IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 10, Issue 1 Ver. I (Jan – Feb. 2015), PP 88-93
www.iosrjournals.org

Design and Simulation of transformer less Single Phase Photovoltaic Inverter without battery for Domestic Application

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Abstract: *This paper presents simulation results of single phase photovoltaic inverter. The proposed inverter system converts photovoltaic power into single phase AC supply efficiently without using transformer and batteries. In this the simulation results of transformer less single phase photovoltaic inverter are shown. Maximum Power Point Tracing (MPPT) algorithm is implemented in order to extract maximum power from a PV module. A boost converter is also implemented to raise the DC voltage level to desired level, an inverter with controlled PWM scheme is implemented for conversion of DC input into AC supply. The simulation is carried out on SIMULINK/Sim power systems.*

Keywords: *PV-AC conversion, PV inverter, transformer less inverter, Boost converter, PV inverter model in Sim Power Systems.*

I. Introduction

Electricity is becoming a central need of human being. Presently maximum electricity is generated at thermal and hydro power plants. These plants depend upon coal which is limited on earth's crust causing shortage of power supply. To overcome these shortcomings use of non-renewable sources is very much useful.

In Asian countries solar energy is abundantly available. Applications using solar energy will minimizes energy crisis. As solar energy is clean source of energy, power generation is easy and eco-friendly. Also for energy conversion moving part or heavy machinery is not required.

For efficient conversion of solar energy into an electrical power various inverter topologies were proposed. Transformer-less inverter topology is proposed for cost effective PV system, which eliminates leakage current in an inverter system, due to which the overheads over transformer were reduced [1]. To reduce an overall costing on an inverter a new methodology for design of transformer-less photovoltaic (PV) inverters for grid-connected PV systems with less switching is demonstrated [2].

A PV converter system with standby distributed generation system is proposed [4], which is more useful for rural and agricultural applications in a developing country like India.

In this work we aim to design an inverter which converts PV power directly into AC power without using Middle linkages and battery storage devices. Many researchers developed variety of inverters for the PV applications which differ in their structure, function and topologies. Some achieves efficiency up to 98% while other introduce concept of hybrid inverter. But very less focus is given on conversion of PV energy directly into AC power.

In the simulation we have designed an inverter topology to extract power from a PV array and to convert it at desire level. This PV power is converted directly into AC voltage and thus eliminating the battery requirements and consequently reducing the overheads on backup.

II. PV Inverter Configuration

Fig. 1 shows the generalized block diagram of proposed PV inverter system. A control unit shall be developed such that it will have firmware for MPPT algorithm to extract maximum power from PV module. It will monitor and regulate operation of the system.

The output of a boost converter is given to an inverter to obtain AC power. PWM scheme is used for switching of inverter switches. LCL filter is used to filter an output of an inverter to reduce harmonics and THD [3].

