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Soft Computing Module of High Step-Up DC–DC Converter for PV Module using Simulink Environment

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ABSTRACT

Within the photovoltaic (PV) power-generation market, the PV module has shown obvious growth. However, a high voltage gain converter is essential for the module's grid connection through a dc–ac inverter. This paper proposes a converter that employs a floating active switch to isolate energy from the PV panel when the ac module is OFF; this particular design protects installers and users from electrical hazards. Without extreme duty ratios and the numerous turns-ratios of a coupled inductor, this converter achieves a high step-up voltage-conversion ratio; the leakage inductor energy of the coupled inductor is efficiently recycled to the load. These features explain the module's high-efficiency performance. The detailed operating principles and steady-state analyses of continuous, discontinuous, and boundary conduction modes are described. A 15V input voltage, 200V output voltage, and 100W output power prototype circuit of the proposed converter has been implemented; its maximum efficiency is up to 95.3% and full-load efficiency is 92.3%.

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1. INTRODUCTION

Photovoltaic (PV) power-generation systems are becoming increasingly important and prevalent in distribution generation systems. 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 total power generated from the PV array is sometimes decreased remarkably when only a few modules are partially covered by shadows, thereby decreasing inherent current generation, and preventing the generation current from attaining its maximum value on the array. To overcome this drawback, an ac module strategy has been proposed. In this system, a low-power dc–ac utility interactive inverter is individually mounted on PV module and operates so as to generate the maximum power from its corresponding PV module. [1]

The power capacity range of a single PV panel is about 100W to 300W, and the maximum power point (MPP) voltage range is from 15V to 40V, which will be the input voltage of the ac module; in cases with lower input voltage, it is difficult for the ac module to reach high efficiency. However, employing a high step-up dc–dc converter in the front of the inverter improves power-conversion efficiency and provides a stable dc link to the inverter. The micro inverter includes dc–dc boost converter, dc–ac inverter with control circuit as shown in Figure 1. The dc–dc converter requires large step-up conversion from the panel's low voltage to the voltage level of the application. The dc-input converter must boost the 48 V of the dc bus voltage to about 380–400 V. Generally speaking, the high step-up dc–dc converters for these applications have the following common features:

1) High step-up voltage gain. Generally, about a ten fold step-up gain is required.
2) High efficiency.
3) No isolation is required. [2]

There are two major concerns related to the efficiency of a high step-up dc–dc converter: large input current and high output voltage.

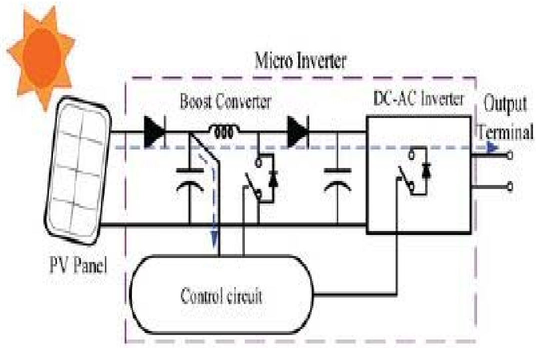

Figure 1. Block diagram of the whole system

Figure 1 shows the solar energy through the PV panel and micro inverter to the output terminal when the switches are OFF.[3] When installation of the ac module is taking place, this potential difference could pose hazards to both the worker and the facilities. A floating active switch is designed to isolate the dc current from the PV panel, for when the ac module is off-grid as well as in the non operating condition. This isolation ensures the operation of the internal components without any residential energy being transferred to the output or input terminals, which could be unsafe.

II. APPLICATIONS OF DC-DC HIGH STEP UP CONVERTER

2.1 DC-DC Converters

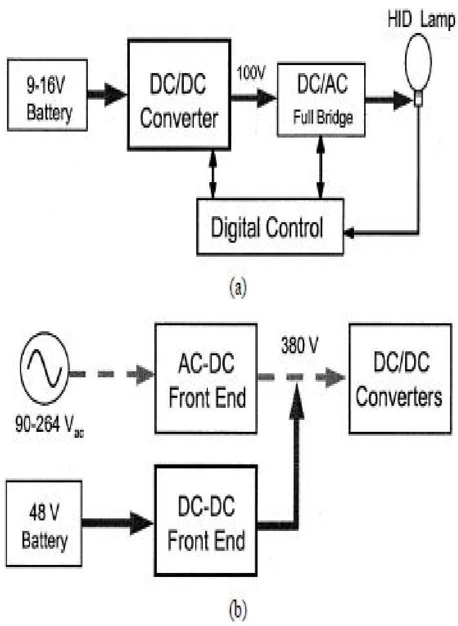

Figure 2. Applications of the dc-dc converter a) HID lamp ballast b) dual-input front –end converters.

