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Modeling and Simulation of Buck Boost Converter - Inverter fed Solar System

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ABSTRACT

This Work deals with the modeling and the simulation of Buck-Boost Converter / Inverter based Solar System. Two Buck-Boost Converters are connected in Parallel to increase the power rating. The DC output is Converted to 50 HZ AC using Single Phase full bridge inverter with LC filter. The Power output of isolated systems and grid connected systems are measured and the results are presented. The Simulation results are coincide with the theoretical results.

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INTRODUCTION

Many types of renewable energy, such as photovoltaic (PV), wind, tidal, and geothermal energy, have attracted a lot of attention over the past decade (Khanh, L.N., *et al*., 2011; Tan, Y.K. and S.K. Panda, 2011; Nami, A., *et al*., 2012).

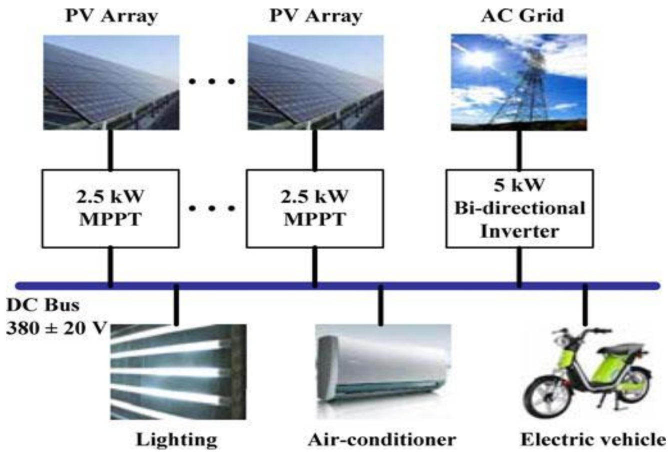

Fig. 1: Configuration of a DC-distribution system

Among these natural resources, the PV energy is a main and appropriate renewable energy for low-voltage dc-distribution systems, owing to the merits of clean, quiet, pollution free, and abundant. In the DC-distribution applications, a power system, including renewable distributed generators (DGs), DC loads (lighting, air conditioner, and electric vehicle), and a bidirectional inverter, is shown in Fig. 1, in which two PV arrays with two maximum power point trackers (MPPTs) are implemented. However, the *i*–*v* characteristic of the PV arrays are nonlinear, and they re-quire MPPTs to draw the maximum power from each PV array. Moreover, the bidirectional inverter has to fulfill grid connection (sell power) and rectification (buy power) with power-factor correction (PFC) to control the power

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flow between DC bus and ac grid, and to regulate the DC bus to a certain range of voltages, such as 380 ± 10 V.

Nowadays, a conventional two-stage configuration is usually adopted in the PV inverter systems (Dwari, S. and L. Parsa, 2012; Shen, J.-M., *et al*., 2013; Kerekes, T., *et al*., 2011; Araujo, S.V., *et al*., 2011; Azzouz, M.A. and A.L. Elshafei, 2013). Each MPPT is realized with a boost converter to step up the PV-array voltage close to the specified DC-link voltage, as shown in Fig. 2. The boost converter is operated in by-pass mode when the PV-array voltage is higher than the DC-link voltage, However, since the characteristics of PV arrays are different from each other, the inverter operated in by-pass mode cannot track each individual maximum power point accurately, and the inverter suffers from as high-voltage stress as the open voltage of the arrays. To release this limitation, an MPPT topology, which combines buck and boost converters is proposed in this study, in which the control algorithm for tracking maximum power points is based on a perturbation and observation method. The MPPT will switch operation modes between buck and boost when the output voltage of a PV array is close to the DC-bus voltage. The designed controller can switch control laws to achieve smooth mode transition and fulfill online configuration check for the MPPTs, which can be either separate or in parallel connection, to draw the maximum power from the PV arrays more effectively. Additionally, a uniform current control scheme is introduced to the controller to equally distribute the PV array output current to the two MPPTs in parallel operation.

To eliminate leakage ground current circulating through PV arrays and ground, several transformerless inverter topologies were proposed (Kakigano, H., *et al*., 2012). Even though they can achieve high efficiency, they require more components than the conventional full-bridge topology. Thus, in this study, the bidirectional full-bridge inverter is operated with bipolar modulation to avoid leakage ground current and to save power components while still sustaining comparatively high efficiency to those in (Kakigano, H., *et al*., 2012). Note that a full-bridge inverter operated with bipolar modulation can achieve only low frequency common-mode voltage ($V_{CM} = (V_{dc} - V_s) / 2$), resulting in low leakage ground current (Kakigano, H., *et al*., 2012).

