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TRANSFORMER LESS GRID CONNECTED SEPIC CONVERTER FOR PHOTOVOLTAIC GENERATION SYSTEMS

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Abstract— ***This paper proposes transformerless grid-connected Single Ended Primary Inductance Converter (SEPIC) for photovoltaic generation systems. The photo voltaic cell can be made up of thin-film solar cell array and the Material used for manufacturing solar cells are polycrystalline si and Mon crystalline si, Using this in solar cell array module enhances the potential to generate the electric power for longer time. The proposed power converter consists of some power electronic switches which are simultaneously used for SEPIC and another converter is (DC to AC) inverter, SEPIC is one of the DC-DC converter and this output voltage are greater then or less then the input voltage and SEPIC is controlled by the duty cycle of the converters. The proposed converter can be used for inverting (DC to AC) voltage which can be connected to any type of loads.***

Keywords- *SEPIC converter, solar power generator thin flim, dc to ac inverter*

1. INTRODUCTION

The wide use of fossil fuel has resulted in the emission of green house gases which results in pollution. In spite of the increase in fuel cost there is an increase in renewable energy trading. The run provides the energy needed to sustain life in our system. It is clean, inexhaustible, abundantly, and universally scare of RE. The most popular renewable energy is solar energy, that can be utilized directly in two ways:(1) by collecting the radiant heat and using it in a thermal system or (2) collecting and converting it directly to electrical energy using photovoltaic system. The thin-film solar cell has the potential to generate the electric power for longer time , than a crystalline si solar cell and thin film can be easily combined with glass, plastics, metal, and it can be incorporated [1]-[8].

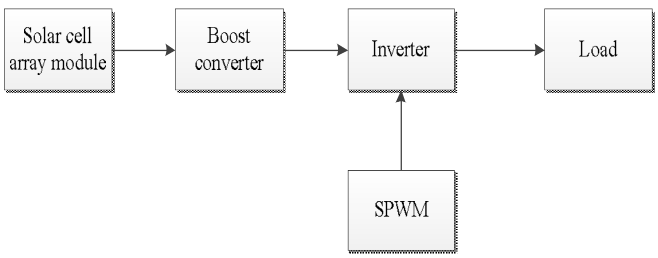


Figure 1.(a) Grid connected converter systems for using boost converter

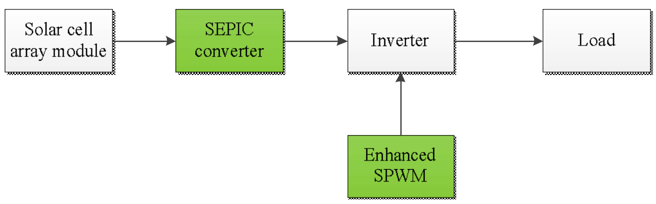


Figure 1. (b) Grid connected converter systems with SEPIC converter

Figure 1(b) shows that the solar array module producing lower level DC voltage, and this voltage is feedback to input of SEPIC converter Based on the requirement these SEPIC converter performs both boost and buck operation. And this change in voltage is the output of SEPIC converter. This output is passed as a Input to the inverter, to convert the DC voltage to AC voltage and connected to load.

The conventional method boost converter is acts as the step-up converter , and the output voltage is greater than the input voltage, and drawback of this method is only the voltage is stepped up and one inductor is used so energy storage is less compare to proposed system

SEPIC converter is used in the proposed method. It is a DC-DC converter to allows the electrical potential (voltage) at its output to be greater than or lesser than the input voltage. It can use coupled inductors and take the form of a single package at cost slightly higher than single inductor. The purpose of inductor is to store the energy in the form of electro magnetic field [5]-[6] Proposed converter is controlled by the duty cycle control method. By increasing duty cycle output voltage can be controlled. The advantage of SEPIC is non-inverted output voltage (the output voltage is of the same polarity as the input voltage).When switched is turned off, it's output drop to zero voltage[2].

