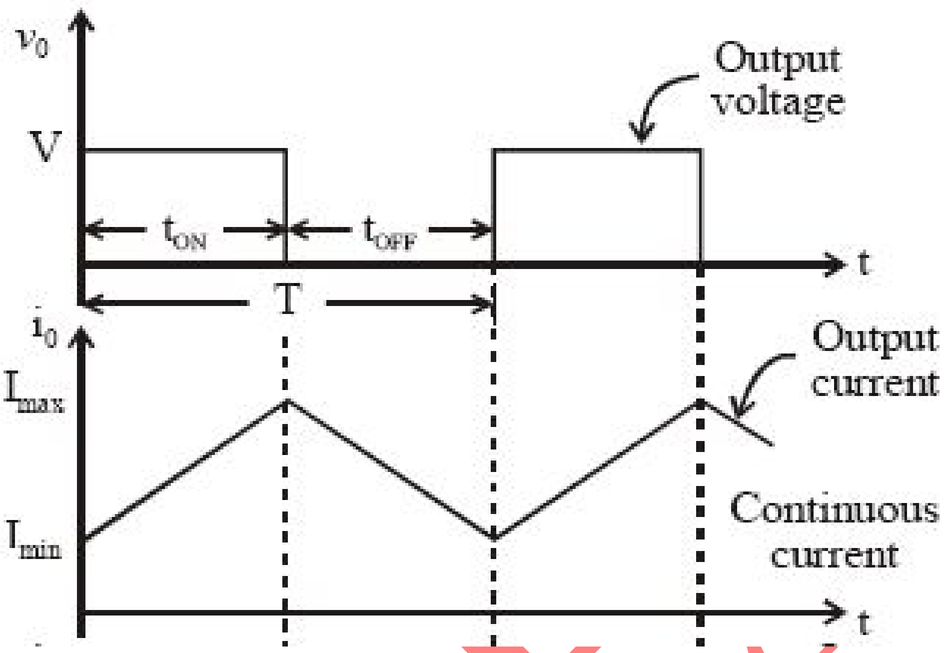

Figure: 4. Current Wave Forms

OPERATING PRINCIPLES OF HIGH STEP-UP BOOST CONVERTER

The polarity definitions of voltage and current in proposed high step-up converter is shown in Fig. 5. The coupled inductor T1 is represented as a magnetizing inductor L_m, primary and secondary leakage inductors L_{k1} and L_{k2} of an ideal transformer.

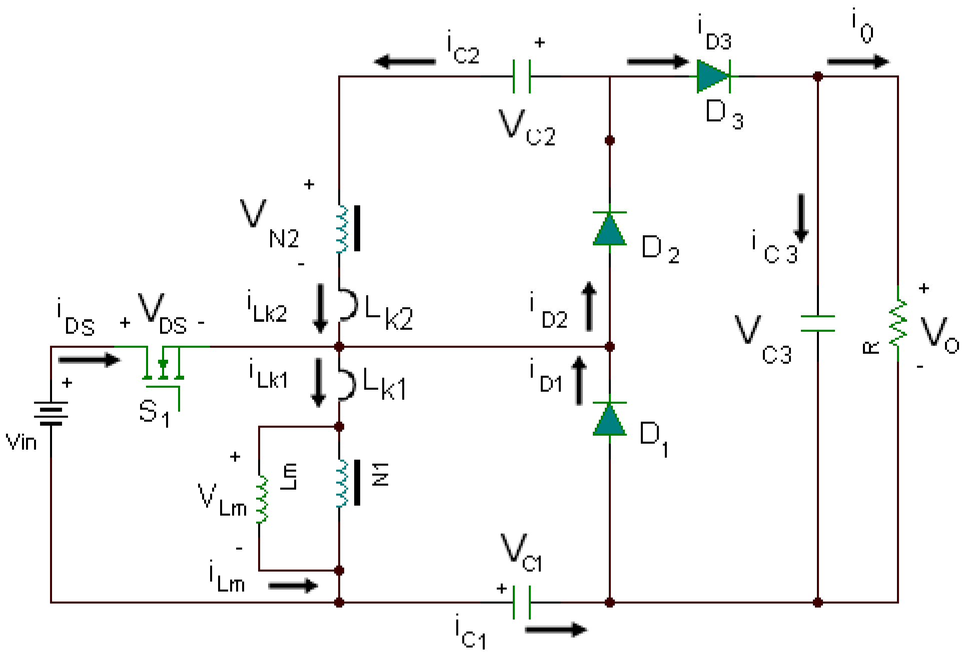

Figure. 5. Polarity Definitions of Voltage and Current in Proposed Converter

The following assumptions are made to simplify the circuit analysis:

1. All components are ideals, expect for the leakage inductance of coupled inductor T1.The on state resistance R_{ds} (on) and all parasitic capacitances of the main switch s1 are neglected, as are the forward voltage drops of diodes D1~D2
2. The capacitors C1~C2 are sufficiently large that the voltage across them are considered to be constant
3. The ESR of capacitors C1~C2 and the parasitic resistance of coupled inductor T1 are neglected
4. The turns ratio n of the coupled inductor T1 winding is equal to N2/N1

When Switch S_1 is turned ON, V_{in} is connected to L_m. Magnetizing inductor L_m continuously charges capacitor C_2.L_m and $L_{k1}$are storing energy from Vin. V_{in} is also serially connected with secondary winding N_2 of Coupled Inductor T_1 Diodes D_1 and D_2 are conducting and charging the capacitor C_1,C_2 respectively, then discharges their energy to capacitor C_2 and load R.