As an example for a high intensity discharge (HID) lamp ballast used in automotive head lamps in which the start-up voltage is up to 400V,an another example diagram shows the the convergence of computer and telecommunications industries in that the dc-input converter must boost the 48V of the dc bus voltage to about 380-400V. [4] The main aim here is to attain the maximum output as much we can get from the dc input similarly in this paper from the pv panel we can the dc voltage as output before connecting the output to grid the voltage from the pv panel is not more sufficient since in between the pv panels and the grid interface we are going for micro inverter which consists of boost converter and inverter. The simulation result in this paper uses 15V input to the boost converter and attains 55.64V as the output voltage respectively. [5]

2.2. Proposed Converter to Attain High Efficiency

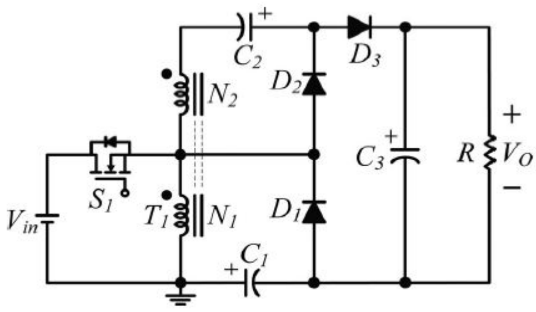

Figure 3. Proposed Converter

The proposed converter, shown in Figure 3, is 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, and capacitor*C*1 and diode *D*1 receive leakage inductor energy from *N*1. The secondary winding *N*2 of 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. The proposed converter has several features: 1) The connection of the two pairs of inductors, capacitor, and diode gives a large step-up voltage-conversion ratio;
2) The leakage-inductor energy of the coupled inductor can be recycled, thus increasing the efficiency and restraining the voltage stress across the active switch; and 3) the floating active switch efficiently isolates the PV panel energy during non operating conditions, which enhances safety. Before get into the connection procedure we should know about the characteristics and functions of the pv panels then only it is very easy to get the maximum power output from the PV panels.[6]

2.3 Demands Defined By the PV Modules

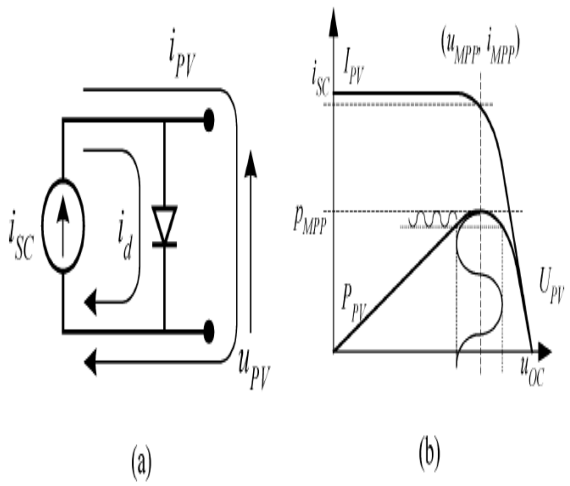

Figure 4. Model and Characteristics of PV Panel

Figure 4(a) model and characteristics of PV panel Electrical model with current and voltages (b) Electrical characteristic of the PV cell, exposed to a given amount of (sun) light at a given temperature. As indicated, ripple at the PV module's terminals results in a somewhat lower power generation, compared with the case where no ripple is present at the terminals. A model of a PV cell is sketched in Figure 4(a), and its electrical characteristic is illustrated in Figure 4(b).[3] The most common PV technologies nowadays are the mono crystalline and the multi crystalline-silicon modules, which are based on traditional, and expensive, microelectronic manufacturing processes . The MPP voltage range for these PV modules is normally defined in the range from 23 to 38 V at a power generation of approximate 160 W, and their open-circuit voltage is below 45 V. [7] However, new technologies like thin-layer silicon, amorphous-silicon, and Photo Electro Chemical (PEC) are in development. These types of PV modules can be made arbitrarily large by an inexpensive "roll-on–roll-off" process. This means that new modules with only one cell may see the light in the future. The voltage range for these cells/modules is located around 0.5 1.0 V at several hundred amperes per square meter cell . The inverters must guarantee that the PV module(s) is operated at the MPP, which is the operating condition where the most energy is captured. This is accomplished with an MPP tracker (MPPT). It also involves the ripple at the terminals of the PV module(s) being sufficiently small, in order to operate around the MPP without too much fluctuation.[8]

