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A Single-Stage Single-Phase Transformer-Less Doubly Grounded Grid-Connected PV Interface

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ABSTRACT: In this paper we developthere is a strong trend in the photovoltaic inverter technology to use transformer-less topologies in order to acquire higher efficiencies combining with very low ground leakage current.The DC/AC inverters are used in grid connected PV energy production systems as the power processing interface between the PV energy source and the electric gridThe energy injected into the electric grid by the PV installation depends on theamount of power extracted from the PV power source and the efficient processing of this power by the DC/AC inverter. This paper presents a new methodology for optimal design of transformer-less photovoltaic (PV) inverters targeting a cost effective deployment of grid- connected PV systems.The proposed configuration cannot only boost the usually low photovoltaic (PV) array voltage, but can also convert the solar dc power into high quality ac power for feeding into the grid. Simulation results confirm the performance of proposed system.

KEYWORDS: Photovoltaic, Transformer-less, Grid connected, Voltage boost, Inverter, efficiency, Resonant converter

I.INTRODUCTION

Renewable energy sources become more and more important contribution to the total energy consumed in the world. Because of their independence from limited fossil and nuclear fuels and their low impact on the environment they will become the only crisis-proof and reliable energy supply within the next decades. Today the contribution from photovoltaic (PV) energy compared to the other renewable energy sources is very low, but due to decreasing system prices the market for PV systems is one of the most stable and fastest growing in the world. If this trend continues, PV will be one of the most important energy sources in the future. To maintain the further spread of PV systems it is important to decrease the cost and at the same time improve the efficiency and reliability of these systems.

Increasing interest in sustainable energy production through PV, however, demands attention on various issues such as maximum power point tracking, personal safety, grid integration, stability and reliability, power quality, power electronic interface of PV with the grid, and operation under various environmental conditions. The grounding of a PV system, referred to as “system earthing” needs special consideration due to safety reasons and to minimize the effects of lighting and other surges. It refers to an intentional connection to earth of one of the current-carrying conductors in the PV system. The ungrounded PV inverters have to fulfill a number of additional requirements.

II.PV CELL POWER GENERATION TECHNIQUES

In order for a material to convert light into electrical energy, it must satisfy twoconditions. First, it needs to be able to absorb incident photons through the promotion of electrons to higher energy levels. Second, it must contain an internal electric field that accelerates the promoted electrons in a particular direction, resulting in an electrical current From the most basic point of view, a photovoltaic cell can be thought of as any devicewhen exposed to light that causes current to flow in an electrical circuit with a given load resistance (e.g. wires plus a light bulb). An example electrical circuit is shown in Figure 1. The voltage drop across the front and back contact and the current in the circuit can be measured with a voltmeter and ammeter respectively. As would be expected, the magnitude of the electrical current depends on the intensity of the incoming light. But in addition, the current also depends on the load resistance of the circuit.