When S_1 is OFF L_m is receiving energy from L_{K1}, stored energy in Magnetizing Inductor L_m is released to C_1 and C_2 simultaneously. The energy stored in capacitor C_3 is constantly discharge to the load R.

To simplify the steady _state analysis, the leakage inductances on the primary and secondary sides are

$$v_{Lm} = V_{in} \quad (1)$$

$$v_{N2} = nV_{in} \quad (2)$$

Where n is the turns ratio.

When S_1 is in the OFF state

$$v_{Lm} = -V_{C1} \quad (3)$$

$$v_{N2} = -V_{C2} \quad (4)$$

Applying a volt second balance on the Magnetizing Inductor L_m yield

$$\int_0^{DTs} (V_{in})dt + \int_{DTs}^{Ts} (-V_{C1})dt = 0 \quad (5)$$

$$\int_0^{DTs}(nV_{in})dt+\int_{DTs}^{Ts}(-V_{C2})dt = 0 \quad (6)$$

Voltage across capacitors C_1 and C_2 are

$$V_{C1} = \frac{D}{1-D}V_{in} \quad (7)$$

$$V_{C2} = \frac{nD}{1-D}V_{in} \quad (8)$$

Where D is the duty cycle.

Output voltage $V_0 = V_{in} + V_{N2} + V_{C2} + V_{C1}$ becomes

$$V_0 = V_{in} + nV_{in} + \frac{nD}{1-D}V_{in} + \frac{D}{1-D}V_{in} \quad (9)$$

The DC voltage gain M_{CCM} can be found as follows:

$$M_{CCM} = \frac{V_0}{V_{in}} = \frac{1+n}{1-D} \quad (10)$$

The voltage stresses on S_1 and D_1~D_3 are given as

$$V_{DS} = V_{D1} = \frac{V_{in}}{1-D} \quad (11)$$

$$V_{D2} = \frac{nV_{in}}{1-D} \quad (12)$$

$$V_{D3} = \frac{1+n}{1-D}V_{in} \quad (13)$$

SIMULATION RESULTS

The Simulation is done using Matlab/Simulink and the results are presented in this section.

5.1Boost Converter Based system:

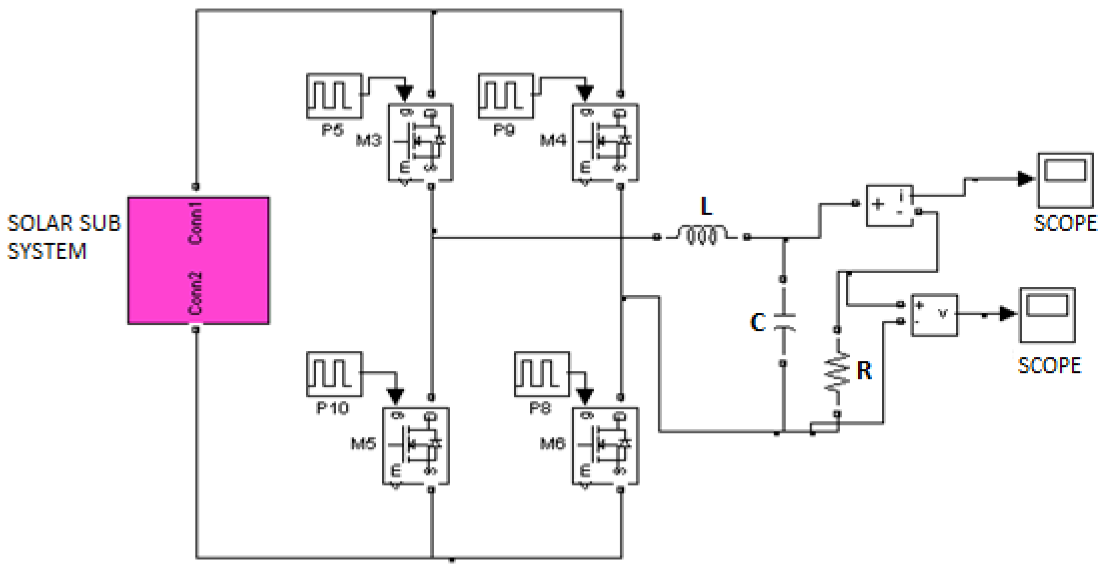

Figure. 6. PV Based Converter-Inverter System

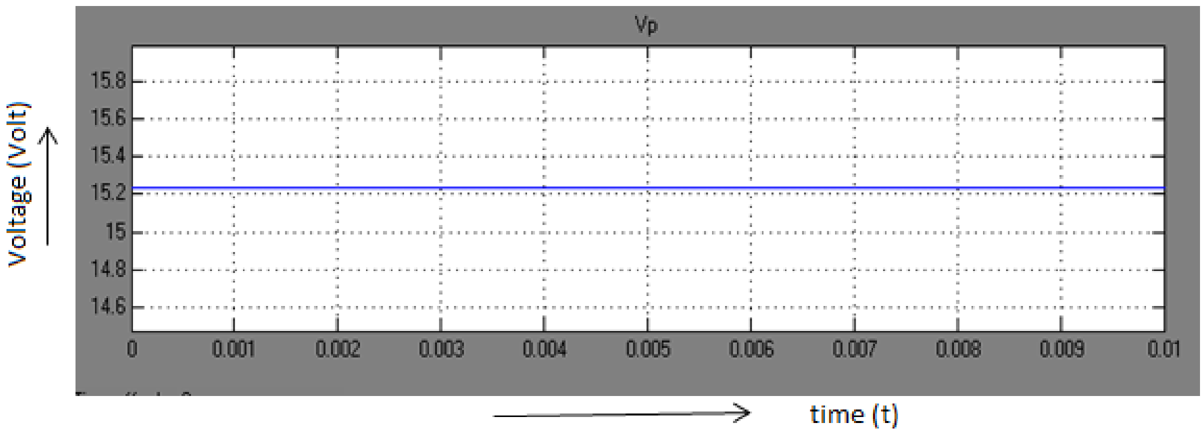

Figure.6.1. Input Voltage

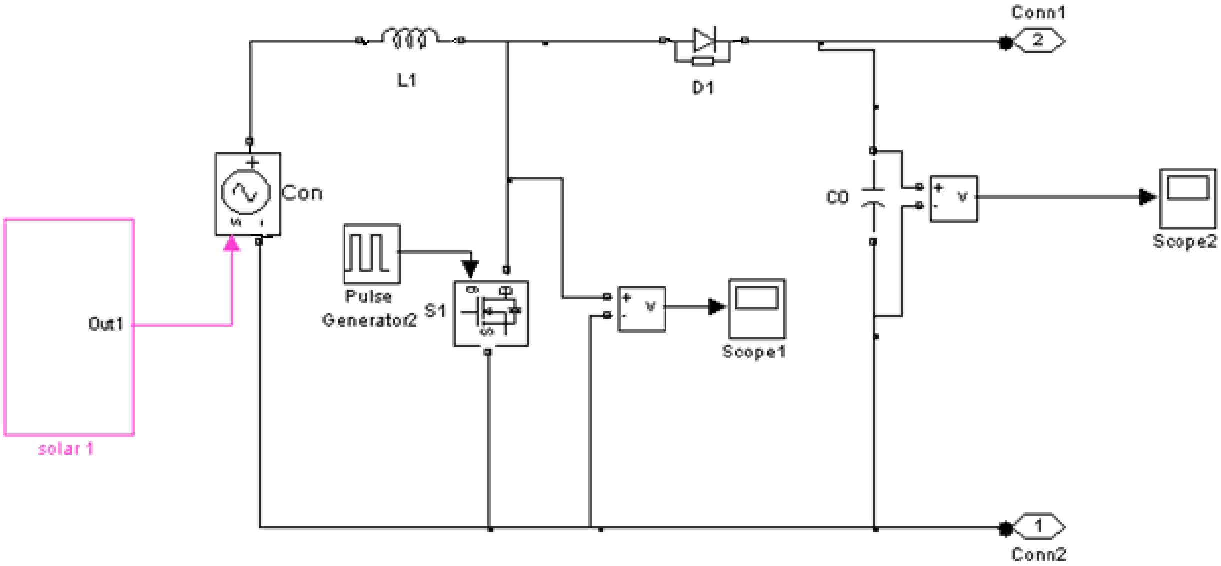

Figure: 6.2. Boost Converter with Solar Cell

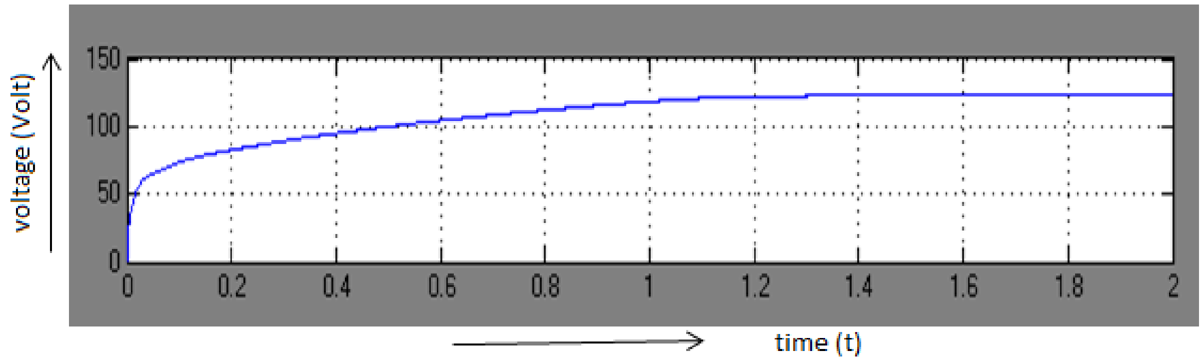

Figure.6.3 Output Voltage of Boost Converter

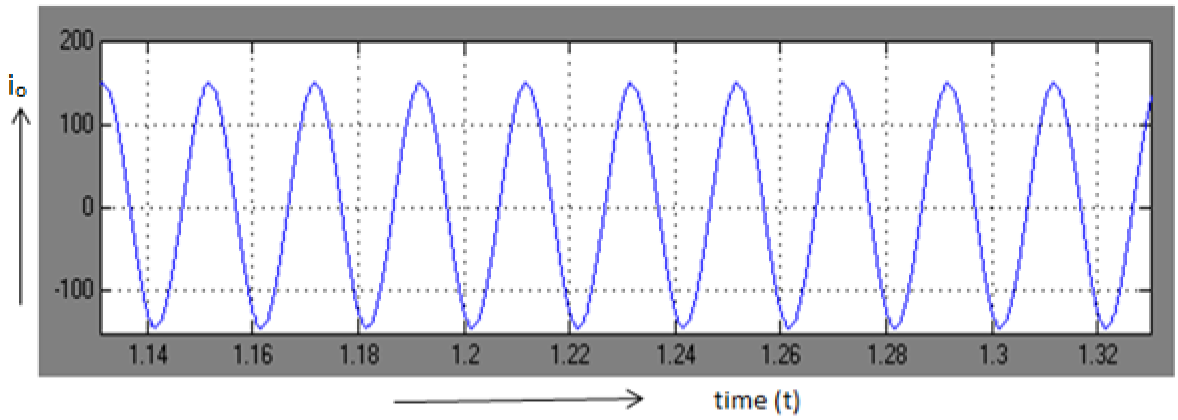

Figure.6.4. Output Voltage of inverter

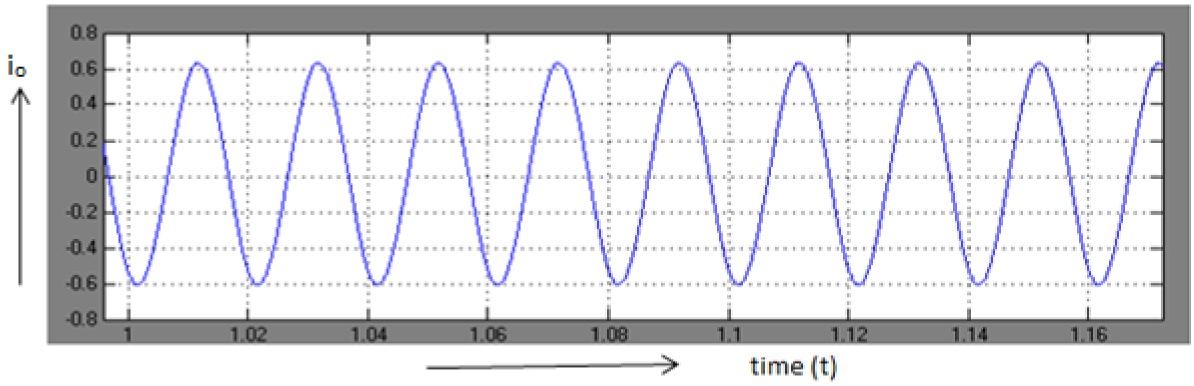

Figure.6.5. Output Current

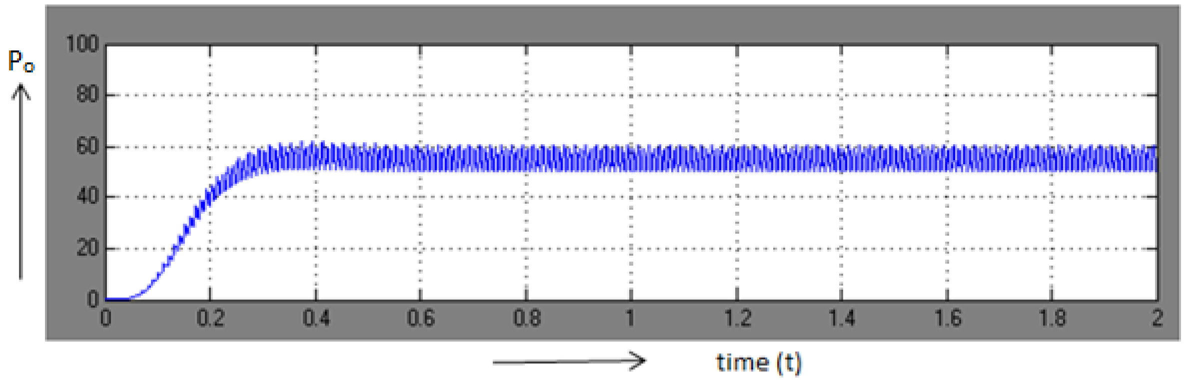

Figure.6.6. Output Power

The circuit of PV based converter Inverter system is shown in Figure: 6.The solar panel is referred as parallel combination of current source and resistance. The solar array and Boost Converter are represented as a subsystem. The solar voltage is shown in Figure.6.1. The DC voltage is 15.2 Volts. The subsystem consisting of solar cell and Boost Converter is shown in Figure.6.2. This 15.2 Volts is given as input to the conventional boost converter-inverter system. The output voltage of Boost converter is shown in Figure.6.3. The voltage is 120 Volts. The output of the inverter with filter is shown in Figure.6.4. The current through the load is shown in Figure.6.5. The current is in phase with the voltage since the load is a Resistive load .The output power is obtained by multiplying the output voltage and output current. The output power is 60 Watts as shown in Figure.6.6.