3 SIMULATION RESULTS

3.1 Simulation of Boost Converter

The simulation results are shown in the figure5, the simulation diagram and the simulation output results separately shown for the boost converter as well as inverter .The parameter values is shown below
Vs=15 V, $L=1e^{-3}$ H, $C_1 = C_2 = 47e^{-6}$ F, $C_3 = 220e^{-6}$ F , R_{load} = 400 ohms, V_o =56 V

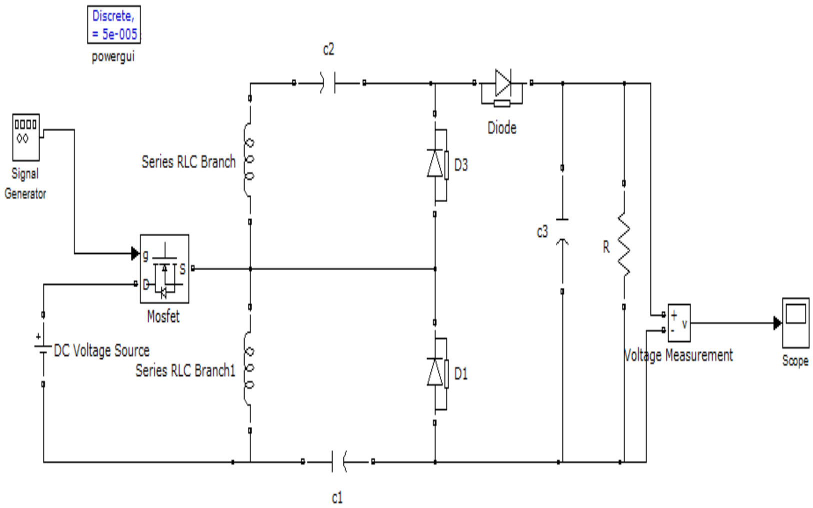

Figure 5. Simulation of Boost Converter using Matlab/Simulink

Figure 5 shows the simulation of Boost Converter using Matlab Simulink, it consists of the DC voltage source input, MOSFET switch.2 inductors,3 diodes,3 capacitors and r load the voltage measurement connected with scope to verify the simulation output results and with the signal generator to give the pulses for the circuit and finally the power GUI is connected. The main concern of this project is to design and construct a DC to DC converter which is one of the main module in the solar PV system that shown in Figure. The main idea of the DC to DC converter is based on boost type. The purpose of the project is to develop DC to DC converter (boost type) that converts the unregulated DC input to a controlled DC output with desired voltage level. The main objectives of this project are designing and constructing a DC to DC converter (boost type) circuit practically with input voltage, 15 V and the output voltage, 56 V. The output voltage waveform is shown in figure.6. [9]

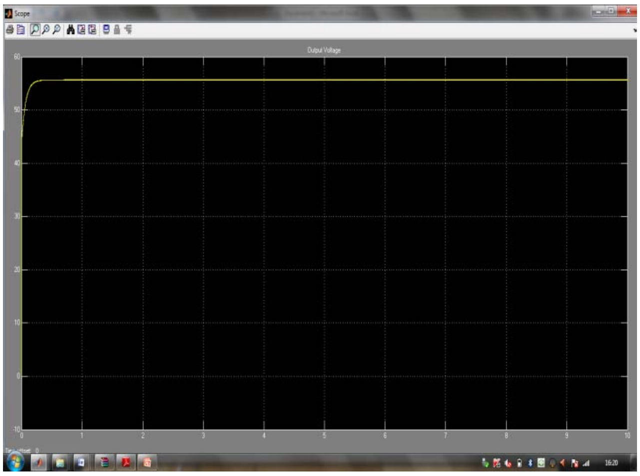

Figure 6. Output Voltage waveform of Boost Converter

3.2 Simulation of Single Phase Full Brige Inverter

Figure 7 shows the simulation of Single phase full bridge Inverter using Matlab simulink, When the S_1 and S_2 conducts the load voltage is V_s where as the S_3 and S_4 conducts the load voltage is $-V_s$. Frequency of the output voltage can be controlled by varying the periodic time T. The circuit connected with the RL load, in the circuit there are 4 IGBTs.

