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Integration of Solar Energy, Transformerless Step-Up Converter and H8 Inverter to Reduce Leakage Currents for Grid Connected Applications

[1]Indhu C N [2]Mr. P. Sundaramoorthy
[1]Student [2]Assitant Professor
[1,2]Department of Electronics and Electrical Engineering
[1,2]Nehru College of Engineering and Research Centre Thrissur, Kerala

Abstract

Solar energy is a promising alternative energy source for a sustainable pollution-free future. But certain factors such as solar irradiation, lack of sunlight during night hours etc. degrade or diminish the scope of solar power. To address with this problem MPPT technique is used here. Due to the requirements of high efficiency, reliability, power density and low cost and reduced size, transformerless PV inverters can be utilized in a grid-connected solar energy system. But the presence of transformerless system will lead to leakage currents, which is not at all acceptable in the case of grid connected applications. So to reduce leakage currents the modified version of H6 inverters ie an H8 inverter is used in this paper. In order to synchronize H8 inverter and grid PI controllers are used. This paper aims to utilize solar energy and reduce the leakage currents produced by transformerless inverter for grid connected applications. This is done by the integration of solar, transformerless step-up converter and h8 inverter. The concept is to utilize renewable sources effectively which helps in reducing the grid demand.
Keyword- Maximum Power Point Tracking (MPPT), Photovoltaic (PV)

I. Introduction

Nowadays due to industrial development and population growth, global energy demand is increasing in an alarming rate. Owing to the depletion of fossil fuels, distributed generation, and local use, the photovoltaic (PV) power generation system has become the most promising renewable energy source. But certain factors such as solar irradiation, unavailability of sunlight during night hours etc. diminishes the scope of utilizing sunlight as a renewable source. In order to deal with this problem, MPPT (Maximum Power Point Tracking) technique is introduced, which is nothing but an algorithm to extract the maximum power from the solar panels. The recent advancements in power electronics and solar technology offers convenient access to solar energy. Nowadays government is also providing offers and tariffs, which promotes the grid connected PV power systems. With the help of grid connected kind of PV system the energy crisis can be suppressed up to a certain level. Since the demand for electrical power is rapidly increasing these days, any suitable method which can contribute to reduce this problem is acceptable. A power conditioning unit (PCU) along with a low-frequency transformer on the AC side or a high-frequency transformer on the DC side is generally required To integrate the PV source with the grid. By using transformers we can step up the input voltage. Also it provides galvanic isolation and avoids DC current injection into the grid [5]. But these transformers are bulky, heavy, and expensive and reduce the efficiency of the overall system. Also, using high-frequency transformer, the PV systems usually consist of several power stages, which reduce the system efficiency and increase the system complexity and cost. To deal with this issues, transformerless PV topologies are introduced which can reach their efficiencies up to 97%-98%. However, no isolation between PV sources and the grid can cause numerous safety issues, corrosion in underground equipment, malfunction of sensors and distribution transformer saturation under the effects of leakage current and DC current injection [6].

The generation of leakage currents is the major problem faced by a grid connected PV system. The leakage current arises because of variations in AC common-mode voltage on stray capacitor between PV panels and ground; this stray capacitance can have a typical value of 60–110 nF/kW for modules with crystalline silicon cells (monocrystalline, polycrystalline); and 100-160 nF for modules with thin-film cells [16]. The variations of the stray capacitor voltage causes the leakage current. The leakage current should be strictly limited, since it can lead to safety issues, increased the total harmonic distortion (THD) of the injected currents, and also electromagnetic interference (EMI) problems; all of which, may violate the grid standards. According to the VDE 0126- 01-01 standard, the RMS value of the leakage current has to be limited below 300 mA [17, 18]. In case of the traditional full-bridge (FB) inverter (also named as B6- type inverter), the leakage current is more than the regulated limit. There are two approaches to eliminate or reduce the leakage current issue: one is to block the leakage current and the other is to reduce the common-mode voltage variations. The first approach is achieved by employing additional switches, which can effectively separate the PV side from the grid side whenever a zero-switching state is produced. The second approach is to keep the common-mode voltage constant over the time or reduce its variations.