To regulate the DC-bus voltage for the grid-connected inverter, the controls were adopted. When adopting these controls for the studied DC-distribution system, a heavy step-load change at the DC-bus side will cause high DC-bus voltage variation and fluctuation, and the system might run abnormally or drop into under or over voltage protection. Bulky DC-bus capacitors can be adopted to increase the hold-up time and suppress the fluctuation of the DC-bus voltage, but it will increase the size and cost of the system significantly. Additionally, even though there are approaches to achieving fast DC-bus voltage dynamics, the systems with load connected to the DC bus have not been studied yet.

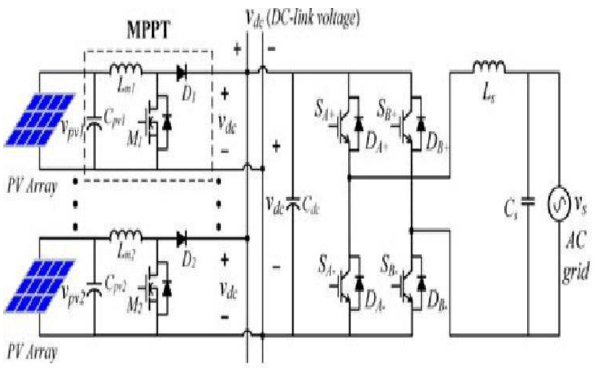

Fig. 2: Conventional two-stage PV inverter system boost-type MPPTs

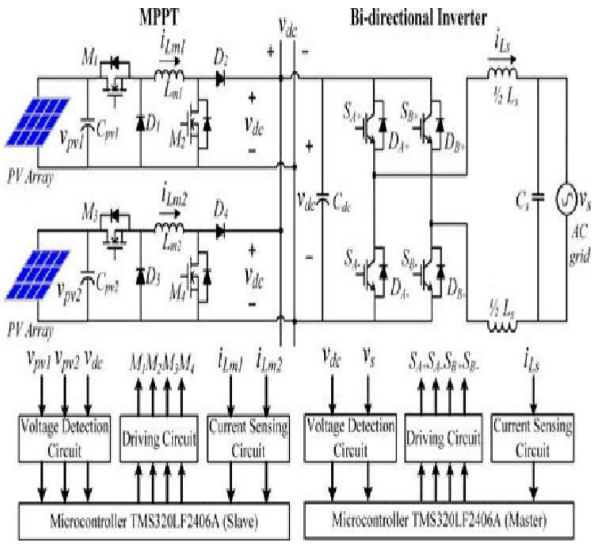

Fig. 3: Configuration of the studied PV inverter with system with the buck/boost MPPT

Operational Principle And Control Laws For The Inverter:

To achieve the desired performance of the proposed PV inverter system, its operational principle is first presented Fig. 3 shows a configuration of the proposed single-phase bidirectional inverter with two buck/boost MPPTs, which can fulfill either grid-connection mode or rectification mode with PFC.

The proposed bidirectional inverter is a full-bridge configuration, which can fulfill grid connection and rectification with PFC. The inverter senses DC-bus voltage V_{dc}, line voltage V_s, and inductor current $i_{L\ s}$, and uses the variable inductance, which is a function of inductor current, obtained with self-learning algorithm to determine the control for operating the inverter stably. When the output power from PV arrays is higher than load requirement, the DC-bus voltage increases; thus, the inverter is operated in grid-connection mode to inject the surplus power into AC grid. On the other hand, the inverter is operated in rectification mode with PFC to convert AC source to replenish the DC bus.

Simulation Results:

The circuit is modeled using the blocks of Simulink as shown in Fig. 4. Power measurement blocks are shown in Fig. 4a. The output voltage and current are PV Cell are measured and they are multiplied to get the power. The output voltage of solar cell is shown in Fig. 4b. The voltage is 12V. The gate voltage and the voltage across the switch of the converter are shown in Fig. 4c.The output voltage is compliment of the input voltage. The output voltage and the input voltage for the switch of the inverter are shown in Fig. 4d. The output voltage of the inverter is shown in Fig. 4e. The output is nearly sinusoidal due to the filter in the output side. The Current through the load is shown in Fig. 4f. The current is in phase with the voltage since the load is a pure resistive load. The output Power without Grid is shown in Fig. 4g.