Table 1 difference between buck-boost and SEPIC converter

parameter	buck-boost	SEPIC
Peak efficiency(percent)	90.2	93.7
Max switching stress(V)	65	55
Max diode stress(V)	125	55
Power components	9	9
Area (sq.inches)	4.6	4.6
Continuous input current	NO	YES
Control loop complexity	moderated	complex

SEPIC converter operating in continuous conduction mode (CCM) is expressed in mathematical form,

$$D = \frac{(Vout + Vd)}{(Vin + Vout + Vd)} \quad (1)$$

Vd is Forward voltage drop

$$D\max = \frac{(Vout + Vd)}{(V\min + Vout + Vd)} \quad (2)$$

Dmax = Maximum Duty Cycle

$$L1 = L2 = \frac{(Vin(\min) * D\max)}{(\Delta IL * Fsw)} \quad (3)$$

Fsw = Switching frequency
Peak to peak ripple current appx, 40%

$$C1 = Iout * \sqrt{((Vout + Vd)/(V\min))} \quad (4)$$

$$C2 \geq \frac{(Iout * D\max)}{(Vripple * Fsw)} \quad (5)$$

C1 and C2 input and output capacitance

$$\Delta IL = \frac{(Iout + Vout + 40\%)}{Vin(\min)} \quad (6)$$

ΔIL = Ripple current

$$\frac{Vo}{Vin} = \frac{D}{1 - D} \quad (7)$$

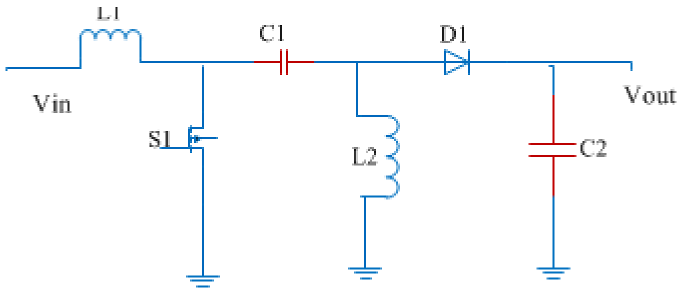


Figure 2 SEPIC converter basic diagrams

Figure 2 shows a simple circuit diagram of a SEPIC converter. This converter consists of an input capacitor C1, output capacitor C2,coupled inductors L1, L2 AC coupling capacitor C1,power MOSFET S1 and a diode D1.It is carried out to operating in the continuous conduction mode(CCM).Q1 is on in the top circuit and off in the bottom circuit. To understand the voltages at the various circuit modes, it is important to analyse the circuit at DC when Q1 is off. During steady-state CCM,Enhanced sinusoidal Pulse width-modulation (Enhanced SPWM) operation is carried out to neglect the ripple voltage.[2]-[3]. capacitor C1 is charged to the input voltage Vin knowing this easily we determine the voltage as shown in fig. when Q1 is off the voltage across the L2 must be Vout ,since C1 is charged to Vin the voltage across S1 is off is Vin + Vout, so the voltage across L1 is Vout . When the S1 is on capacitor C1 is charged to Vin which is connected in parallel with L2, so the voltage across L2 is negative voltage [2].