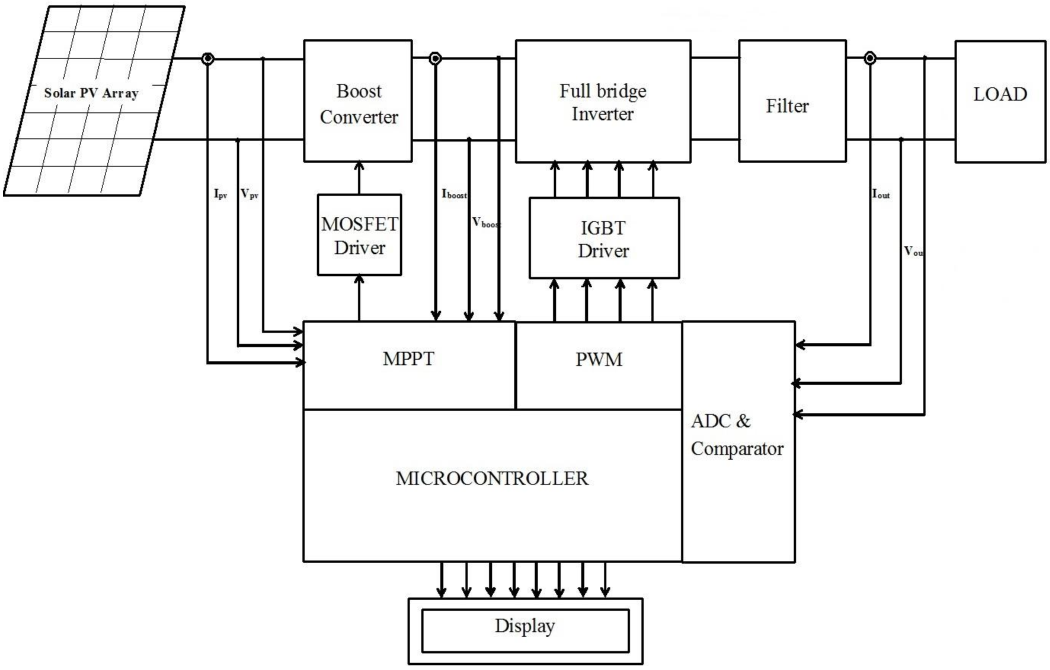

Fig. 1Generalized block diagram of Proposed PV inverter

III. Simulation circuit diagram

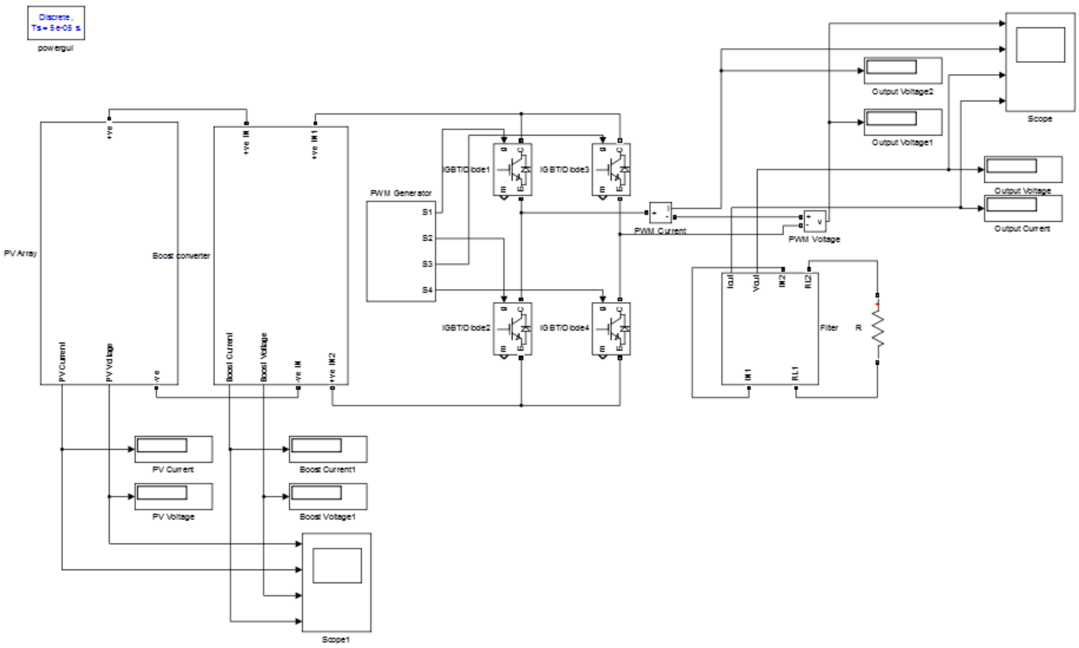

Fig. 2 Simulation model of proposed PV inverter system.

A simulation model of proposed inverter system is shown in Fig. 2. The simulation is carried out in MATLAB/ SIMULINK the model contains various blocks such as PV cell, Boost converter, Inverter, PWM generator and Filter.

The PV cell generally acts as a Current dependent voltage source the output is depends upon current which follows the insolation and irradiance [5].

The solar cell can be modeled as a current source in anti-parallel with a diode (Fig. 3). The direct current get generated when the cell is exposed to light, current varies linearly with variation in solar radiation. Rs and Rsh are series and shunt resistances respectively.