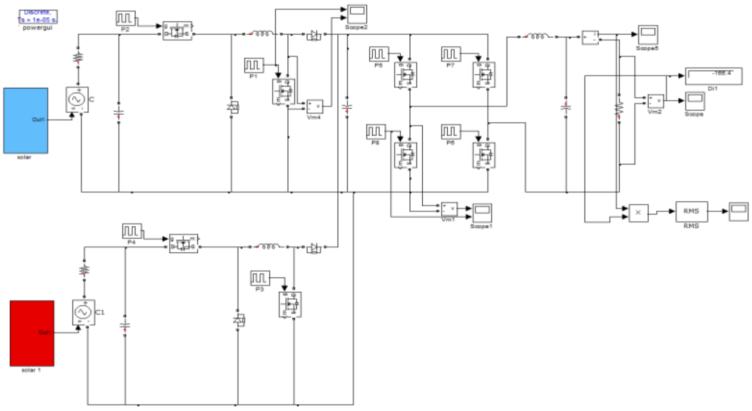

Fig. 4: Circuit without Grid Connection

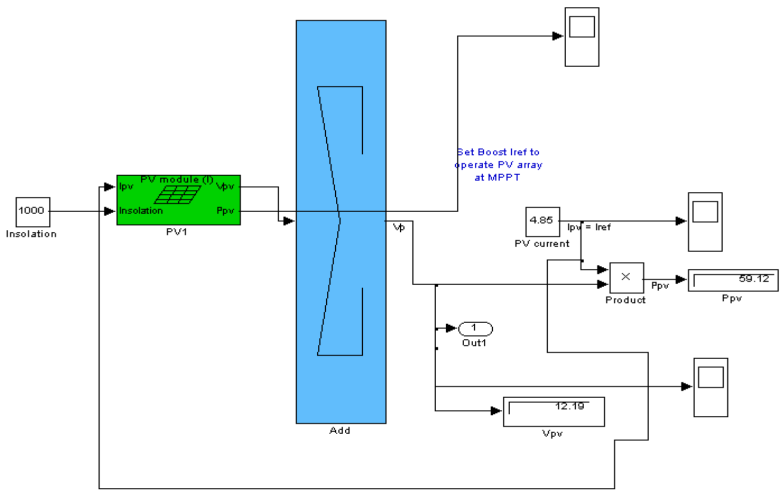

Fig. 4a: Power Measurement Blocks

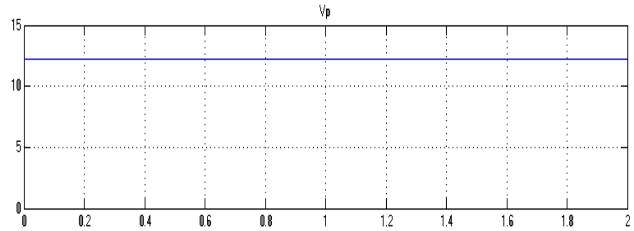

Fig. 4b: Output Voltage of Solar Cell

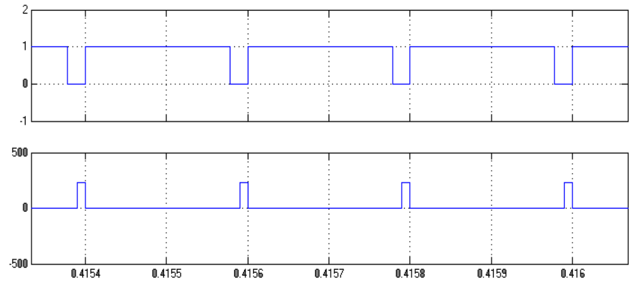

Fig. 4c: Switching Pulse and V_{ds} for Converter

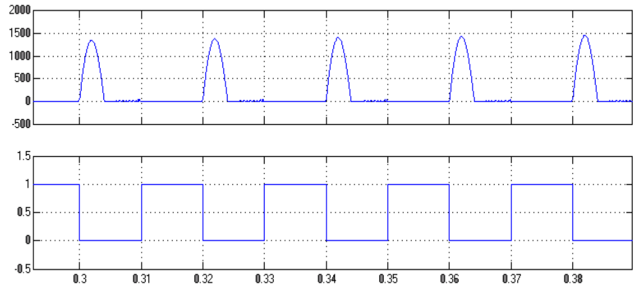

Fig. 4d: Switching Pulse and V_{ds} for Inverter

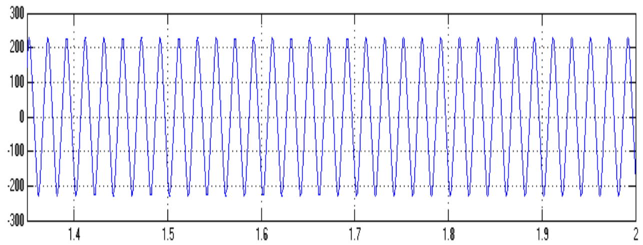

Fig. 4e: Output Voltage of Inverter

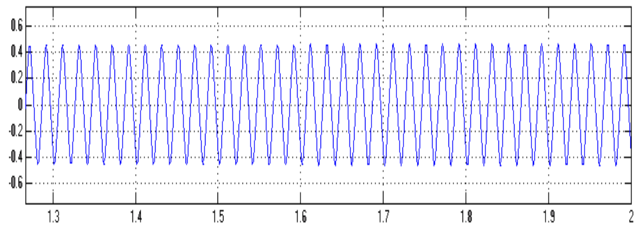

Fig. 4f: Current through the load

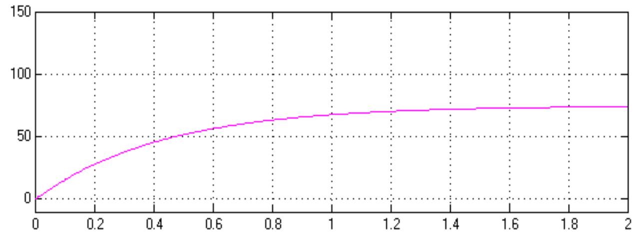

Fig. 4g: Output Power Without Grid Connection

The Simulation Circuit with grid connection is shown in Fig. 5. The load receives power from the grid and the solar system. The output voltage of solar cell is shown in Fig. 5a. The switching pulse and the output voltage of the MOSFET in the buck-boost converter is shown in Fig. 5b. The Switching pulse and the voltage across the switch of the inverter are shown in Fig. 5c. The voltage across the load is shown in Fig.5d. The Output Power with Grid is shown in Fig.5e. The variation of output power with load resistance is shown in Fig.5f. The output power with and without grid are given in Table- 1for different load conditions.