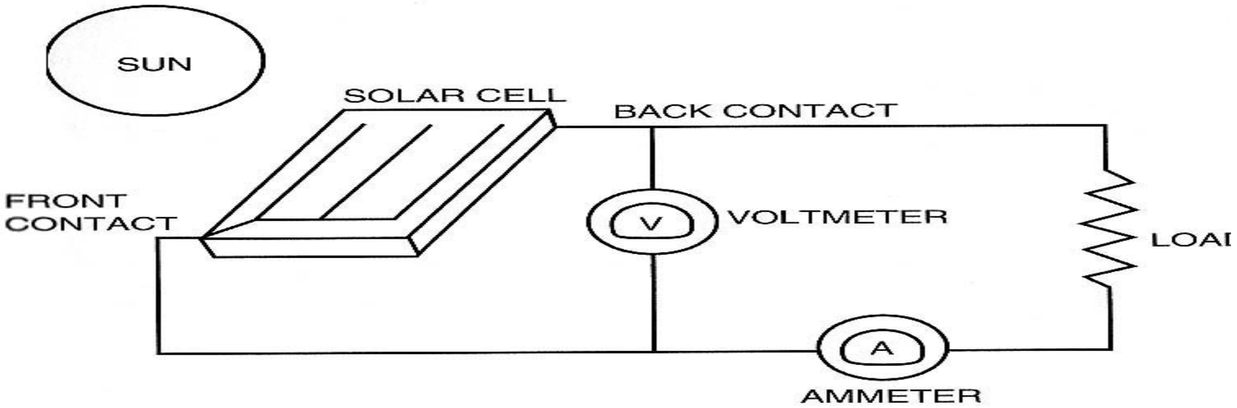

Fig.PV cell power generation techniques

In this scheme, In this, a new transformer less doubly grounded grid connected PV interfacing theory is developed. The developed system consist transformer less doubly grounded grid connected splited PV cells. Two PV cell of same rating are used for each positive and negative half cycle. In this system unbalanced power is generated due to non- uniform solar insolation then the current injected into the grid may not be symmetrical (highly distorted with high THD), and may have a dc component that does not allowed by standard.

III.CIRCUIT CONFIGURATION WORKING

Unlike some other topologies, which use two PV strings, the circuit of Fig. employs only one PV string as the energy source. In addition, the negative conductor of the PV source always remains grounded, thereby providing double grounding. The circuit uses 5 switches (S1 through S5) and three diodes (D1 through D3). It uses only one buck-boost inductor L. Inductor Lf and capacitor Cf form the low-pass filter, which allow only the 50-Hz component of the inverter output current to enter into the grid.

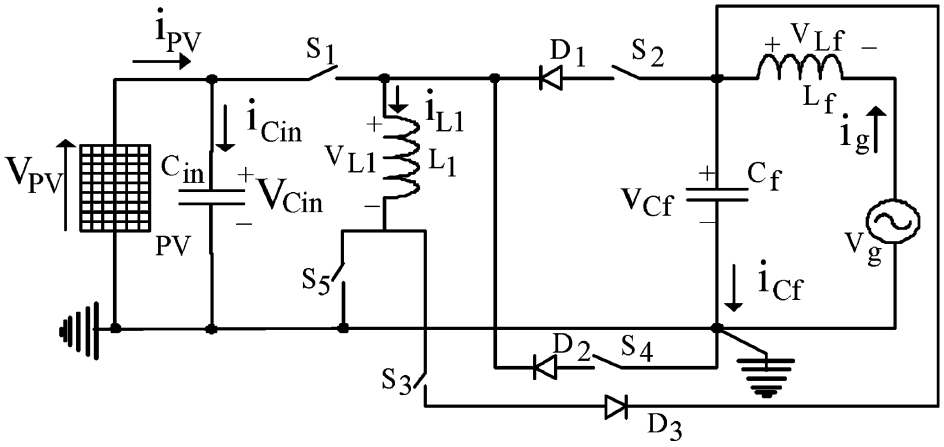

Fig.circuit configuration

VI. WORKING

The various modes in which this circuit operates are shown in Fig. 4.1 to 4.6.