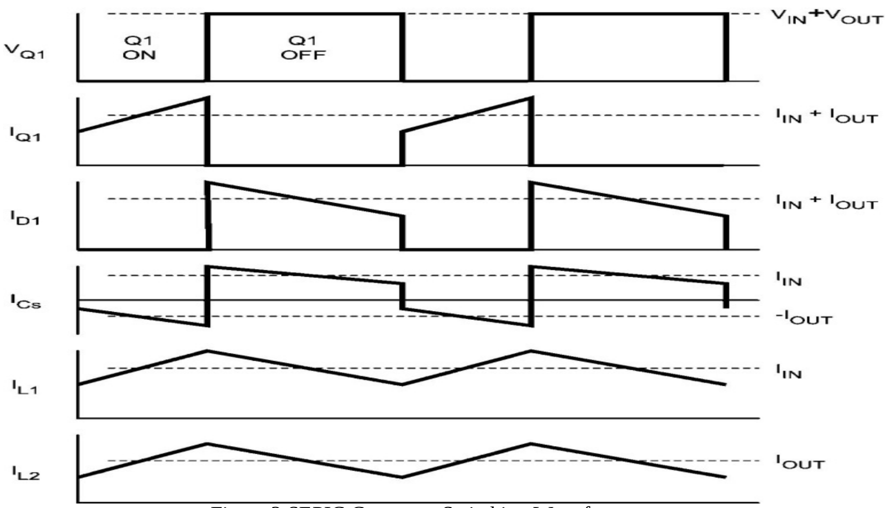


Figure 3 SEPIC Converter Switching Waveforms

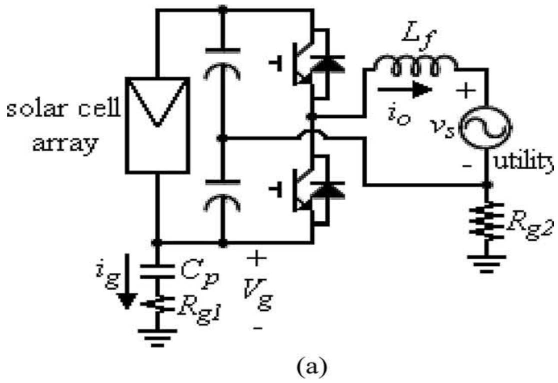
Table 2
Main parameters for different inverter used in the simulation

parameters	Value
Cp	0.001F
Fsw	10khz
Lf(type 1)	53mH
Lf(type 2)	3mH
Lf(type 3)	2mH
Lf(type 4)	2mH

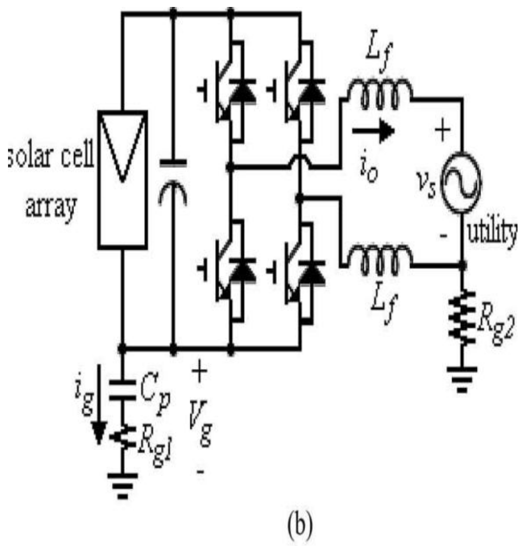
II. LEAKAGE CURRENT OF DC-AC INVERTER

This section analyzes the problem of leakage current in a grid-connected photovoltaic generation system that uses a conventional half-bridge inverter, a conventional full-bridge inverter, and a diode-clamped multilevel half-bridge inverter. Figure.4 shows the relevant circuit configurations. In the following analysis, the capacity of the solar cell array shown in Figure. 4 is assumed to be 1 kW. An equivalent capacitor *Cp* is serially connected to an equivalent resistor *Rg*1to represents the parasitic elements of the solar cell array. The utility is connected to the ground by an equivalent resistor *Rg*2. The capacitance to the parasitic capacitor *Cs* is typically 1 μF in a 1-kW solar cell array. Since the utility voltage is 120V, *Rg*2 must be lower than 25Ω to satisfy the requirements [24]. Fig.4 (a) shows a conventional half-bridge inverter, which is controlled by pulse width modulation (PWM) and named as type 1.Fig.4(b) shows a conventional full-bridge inverter. The Fig.4(c) shows the diode-clamped multilevel half-bridge inverter. A Filter inductor and capacitor connected to the output of the dc–ac inverter is used for filtering the switching harmonic of the dc–ac inverter.

Table 2 shows the main parameters of the simulation system. Fig. 4 shows the simulation results for the resistors. The grounding voltage *vg* and the leakage current *ig* differ for different types of dc–ac inverters. For the conventional half-bridge and diode-clamped multilevel half-bridge inverters, the neutral line of the utility is directly connected to the middle point of the split dc capacitors. The voltage between the negative terminal of the solar cell array and the ground is stabilized by the lower dc capacitor of these types of dc–ac inverters. A voltage ripple with a frequency equalling that of the utility is incorporated in the voltage of the negative terminal because the ac current connected to the utility passes through the split dc capacitors. This voltage ripple is very small and depends on the capacitance of the split dc capacitors. Since the impedance of the earth parasitic capacitance is very large at the utility frequency, the leakage current of the utility frequency is very small. Fig. 4 shows a small high-frequency leakage current in the half-bridge inverter. This is due to the equivalent ground resistor *Rg*2of the utility and switching operation of the power electronic switches. However, the leakage current for the half-bridge inverter is less than 2.5 mA.