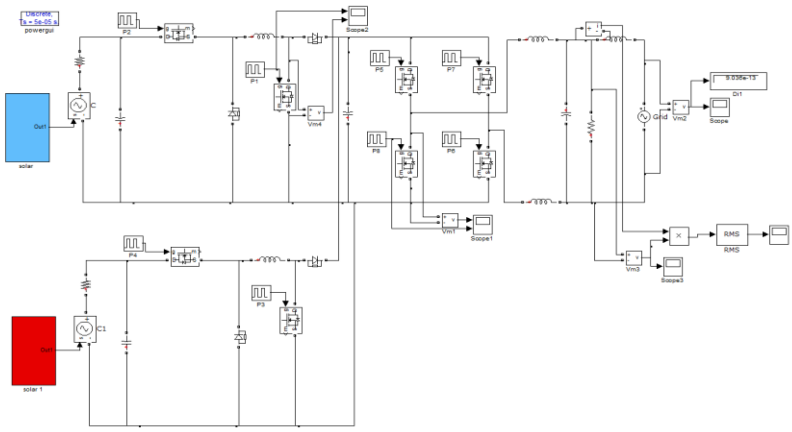

Fig. 5: Circuit With grid Connection

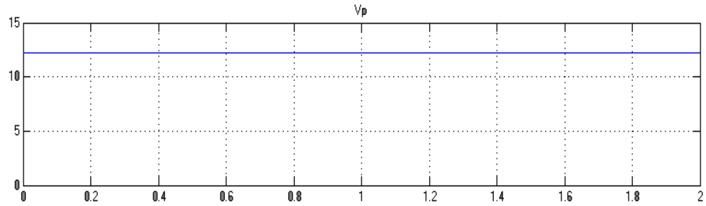

Fig. 5a: Output Voltage of Solar Cell

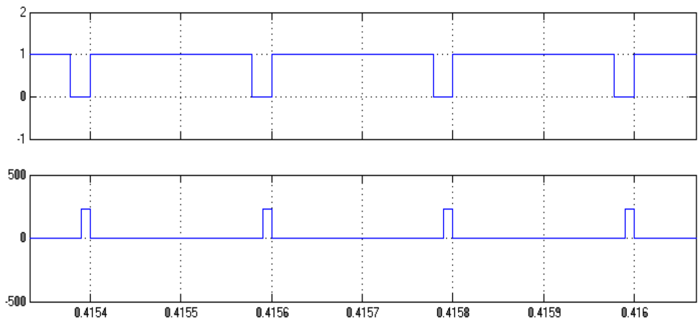

Fig. 5b: Switching Pulse and V_{ds} for Converter Switch

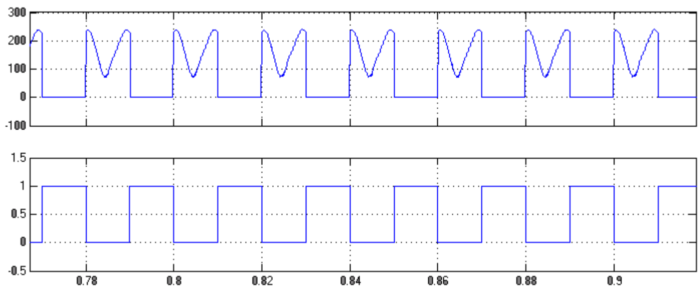

Fig. 5c: Switching pulse and V_{ds} for Inverter Switch

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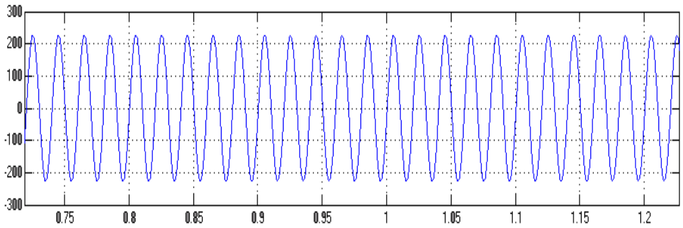

Fig. 5d: Voltage across the load

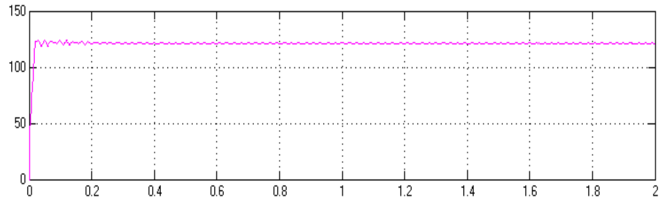

Fig. 5e: Output Power With Grid

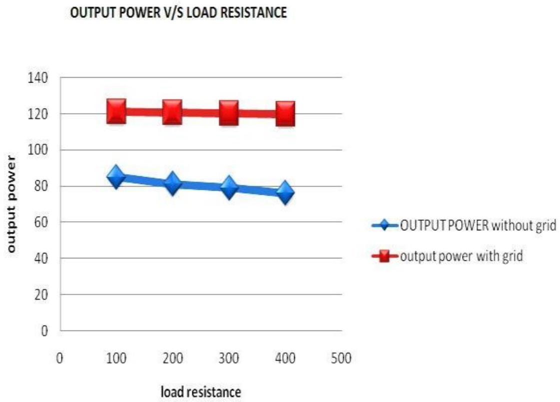

Fig. 5f: Output power with load resistance

Table 1: Variation of Output Power With Load

LOAD RESISTANCE (R) (Ohms)	OUTPUT POWER WITHOUT GRID (W)	OUTPUT POWER WITHGRID (W)
100	85	121
200	81	120.6
300	79	120.1
400	76	119.8

Conclusion:

Parallel connected buck-boost converter / Inverter based solar system is successfully modeled and simulated using Sim Power System. The results of isolated and grid connected systems are presented. The Power received by the load in grid connected system is higher than that of isolated system. The Circuit has the advantages like reduced hardware, buck-boost ability and improved output voltage waveform. The Simulation results are in line with the expectations. The disadvantage of this system is that it can be used for low power levels. The Scope of this work is the modeling and simulation of the parallel buck-boost converter and inverter based solar system. The analysis of hardware model will be implemented in future.

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