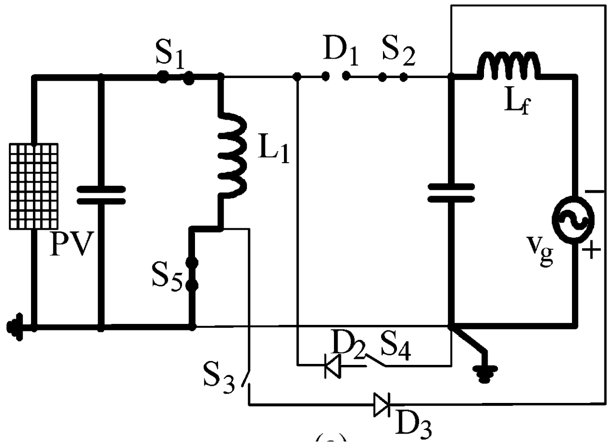

Figure 4.1: Mode I operation

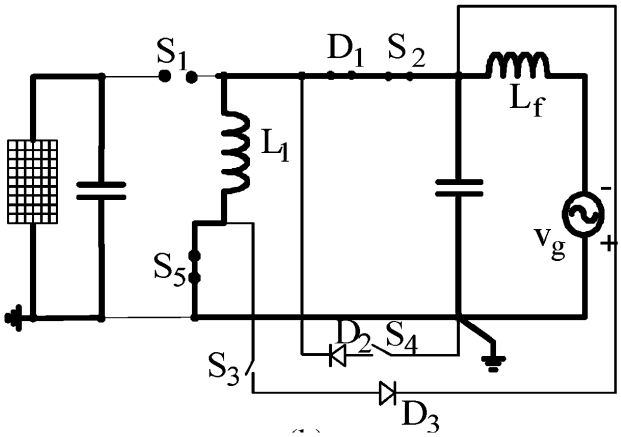

Figure 4.2: Mode II operation

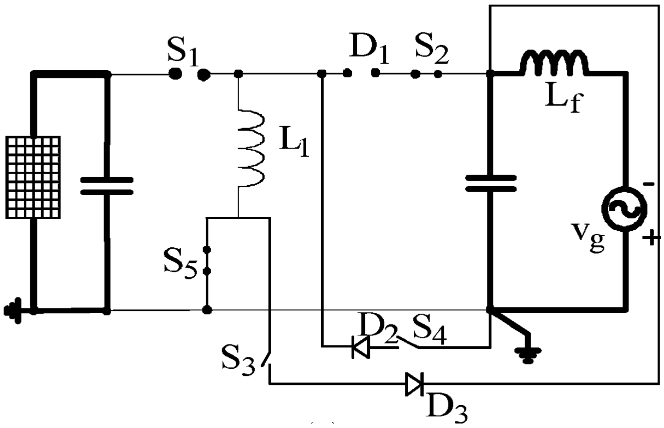

Figure 4.3: Mode III operation

During the negative half cycle of the ac grid voltage, switches S1, S2, and S5 along with the diode D1 form a buck-boost converter. The switches S3 and S4 always remain OFF. Fig. 4.1-4.3 shows modes I through III, respectively, in which the converter operates during the negative half cycle. In the negative half cycle, switches S2 and S5 are always kept ON, while the switch S1 is triggered with the sine-triangle pulse-width modulation (PWM) technique. When switch S1 is ON, energy is stored in inductor L1 [mode I, Fig. 4.1]. When S1 turns OFF, the stored energy is transferred to the grid [mode II, Fig. 4.2]