5.2 High Step up converter based system:

Normal boost converter is replaced by high step-up boost converter as shown in Figure.7. The values of capacitors in the high step-up converter are C=C1=2200µF.C3=2000µF. The output voltage of solar energy is shown in Figure.7.1. The output voltage is 15.2 Volts. The MPPT technique used in the circuit is Constant Voltage Control. PI controller is used in control circuit for simulating this high step-up converter-inverter system.Measurement of power from the PV cell is shown in Figure.7.2. The simulation is done by assuming an insolation of 1000.The drain to source voltage and gate voltage of the MOSFET are shown in Figure.7.3. The output voltage of solar system is given as input to the high step-up converter that is 15.2 Volts. DC output voltage of proposed high step-up converter is shown in Figure.7.4. The DC output voltage is 200V.The output voltage of the inverter is shown in Figure.7.5. Current through load is shown in Figure.7.6. The output power is shown in Figure.7.7. The output power is 110 Watts; therefore the high step up converter system gives higher output power than normal boost converter system.

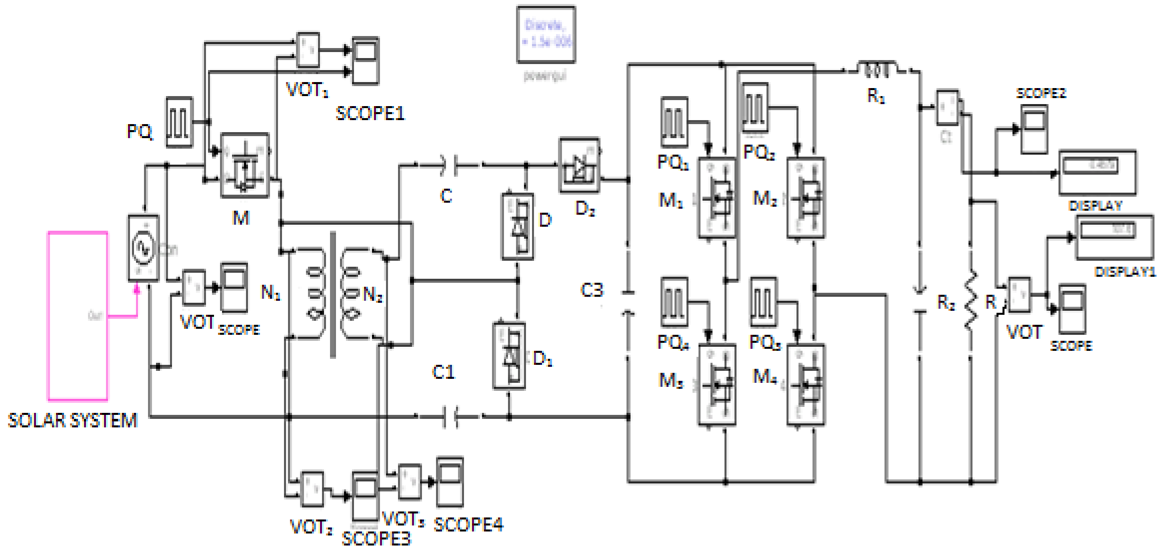

Figure.7. High Step-Up Boost Converter with Inverter

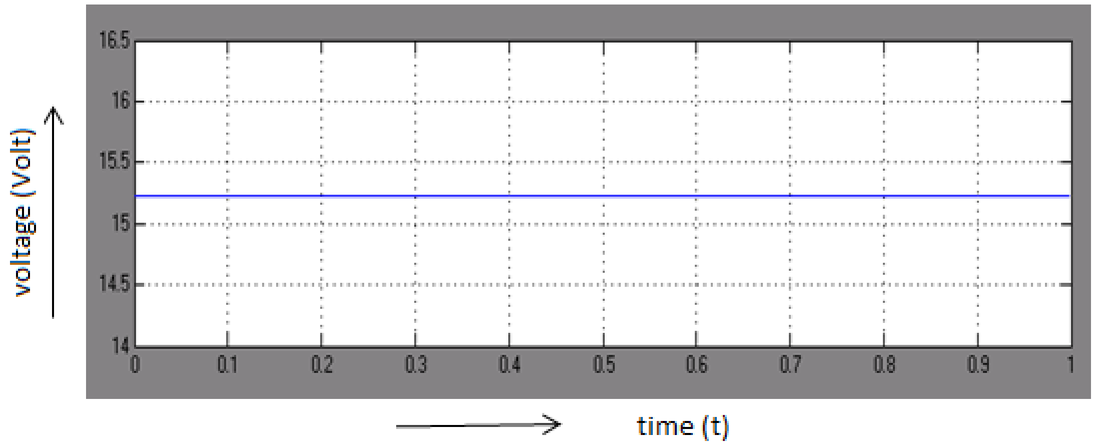

Figure.7.1. Output Voltage of Solar System

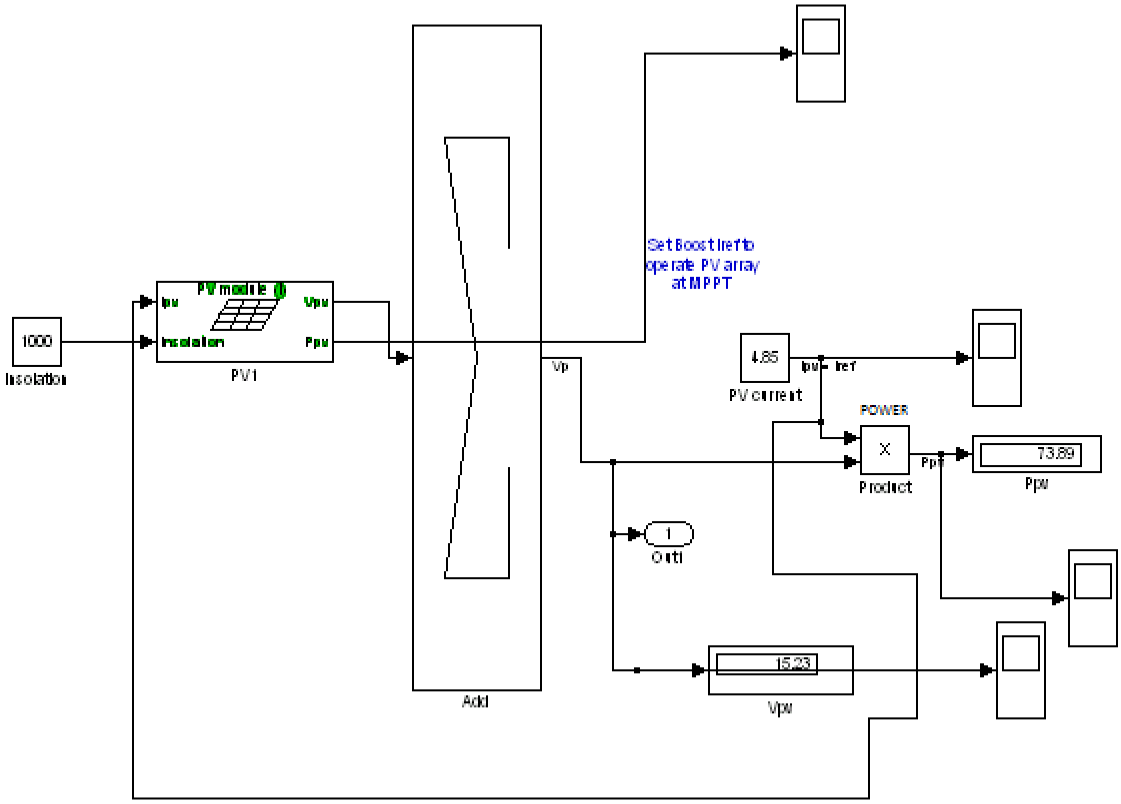

Figure.7.2. Power Measurement in Solar System

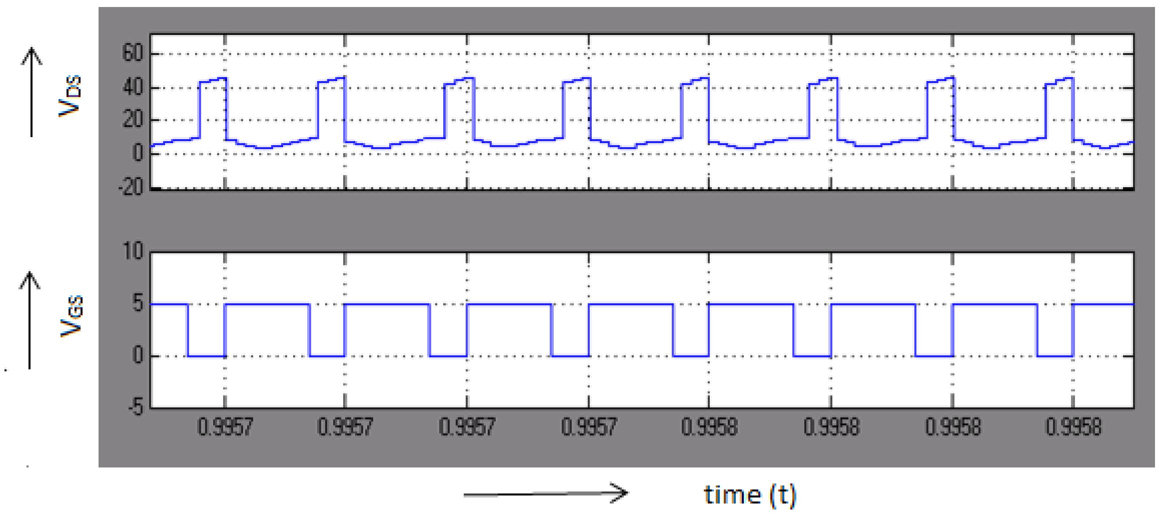

Figure.7.3. Drain to Source Voltage and Switching Pulse

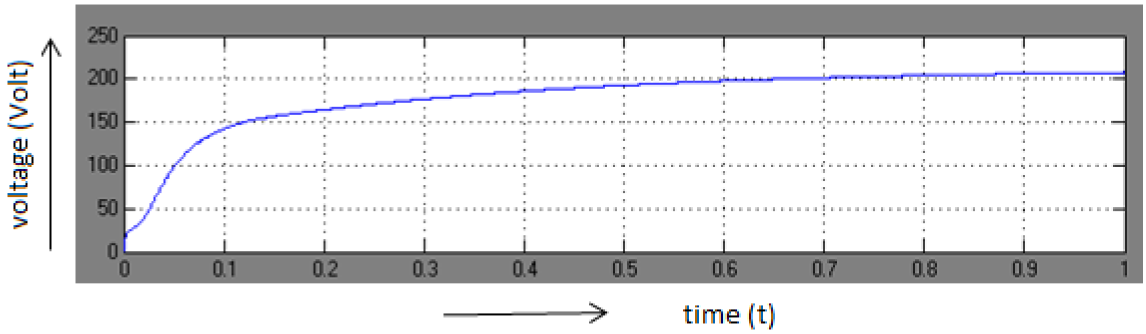