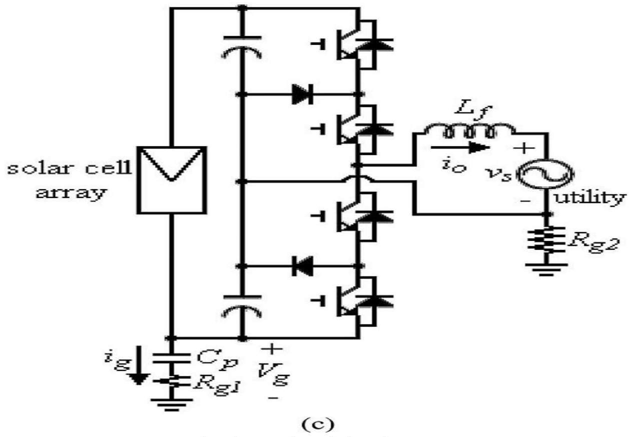


(a) conventional half-bridge inverter



(b) Conventional full-bridge inverter

This one of DC-AC converter. Here four power electronics switches (MOSFET) can be used; MOSFETs offer much higher input impedance and lower voltage drop and four power electronics switch can be operate.



(c) Diode-clamped multilevel inverter

Figure 4 inverter topology in the grid connected photovoltaic generation system

During the positive half cycle of the utility voltage, the circuit Configuration and better suppress the leakage current, two filter inductors are connected between the outputs of the dc to ac inverter and connected to load.

The voltage at the negative terminal of type 2 contains no pulsating voltage at the switching frequency due to the symmetric switching of the bipolar PWM. Since this voltage ripple is low frequency, the peak value of the leakage current is smaller than 50 mA. However, this leakage current is larger than that of the conventional half-bridge and the diode-clamped multilevel half-bridge inverters. Fig. 4 also shows that the voltage at the negative terminal of type 3 contains a pulsating voltage with a frequency equalling the switching frequency due to the asymmetric switching of the Enhanced SPWM. The magnitude of this pulsating voltage and results in a serious leakage current (about 1A) through the parasitic capacitance of the solar cell array.

III.TWO STAGE CONVERTER

One is DC-DC converter, which is used for SEPIC converter and another one is DC-AC inverter which is used for full bridge inverter. Using this method we can reduce the harmonic and inductor, capacitor design is simple. So two stage converter is better than the single stage converter. It is combination of both SEPIC converter and full-bridge inverter. Here SEPIC converter switch operates high frequency because charging and discharging of inductor and capacitor is very fast, so it will produce constant output voltage. Switch S1 is used for MOSFET, which is higher input impedance, lower voltage drop and operates in a high switching frequency. Another converter is Single Phase Full Bridge inverter, which is used to convert DC-AC voltage. Output of this inverter produces not sinusoidal waves and only produces square wave. Using LC filters to eliminate the lower and higher order harmonic and then produces sinusoidal waves.