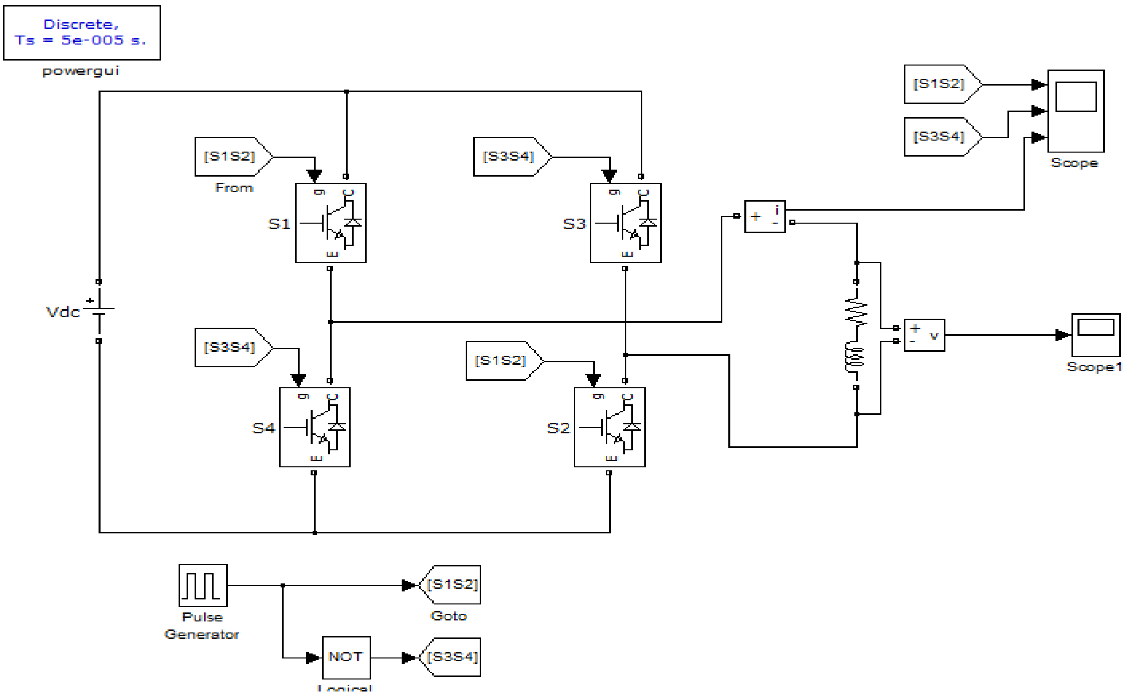

Figure 7. Simulation of Single Phase Full Bridge Inverter using Matlab/Simulink

The basic working principle of the inverter is to converts the dc power into ac power at desired output voltage and frequency. The inverters are mainly classified into two types 1) voltage source inverters 2) current source inverters. In the above circuit it uses voltage source inverters. The voltage source inverters is the one in which the dc source has small or negligible impedance. In other words, voltage source inverters has stiff dc voltage source at its input terminals. The output voltage and output current waveforms are shown in Figure 8 and Figure 9 [10].

The parameter values is shown below:

V_{dc} = 56 V

Pulse generator:
Amplitude = 1V
Period (secs) = 0.02 sec
Pulse width(% of period) = 50%
Phase delay(secs)=0
Load:
R load =1 ohms
$L_{load} = 10e^{-3}$ H

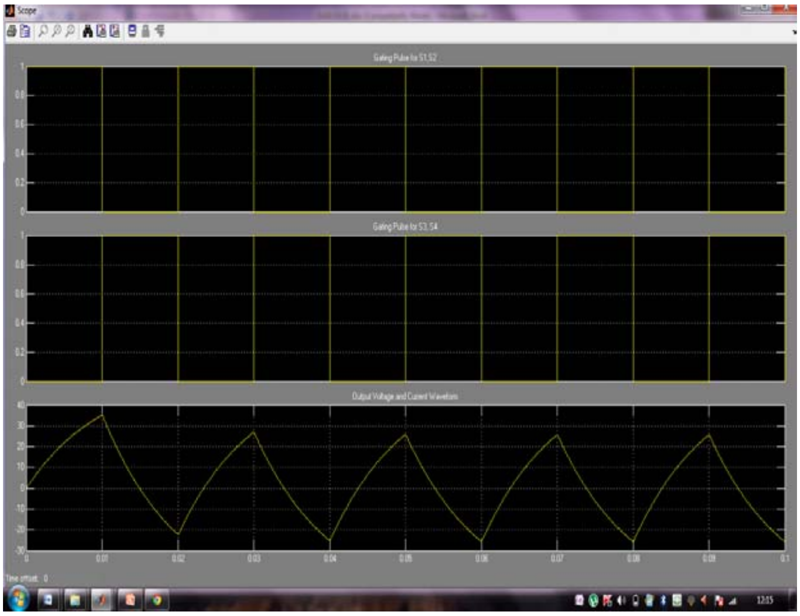

Figure 8. Pulse voltage and Output Current waveform for Single Phase Full Bridge Inverter