Figure.7.4. Output Voltage of Proposed High Step-Up Boost Converter

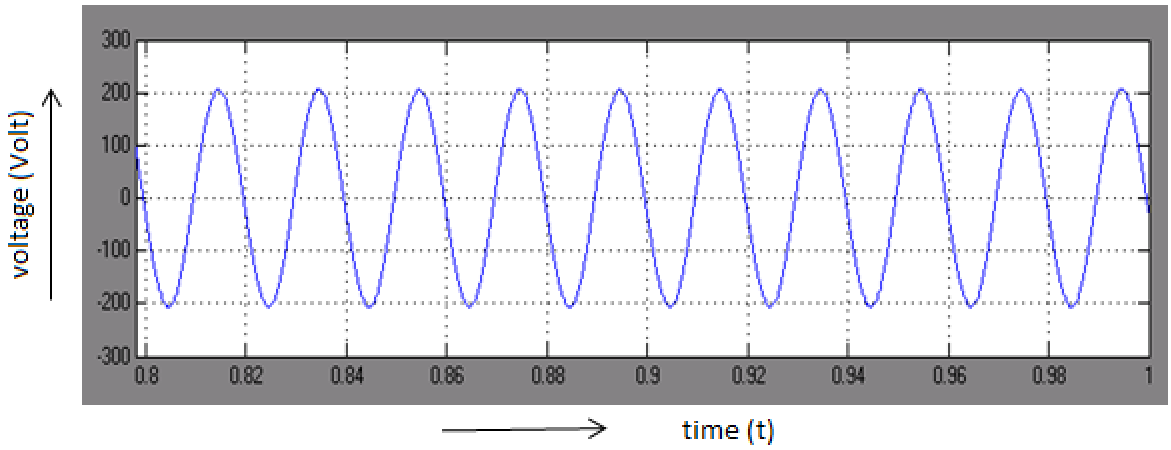

Figure.7.5. Output Voltage of Inverter

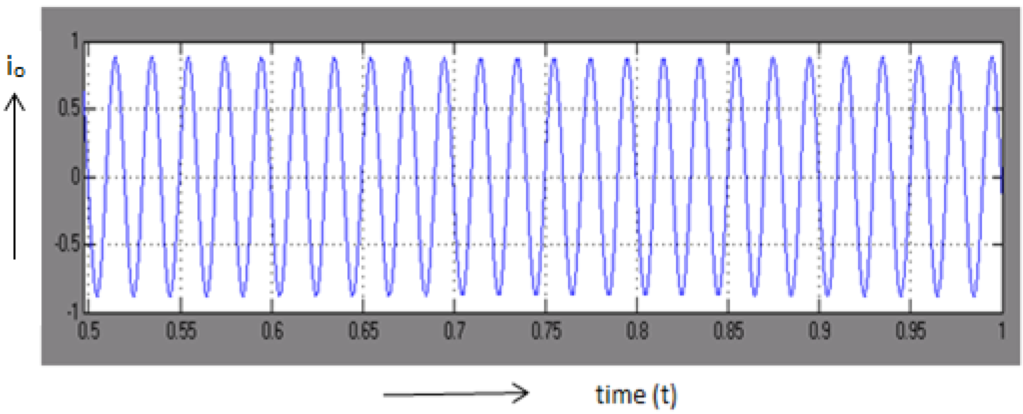

Figure.7.6. Output Current

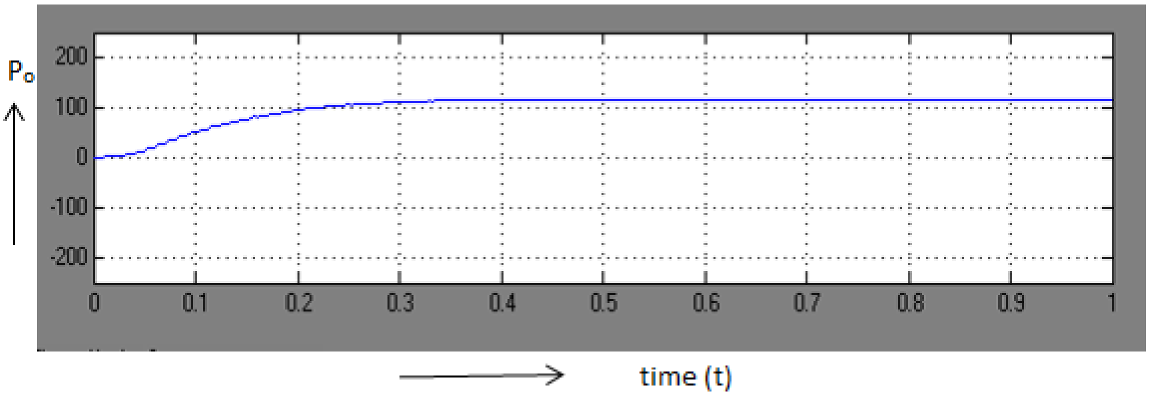

Figure.7.7. Output Power

CONCLUSION

High step-up DC to DC converter for Distributed generation employing PV systems is successfully designed, modulated and simulated using Matlab/ Simulink .The results of high step-up converter system are compared with normal boost converter system and it is observed that the power supplied by the high step-up converter system is 40% higher than that of normal boost converter system. The power delivered by the boost converter-inverter system is 60 watts.The power supplied by the high step-up converter-inverter system is about 110 watts.The advantage of the proposed system are reduced switching losses ,reduced stresses and increased power. The switching losses are reduced by using zero current switching. The stress is reduced due to the presence of inductor and capacitor in the circuit. The disadvantages are requirement of coupled inductor and two additional capacitors. The simulation results are in line with the predictions. The scope of this work is the simulation of high step -up converter. The hardware will be done in future.

REFERENCES

[1] Kuo-Ching Tseng, Chi- Chih Huang, and Wei- Yuan Shih, June 2013. “A High Step-Up Converter with a Voltage Multiplier Module for a Photo Voltaic System.” *IEEE Trans. on Power Electronics.* 28(6).