II. BLOCK DIAGRAM OF THE PROPOSED SYSTEM

The block diagram of the proposed system is shown in the figure 1. It consists of PV panels, MPPT along with boost converter, H8 inverter, and electrical grid. Electrical power is generated by using sunlight by means of sunlight. This is done with the help of photovoltaic panels. A standalone PV panel will not be able to generate the required power; in order to track or extract maximum power by using PV panels an MPPT algorithm is used. There are many MPPT algorithms available such as perturb & observe, incremental conductance, short circuit current, open circuit voltage, ripple correlation technique etc. In this paper incremental conductance is the method utilized. The voltage obtained from the PV panels with the help of MPPT is the fed to a step up converter to boost the voltage level. Boost converter is used here because of its simple structure and ease of control. It is obvious that the boosted voltage is purely dc voltage, which we need to convert to ac voltage since we need to inject the voltage to the electrical grid. H8 inverter is used here because of its ability to suppress the leakage currents. When compared with H6 inverter, H8 shows improved and better results in terms of leakage current. H8 inverter is composed of six switches, MOSFET switches are used because of its voltage controllability. After conversion from dc to ac by using H8 inverter the power is injected to the electrical grid. Certain parameters should match between the grid power and inverter output power, which will be discussed later.

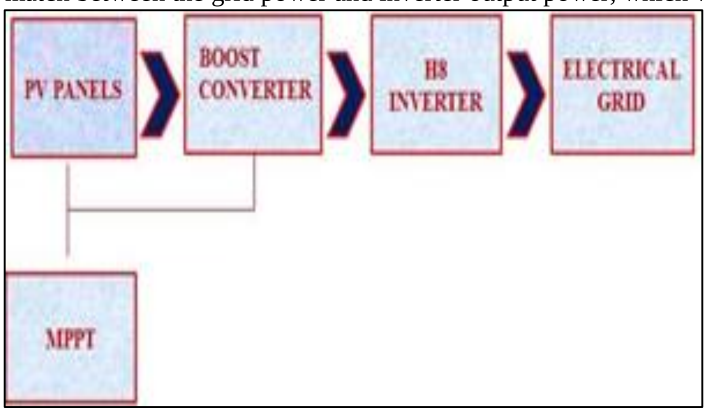

Fig. 1: Block diagram of the proposed system

III. CIRCUIT DIAGRAM AND WORKING

In transformerless topologies, PV inverter is directly connected to the grid, a DC/DC converter is required for boosting the low voltage of PV panels and extract the maximum power from the PV source. The MPPT algorithm generates and adjusts the duty cycle of the boost converter based on solar irradiation and temperature to maintain constant voltage at the input of the PV inverter. The DC/AC inverter generates suitable AC voltage to synchronize solar system with the grid through the filter to meet the grid requirements. These inverters are required to meet the requirements of interconnection as well as power quality imposed by the grid. Therefore, continuous monitoring of grid parameters such as voltage, current and phase angle are essential. A novel sinusoidal pulse width modulation (SPWM) method is used for the proposed topology that is able to reduce the common-mode behaviour without compromising the harmonic distortion of the output current. Both B6-type and H8 inverters are 2-level 3-phase inverters. A two-level three- phase inverter has eight possible inverter switching states whether the modulation method is sinusoidal PWM or space- vector modulation (SVM). SPWM method is used in this paper.

The proposed three-phase PV topology with the proposed modulation strategy, works as explained in the following:

1) During odd active switching states V1, V3, and V5, S7 and S8 are on to generate the desired output voltage and the corresponding common-mode voltage becomes Vdc/3
2) During even active switching states V2, V4, and V6, S7 and S8 are on to generate the desired output voltage and the corresponding common-mode voltage becomes 2Vdc/3.
3) During zero switching state V7, all the upper switches S_1, S_3, and S_5 are turned on. At this moment, S_7 is turned off to disconnect the PV array from the grid and the corresponding common-mode voltage becomes Vdc/2. Therefore, there is no path to allow the leakage current to flow.
4) During the zero switching state V0, all the lower switches S_4, S_6, and S_2 are turned on. At this moment, S_8 is turned off to disconnect PV from the grid and the corresponding common- mode voltage becomes Vdc/2. Therefore, leakage current finds no path to flow.

The switches S_7 and S_8 allow to isolate PV array from the grid during zero voltage states. As a consequence, the leakage current does not flow through the stray capacitor during the zero voltage states, which results in leakage current reduction.