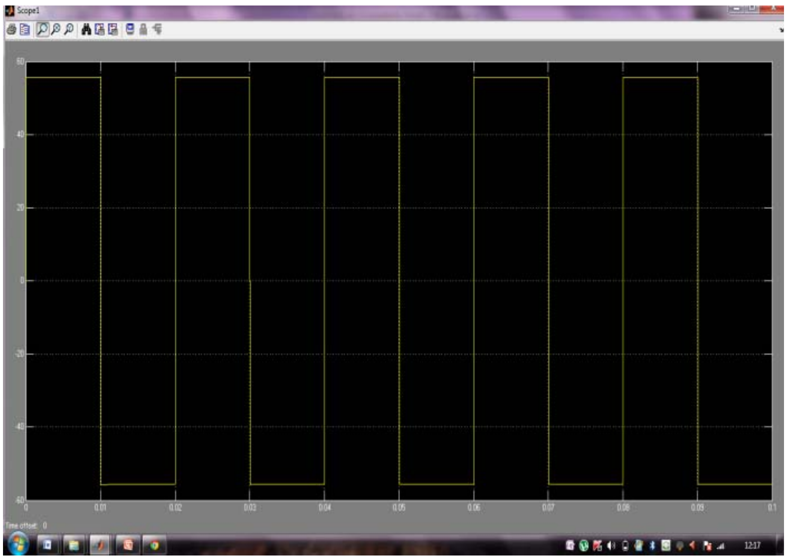

Figure 9. Output Voltage waveform for Single Phase Full Bridge Inverter

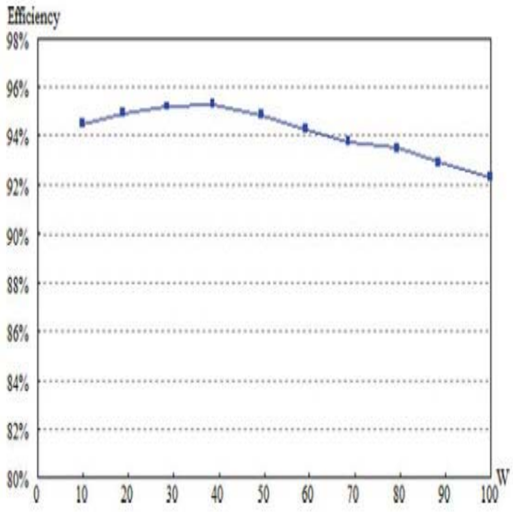

Figure 10. Maximum Efficiency of Proposed Converter

Figure 10 shows that the maximum efficiency of 95.3% occurred at 40% of full load; and the full-load efficiency is maintained at 92.3%. The efficiency variation is about 3%, and the flat efficiency curve is able to yield higher energy from the PV module during periods when sunlight is fading. The residential voltage discharge time of the proposed converter is 480 milliseconds, which prevents any potential electrical injuries to humans. [11-12]

4. CONCLUSION

Since the energy of the coupled inductor's leakage inductor has been recycled, the voltage stress across the active switch *S*1 is constrained, which means low ON-state resistance *R*DS (ON) can be selected. Thus, improvements to the efficiency of the proposed converter have been achieved. The switching signal action is performed well by the floating switch during system operation; on the other hand, the residential energy is effectively eliminated during the non operating condition, which improves safety to system technicians. From the prototype converter, the turns ratio n = 5 and the duty ratio D is 55%; thus, without extreme duty ratios and turns ratios, the proposed converter achieves high step-up voltage gain, of up to 13 times the level of input voltage. The experimental results show that the maximum efficiency of 95.3% is measured at half load, and a small efficiency variation will harvest more energy from the PV module during fading sunlight.

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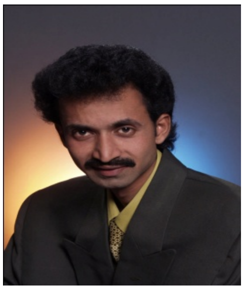

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