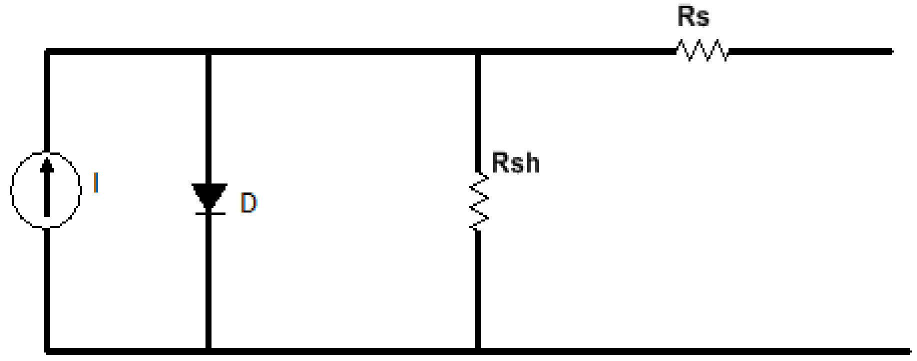

Fig. 3 Equivalent electronic circuit of an ideal Solar Cell

The simulation model of boost converter is as shown in Fig. 4; it has an input inductor which stores energy from PV cell and is delivered to an output capacitor by controlling the switching of MOSFET. To avoid back effect of charge stored by capacitor, a Schottky diode is used. In designing process the switching frequency fs and duty cycle D plays an important role [6].

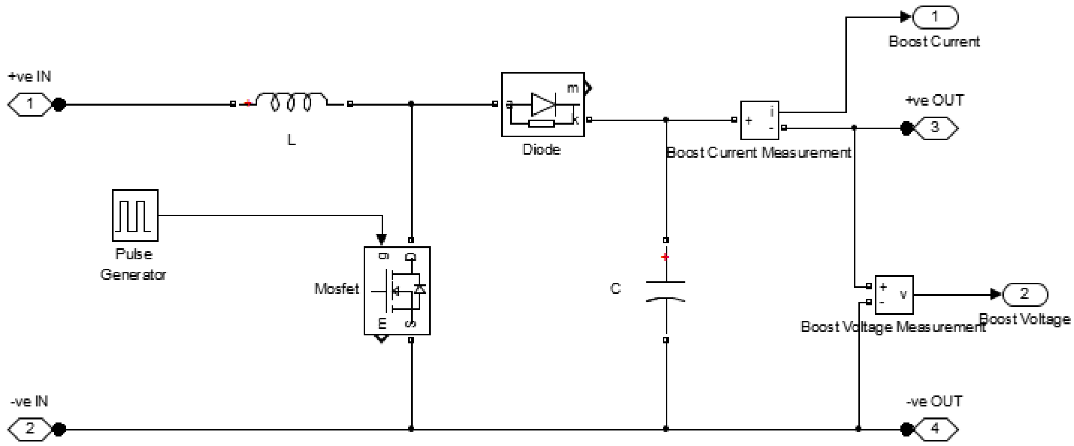

Fig. 4 Simulation Model of Boost converter

$$D = 1 - \frac{V_{in\,(min\,)} \times \eta}{V_{out}} \tag{1}$$

$$L = \frac{V_{in} \times (V_{out} - V_{in})}{\Delta I_L \times f_s \times V_{out}} \tag{2}$$

$$C_{out\,(min)} = \frac{I_{out(max)} \times D}{f_s \times \Delta V_{out}} \tag{3}$$

An output of boost converter is regulated and delivered to next stage i.e. inverter. H-bridge inverter is simulated in this model. Transformer is not used in the simulation as it causes losses and makes the system bulky. Transformer less inverter topology is simulated [7]. PWM scheme is used to switch IGBTs shown in inverter section of Fig.2.