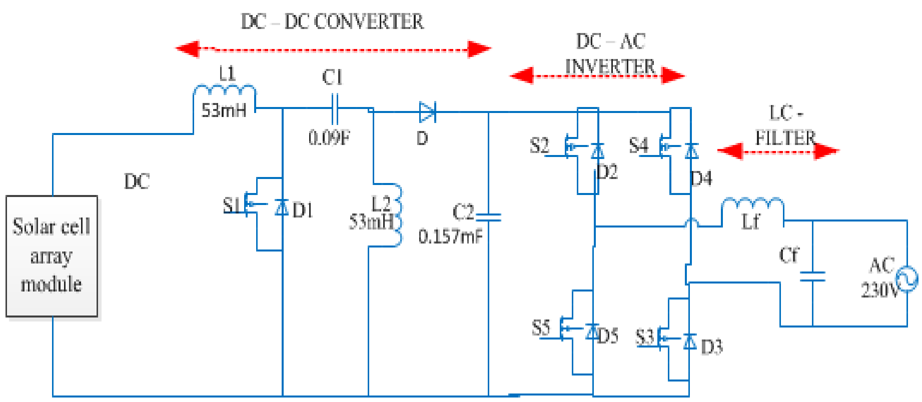


Figure 6. Circuit diagram of two stage converter

IV.OPERATING PRINCIPLE OF THE PROPOSED SYSTEM CONVERTER

Figure.7 shows the Enhanced SPWM switching pattern for the power electronic switches of the proposed transformer less grid-connected power converter. Here switches S1, S2, S3 operating at high frequency (10 kHz) and other switches S4, S5 operating as normal frequency. *S*1 is switched at high frequency to store or release the energy in the inductor *L*1 and capacitor C1, and then regulate the output voltage of the dc – dc power converter.

S2 and *S3* are switched at high frequency during the positive half-cycle and the negative half-cycle of the load voltage to control the output current of the dc–ac inverter. Since only two power electronic switch in the dc–ac inverter is switched at high frequency, the power loss caused by the switching operation is reduced.

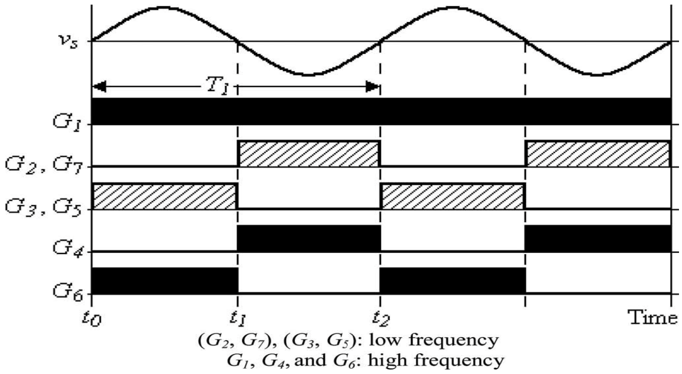


Figure 7. Switching pattern of enhanced sinusoidal pulse width modulation

V. SIMULATION AND HARDWARE RESULTS

Figure 8 shows the switching pattern of Enhanced sinusoidal pulse width modulation. Here four power electronics switches were used. Two switches operating at high frequency and other two switches operate at normal frequency. Using in this method to reducing the harmonics, compare to normal SPWM technique.

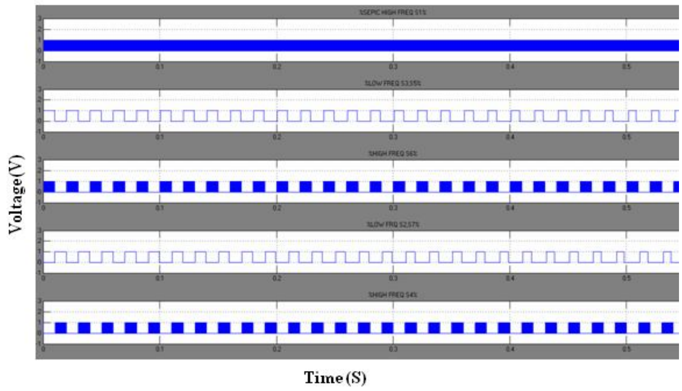


Figure 8 switching signal generation in enhanced SPWM Technique

Figure 9(a) and 9 (b) Shows the output voltage waveform for SEPIC converter, it is perform both buck and boost operation. Here S1 operating at high frequency so charging and discharging of inductor and capacitor is very fast, so producing continuos output voltage for longer time duration and producing non inverted output voltage.