[2] Kuo-Ching Tseng, Chi- ChihHuang, Mar 2014. ”High Step-Up High Efficiency Inter Leaved Converter with Voltage Multiplier Module for Renewable Energy Systems.”*IEEE Trans. on Industrial Electronics.*61(3).

[3] Kjaer, S.B., Pedersen, J.K., and Blaabjerg, F., Sep./Oct. 2005. “A review of single-phase grid-connected inverters for photovoltaic modules,” *IEEE Trans. Ind.Appl.*, 41(5), 1292–1306.

[4] Umeno, T., Takahashi, K., Ueno, F., Inoue, T., and Oota, I., Jun. 1991. "A new approach to lowripple-noise switching converters on the basis of switched- capacitor converters," in *Proc. IEEE Int. Symp. Circuits Syst.*, 1077–1080.

[5] Axelrod, B., Berkovich, Y., and Ioinovici, A., Mar. 2008. "Switched-Capacitor/Switched-Inductor
structures for getting transformerless hybrid DC–DCPWM converters," *IEEE Trans. on Circuits Syst. I, Reg. Papers*, 55(2),687–696.

[6] Axelrod, B., Berkovich, Y., and Ioinovici, A., 2003. "Transformerless DC-DC converters with a very high DC line-to-load voltage ratio," in *Proc. IEEE Int.Symp. Circuits Syst. (ISCAS)*, 3,435–438.

[7] Liang, T.G., and Tseng, K.C., Mar. 2005. "Analysis of integrated boost-fly back step-up converter," *IEEE Proc. Electrical Power Appl.*, 152(2), 217–225

[8] Zhao, Q., and Lee, F.C., Jan. 2003. "High-efficiency, high step-up dc–dc converters,"*IEEE Trans. on Power Electron.*, 18(1), 65–73.
.
[9] Baek, J.W., Ryoo, M.H., Kim, T.J., Yoo, D.W., and Kim, J.S., 2005. "High boost converter using voltage multiplier," in *Proc. IEEE Ind. Electron.Soc. Conf. (IECON)*, 567–572.

[10] Xu, J., 1991. "Modeling and analysis of switching dc–dc converter with coupled inductor,"in *Proc. IEEE 1991 Int. Conf. Circuits Syst. (CICCAS)*, 717–720.