At an output of inverter LCL filter is employed [8] shown in Fig. 5, to get a sinusoidal output. LCL filter is designed using expression 4.

$$F = \frac{1}{2\pi} \sqrt{\frac{L_1 + L_2}{L_1 L_2 C_f}} \tag{4}$$

The simulated inverter shall be designed by considering reliability issues of converters and inverters as discussed in ref. [9].

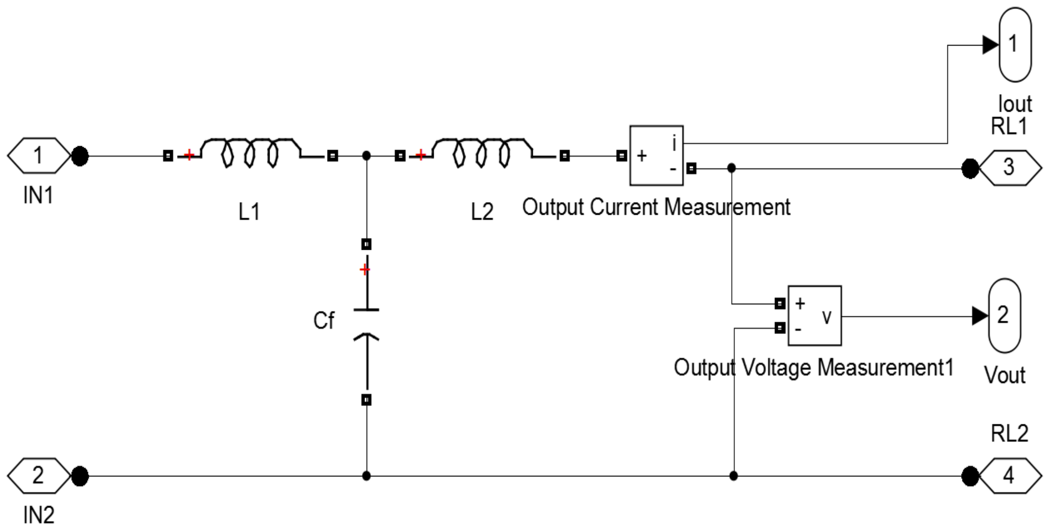

Fig. 5 Filter Circuit

IV. Results And Discussions

Simulation results of a PV inverter system are as follows:

Fig. 6 shows current and voltage waveforms of PV cell and boost stage respectively. The PV cell is designed to deliver 96V and 6.5A current. The system is simulated by considering a maximum power point.