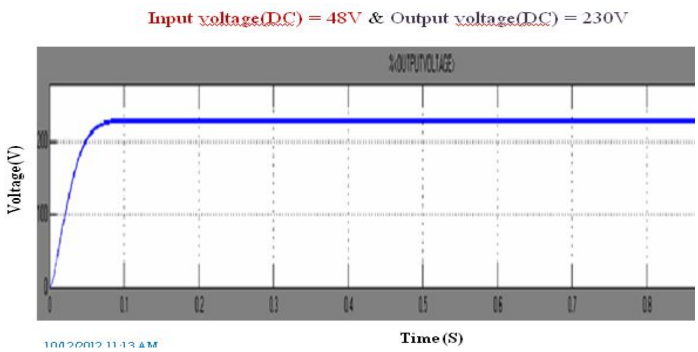


Figure 9 (a) Simulation results of boosting operation in SEPIC converter

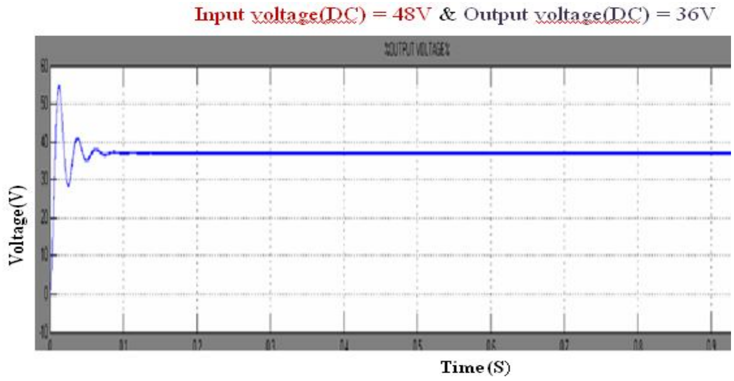


Figure 9 (b) Simulation results of buck operation in SEPIC converter

Figure 10 shows that output voltage of solar Photovoltaic module. This PV module contains 72 cells and each cell produce 0.35V, one solar panel produces for 24V.

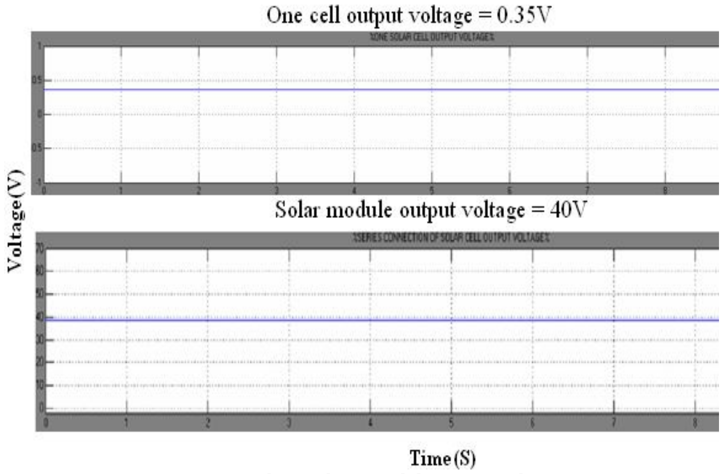


Figure 10. Photovoltaic module output voltage

In this converter inductor L1 and inductor L2 coupled in single package so we can store more energy in electro magnetic field and cost is slightly higher compare to other converters. Figure 11 shows the output voltage of proposed system. Here single phase full bridge inverter can be used, Help of this inverter to inverting DC-AC voltage and adding LC filter to produces for pure sinusoidal voltage and reducing the total harmonic distortion.