[11] Wai, R.J., Lin, C.Y., Duan, R.Y., and Chang, Y.R.., Feb. 2007. "High-efficiency dc–dc converter with high voltage gain and reduced switch stress," *IEEE Trans. on Ind. Electron.*, 54(1), 354–364.

[12] Park, Y., Choi, S., Choi, W., and Lee, K.B., Oct. 2011. "Soft-switched interleaved boost converters for high Step-Up and high power applications," *IEEE Trans. on Power Electron.*, 26(10), 2906–2914.

[13] Kwon, J.M., and Kwon, B.H., Jan.2009. "High step-up active-clamp converter with input-current doubler and output-voltage doubler for fuel cell power systems,"*IEEE Trans. on Power Electron.*, 24(1), 108–115.

[14] Yang, L.S., Liang, T.J., and Chen, J.F., Aug. 2009. "Transformer less DC–DC converters with high step-up voltage gain," *IEEE Trans. on Ind. Electron.*, 56(8), 3144–3152.

[15] Shih-Ming Chen, Tsorng-Juu Liang, Lung-Sheng Yang, and Jiann-Fuh Chen, April 2012. "A Safety Enhanced High Step-Up DC-DC converter for AC Photovoltaic Module Application," *IEEE Tran. on Power Electronics,* 27(4), 1809.

ABOUT AUTHORS

Malathi has done her BE Electrical and Electronis Engineering fromAnnamalaiUniversity in 1995 and ME from Sathyabama University in 2005. She is presently a research scholar in SCSVMV University, Kancheepuram. Her area of research is Photo Voltaic Systems.

Prof.Dr. M.Rathinakumar has done his BE inThiagarajar college of Engineering Madurai and ME inThiagarajar college of Engineering Madurai. He is presently heading the department of Electrical and Electronics Engineering,SCSVMVUniversity,Kancheepuram.