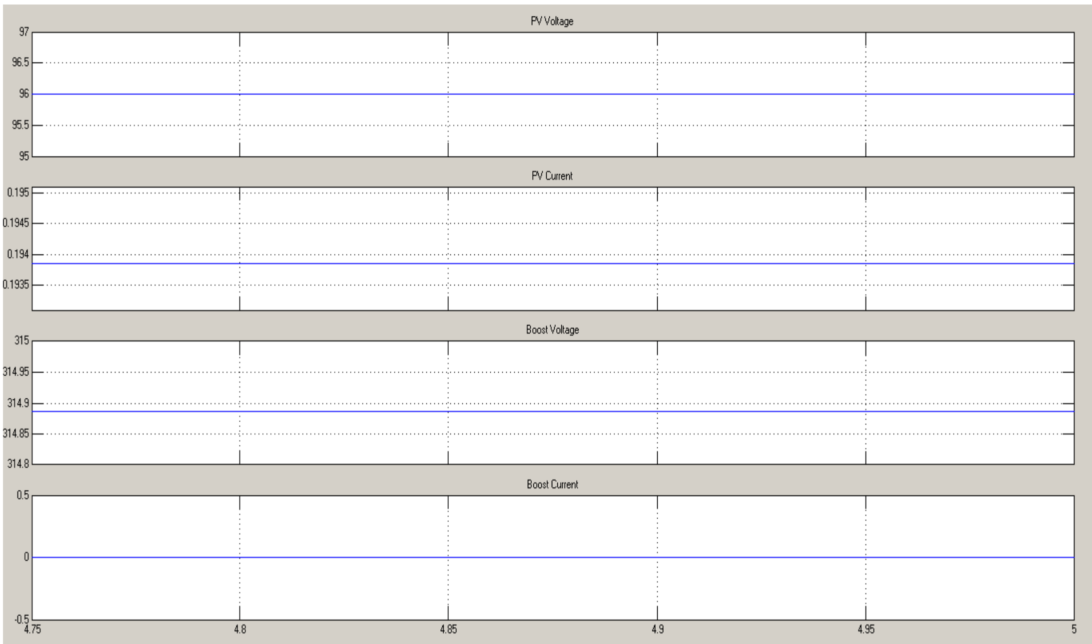

Fig. 6 Output voltage and current of PV cell and Boost converter at no load condition.

The boost converter is so designed to deliver output voltage of 320V DC. Boost output is directly given to an inverter. Inverter switches are controlled using PWM scheme and modulation index is selected as 0.6.

PWM output of an inverter is shown in Fig. 7. Output voltage and current waveforms are shown in Fig. 8; readings are taken for resistive load of 110 ohm. Voltage waveform shows V_{rms} value of 230V and current waveform shows I_{rms} of 2.2 A.

Fig. 9 shows Harmonic profile of an inverter output, THD is minimized to 0.645 and the odd harmonic content in the output is also reduced leading to increase in efficiency. From simulation results it is clear that system with less THD and light weight can be implemented.

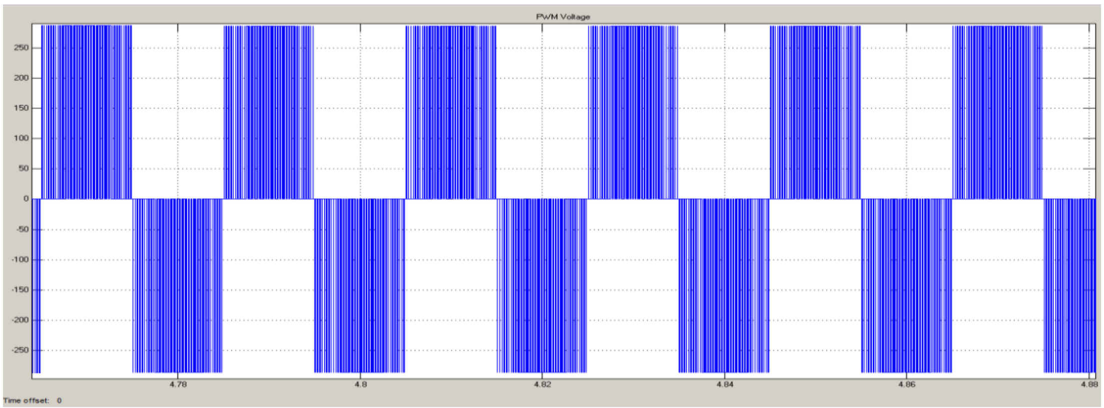

Fig. 7 Output of an Inverter without filter.