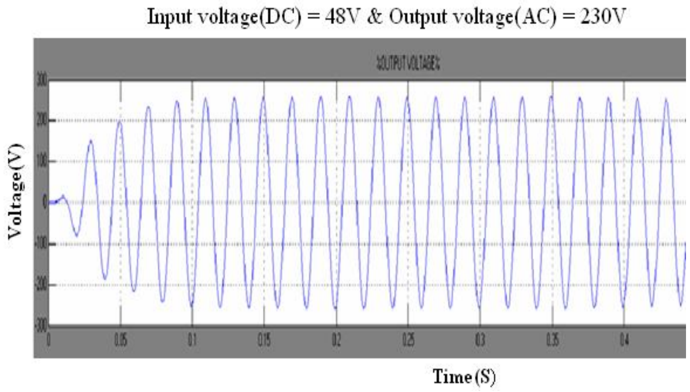


Figure 11 Output voltage of with filter

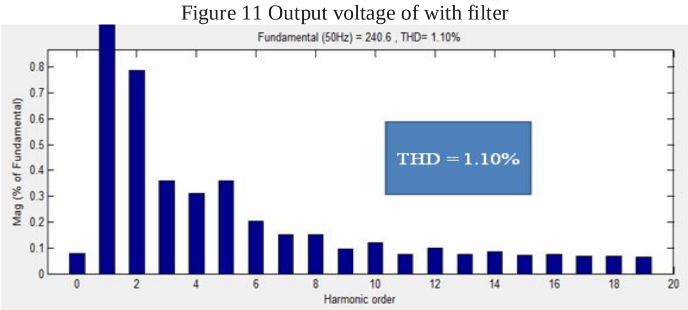


Figure 12 THD value of with filter

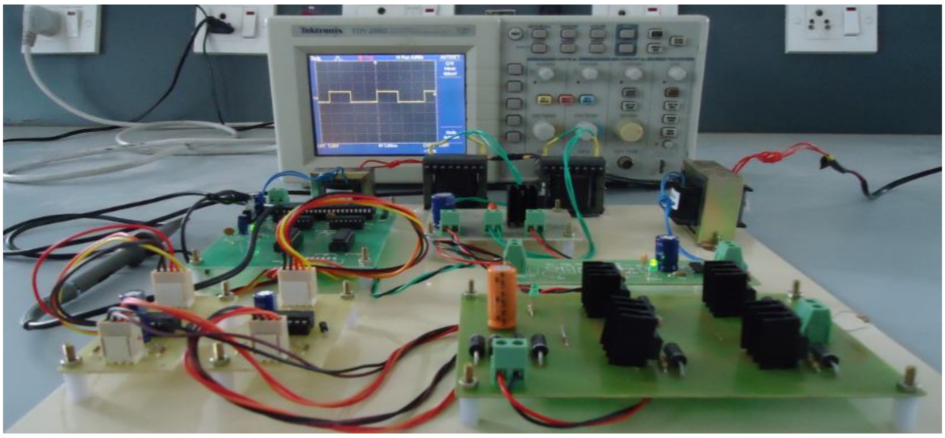


Figure 13 Laboratory Experimental Setup of switching pulse

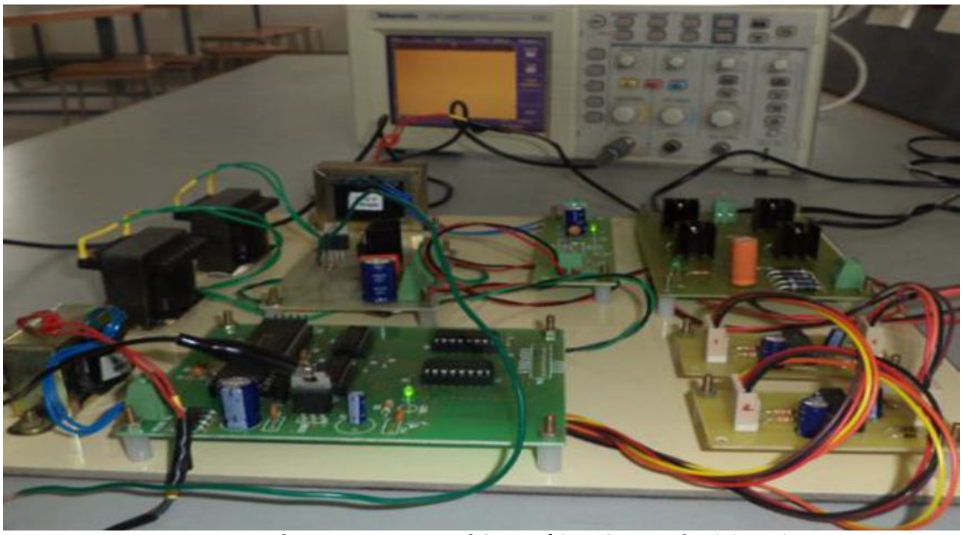


Figure 14 Laboratory Experimental Setup of SEPIC gate pulse (10KHZ)