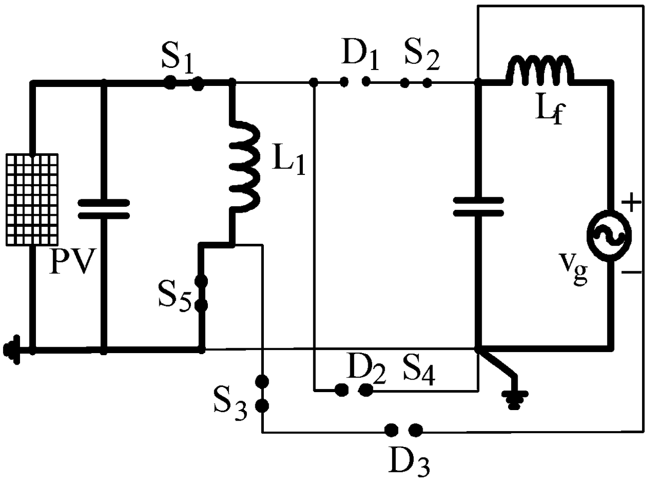

Figure 4.4: Mode IV operation

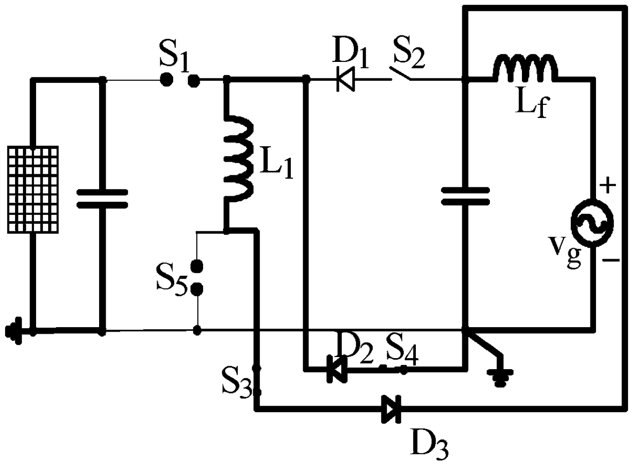

Figure 4.5: Mode V operation

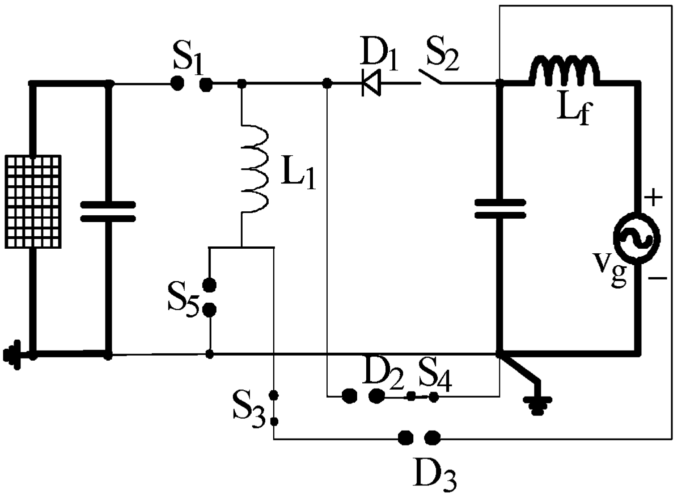

Figure 4.6: Mode VI operation

Fig. 4.1 to 4.6 Circuit diagrams for various operating modes of the proposed configuration. Fig. 4.1 to 4.3 Operation during negative half cycle: modes I to III. Fig. 4.4to 4.6 Operation during positive half cycle: modes IVV. Bold lines show the active current paths. 4.3 And 4.6 Operation after all the energy stored in the buck-boost inductor is transferred to the grid.

During the positive half of the ac cycle, switches S1, S3, S5, along with diodes D2 and D3, form a buck-boost converter. Switch S2 always remains OFF. The buck-boost converter is now operated by controlling the switches S1 and S5 using the signal derived from the sine-triangle PWM. Fig. 4.4 to 4.6 shows modes IV through VI, respectively, in which the converter operates during the positive half cycle. During these modes, switches S3 and S4 are always ON. When switches S1 and S5 are ON, energy is stored in inductor L1 [mode IV, Fig. 4.5]. When S1 and S5 turn OFF, the stored energy is transferred to the grid [mode IV, Fig. 4.5].

The amplitude of the reference sinusoidal waveform used for the sine-triangle PWM (mentioned before) is controlled to track the maximum power point (MPP). The controller implements the perturb and observe (PO) method, and identities whether to increase or decrease the amplitude of the reference waveform to achieve MPP. It then increases/decreases the amplitude of the sinusoidal template, which is derived from the grid voltage.

Unlike the operating modes shown in Fig. 4.1 to 4.6, where the operation in both the half cycles is based on the buck-boost principle, it is possible to operate the proposed configuration even with asymmetric operating principle. During the negative half cycle, the operating modes are similar to those shown in Fig. 4.1 and 4.2, i.e., employing the buck-boost principle. But in the positive half cycle, instead of operating the configuration as a buck-boost converter, it is operated as a buck converter for that period of the half cycle where VPV > Vg and as a boost converter for the remaining period. This feature of operating the circuit distinctly as a buck and a boost converter for the positive half cycle can reduce stress on the components. This is a desirable yet unacceptable proposition on account of the asymmetry it introduces between the positive and negative half cycles because the topology does not support distinct buck and boost operations during the negative half cycle.