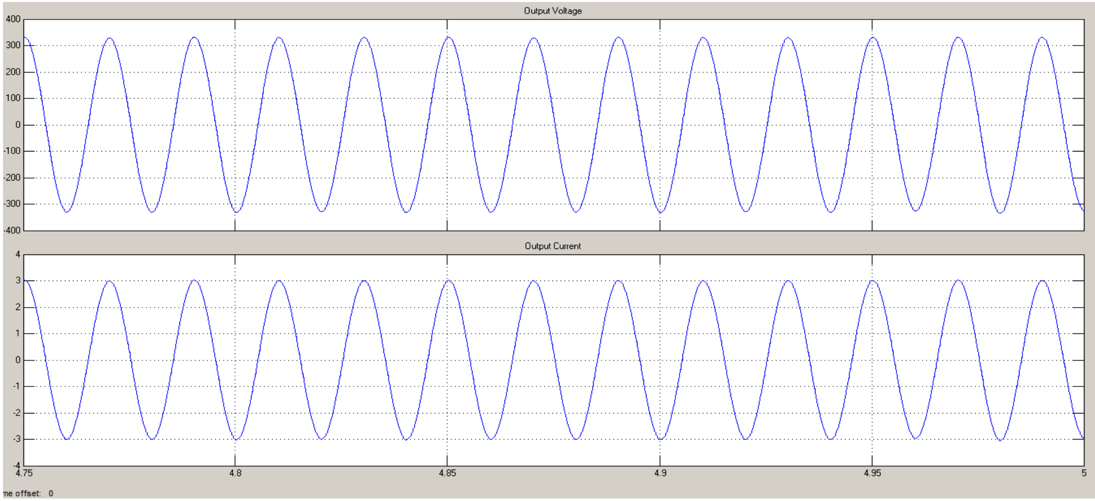

Fig. 8 Output Voltage and Current of an inverter with LCL filter.

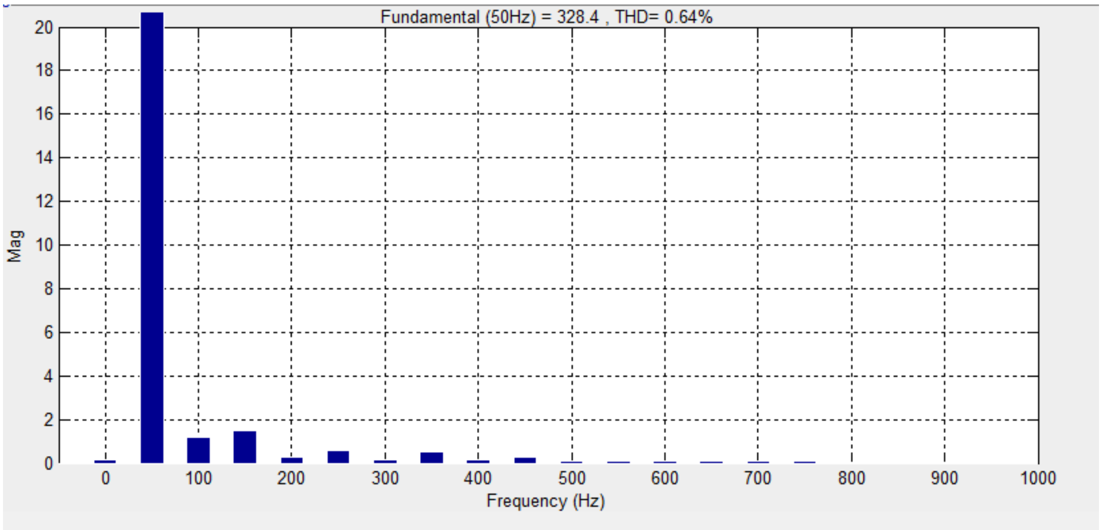

Fig. 9 Harmonic profile of a system.

Parameters	Specification
PV Voltage	96 V
PV Current	6.5 A
Insolation	1000 Watt/m^2
Temperature	25^0C
Boost Inductor (L)	400 mH
Boost Capacitor(C)	1000 μF
Duty Cycle(D)	70%

Efficiency of Boost(η)	80%
Switching Frequency(f_s)	250KHz
PWM Carrier Frequency(f_c)	2KHz
PWM Modulation Index(m_a)	0.6
Filter Inductor(L_1)	10 mH
Filter Inductor(L_2)	10 mH
Filter Capacitor(C_f)	680 μF
Load Resistor (R_L)	110 Ohm
Output Voltage (V_{rms})	230 V
Output Current (I_{rms})	2.2 A
Output Frequency (f_o)	50 Hz

Table 1 Parameter specifications

V. Conclusion and future work

Simulation results shows that PV power can be efficiently converted into AC power without using battery storage and transformers. Also middle linkages can be omitted to make system light and low cost. The harmonic distortions are also reduced in an output.

Hardware implementation of a proposed system is in process, suitable high speed microcontroller shall be used to regulate sine wave of desired RMS value and frequency. Since transformer has not been used, poor isolation will be demerit of the system.

Acknowledgements

Authors are thankful to Shivaji University, Department of Technology, Kolhapur, India for providing necessary facilities for completion of this manuscript

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