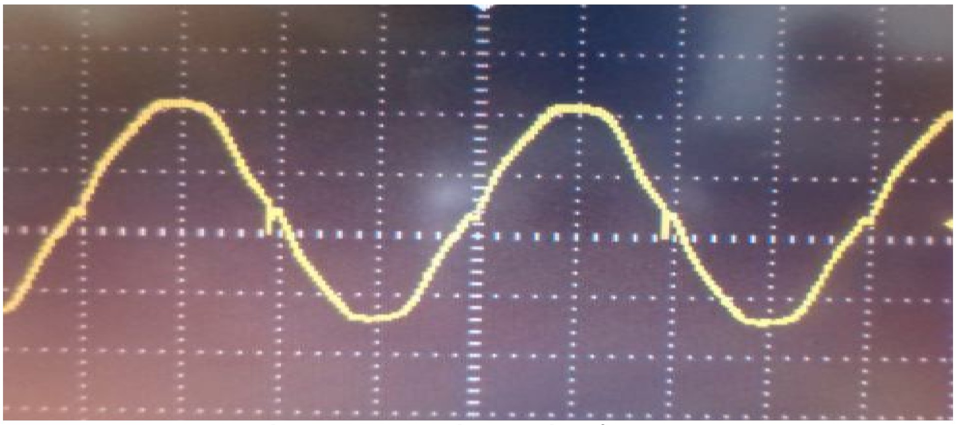


Figure 15 Laboratory Experimental output voltage for two stage converter

VI.CONCLUSION

This paper proposes a transformerless grid-connected SEPIC converter for photovoltaic generation system, the photovoltaic cell can be made up of thin-film solar cell array and material can be used for manufacturing polycrystalline Si only. Using in this solar cell array module enhance the potential to generate higher electric power. And the salient features of the proposed SEPIC converter is that two inductors can be used to store more energy In the electromagnetic field, producing non-inverted output voltage and then producing continuous output voltage for long time duration. The SEPIC converter operates at high switching frequency when compared with the existing methods of converter.

REFERENCES

[1] Jin-min shen, Hurng – Liahing Jou, Jinn-caang wu "novel transformer less grid- connected power converter with negative grounding for photovoltaic generation systems" April 2012.

[2] Robert W. Erickson and dragan maksimovic, fundamentals of power electronics ,2nd ed. (new York : business media LLC,2001)

[3] Z. Liang, R. Guo, J. Li, and A. Q. Huang, "A high-efficiency PV module integrated DC/DC converter for PV energy harvest in FREEDM systems,"IEEE Trans. Power Electron., vol. 26, no. 3, pp. 897–909, Mar. 2011.

[4] R. Gonzalez, J. Lopez, P. Sanchis, and L. Marroyo, "Transformerlessinverter for single-phase photovoltaic systems," IEEE Trans. Power Electron.,vol. 22, no. 2, pp. 693–697, Mar. 2007

[5] H. Schmidt, "Do thin-film modules need special inverters?" presented at the Fifth User Forum Thin-Film Photovoltaic, Wartburg, Germany, Jan.26–28, 2009.

[6] O. Lopez, R. Teodorescu, and J. Doval-Gandoy, "Multilevel transformerlesstopologies for single-phase grid-connected converters," in Proc. IEEEConf. Ind. Electron., Nov. 6–10, 2006, pp. 5191–5196.

[7] T. Kerekes, M. Liserre, R. Teodorescu, C. Klumpner, and M.Sumner, "Evaluation of three-phase transformer less photovoltaic inverter topologies," IEEE Trans. Power Electron., vol. 24, no. 9, pp. 2202–2211,Sep. 2009.

[8] Diorge Jambra, Cassiano Rech and Jose Renes Pinheiro "Comparision of Neutral-Point-Clamped, Symmetrical and Hybrid Asymmetrical Multilevel Inverters", IEEE Transactions on Industrial Electronics, Vol. 57, No. 7, 2010.

[9] Fanghua Zhang and Yangguang Yan "Selective Harmonic Elimination PWM Control Scheme on a Three-Phase Four-Leg Voltage Source Inverter", IEEE Transactions on Power Electronics, Vol. 24, No. 7, pp.1682-1689, 2009.

[10] Mohd, A., Ortjohann, E., Hamsic, N., Sinsukthavorn, W., Lingemann, M., Schmelter, A. and Morton, D. "Control Strategy and Space Vector Modulation for Three leg four-wire voltage source inverters under Unbalanced Load Conditions", IET Power Electronics, Vol. 3, No. 3, pp.323-333, 2010.

[11] Jang-Hwan Kim and Seung-Ki Sul "A Carrier-Based PWM Method for Three-Phase Four-Leg Voltage Source Converters", IEEE Transactions on Power Electronics, Vol. 19, No. 1, pp.66-75, 2004

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