V. DESIGN OF THE COMPONENT, RESULT AND DISCUSSION

The design of various components used in the proposed inverter is very crucial for generating a sinusoidal grid current, which is in phase with the grid voltage. The design also decides the discontinuous conduction mode (DCM) or CCM operation. The analysis leading to the design of the various components for the DCM operation is presented next.

$$P_{\mathrm{PV\_max}} = V_{\mathrm{PV\_mpp\_max}} I_{\mathrm{PV\_mpp\_max}}$$

$$T_s = T_{\mathrm{ON}} + T_{\mathrm{OFF}} = L_{\mathrm{crit}} I_{\mathrm{peak}} \left[\frac{1}{V_{gm}} + \frac{1}{V_{\mathrm{PV\_mpp\_max}}} \right]$$

5.1Design of Inductor L1:-

$$L_{\mathrm{crit}} = \frac{0.25 T_s}{V_{\mathrm{PV\_mpp\_max}} I_{\mathrm{PV\_mpp\_max}}} \left[\frac{1}{V_{gm}} + \frac{1}{V_{\mathrm{PV\_mpp\_max}}} \right]^{-2}$$

5.2 Design of Filter Capacitor Cf:-

$$C_f = \frac{T_s^2}{4 L_{\mathrm{crit}} V_{gm}\, \Delta V} \left[\frac{1}{V_{gm}} + \frac{1}{V_{\mathrm{PV\_mpp\_max}}} \right]^{-2}$$

5.3 Design of Filter Inductor Lf:-

$$L_f = \frac{1}{\omega^2 C_f} = \frac{1}{(2\pi f_c)^2 C_f}$$

5.4 Design of Decoupling Capacitor Cin:-

$$C_{\mathrm{in}} = \frac{P_{\mathrm{PV}}}{4\pi f V_{\mathrm{PV\_mpp\_max}}\, \Delta V_{\mathrm{PV}}}$$

RESULTS:-

EXPERIMENTAL RESULTS

The experimental setup comprises three parallel-connected PV strings, each with six series-connected PV modules. The specifications of the PV module (output power, current and voltage at MPP, short-circuit current, and open-circuit voltage) at an insolation level of 1 kW/m2 and 25 C temperature are Pmax = 38 W, Impp = 2.29 A, Vmpp = 16.6 V, ISC = 2.55 A, and VOC = 21.5 V. Partial shading, using the transparent gelatin papers, is applied artificially by shading the two modules in the first PV string and three modules in the second PV string.

TOPOLOGY RESULT

The operating voltage, current, and power at this point are 92 V,2.1 A, and 193.2 W, respectively. The grid voltage is adjusted (using a variac) to about 100 V with a peak of 141 V. The power supplied to the grid is 168 W.

VI.CONCLUSION

The double grounding problem is solved by Single-phase, single-stage, transformer-less grid-connected PV interfaces. Most of the existing transformer-less topologiesachieves double grounding by using a split PV source. Such topologies, when operating under non-uniform conditions, face problems such as in efficient array utilization

and dc current injection into the grid. Even inverters sourced by a single PV string, but which operate on different principles in the two halves of the ac cycle, inject a significant dc component into the grid current. A compact PVgrid interface, which operates with a single PV source and has the capability of double grounding has been proposed,analyzed, designed, and developed. It is observed that the maximum voltage that can develop on the ungrounded conductor is limited to the PV array output voltage, and hence, the topology exhibits a good safety feature. The topology uses only one PV source, a single buck-boost inductor, and a decoupling capacitor that are shared in both the half cycles. This eliminates the problems arising out of asymmetrical operation and mismatch in the

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