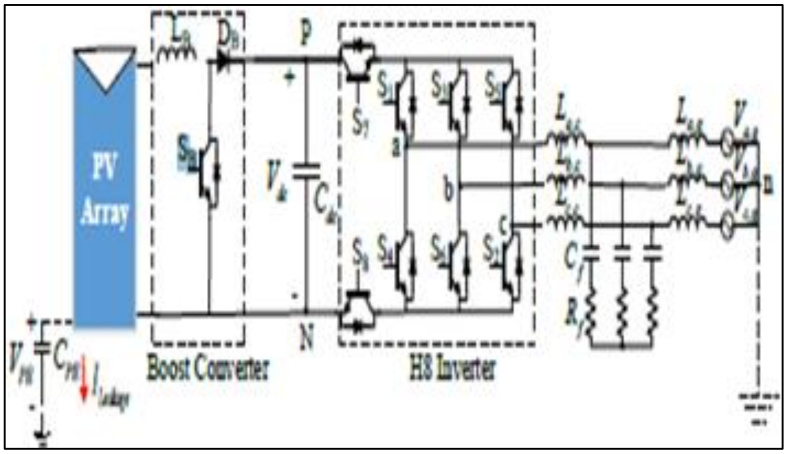

Fig. 2 (a): Circuit diagram of the proposed system

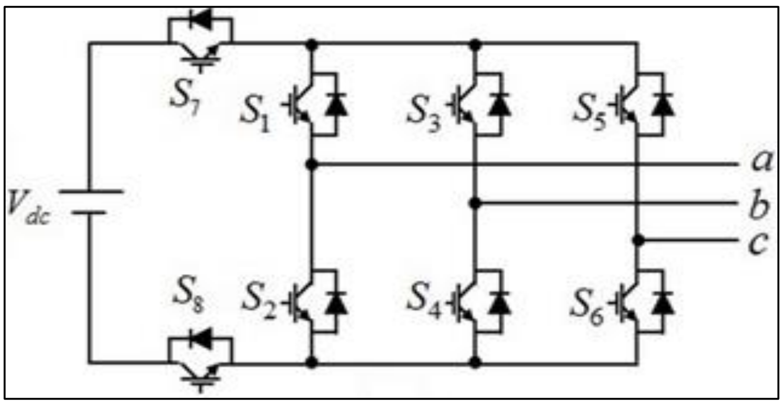

Fig. 2 (b): Circuit diagram of the H8 inverter

IV. SIMULATION DIAGRAM AND RESULTS

The simulation diagram of the proposed grid tied H8 inverter is shown in Fig.3. The simulation is carried out in Matlab Simulink software. In the PV panel section 24 V is generated, for that four arrays are used. Each array consists of twelve cells and each cell generates 0.5V. Hence total 24 V is obtained from the PV panels. Incremental conductance is the algorithm here used in the MPPT, which helps in extracting maximum power from the PV panels. Next comes the step-up converter. It consists of a diode, inductor and MOSFET switch. A constant duty cycle cannot be applied here; since it's a closed loop system it's quite difficult to maintain constant duty cycle. A varying duty cycle is suitable here. After boosting the voltage level, H8 inverter converts it in to AC voltage. In the H8 inverter configuration, eight MOSFET switches are used. For the first switch there is no delay, from there for each switch the switching delay is added by 0.003 sec.

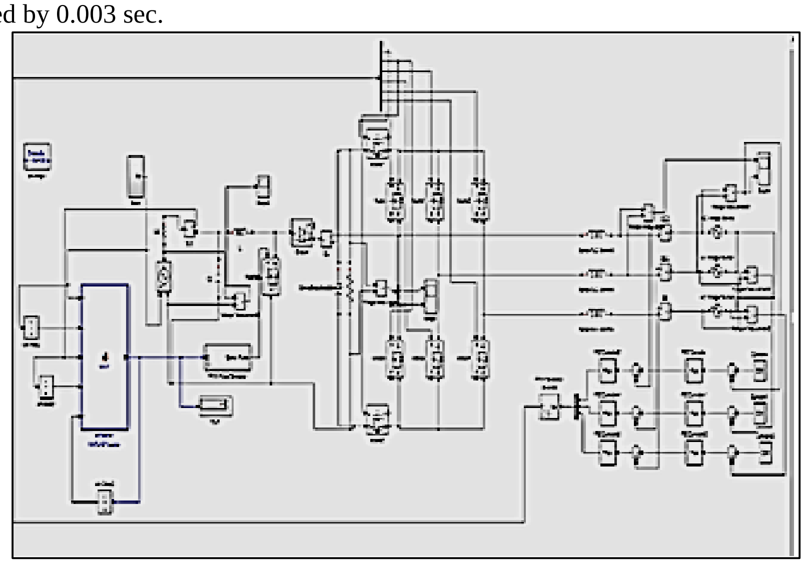

Fig. 3: Simulation diagram of the proposed system

The Fig.3 below shows the output waveform from the solar panel. The amplitude of the voltage obtained is 24 V. The output from the boost converter is shown in Fig. 5.It starts from origin and increases rapidly and settles about 60V. Even though the duty ratio cannot be maintained at a constant value, it's made between 0.5-0.6 for getting the expected waveform. Fig. 6 shows the voltage waveform between two phases. This is the voltage which will be injecting to the grid. In order to synchronize the phase, frequency and phase angle of grid voltage and inverter output, control scheme is included. The proposed new carrier based modulation technique ensures good performance in terms of output current with low THD.
In addition, the leakage current is reduced significantly with proposed H8 topology.

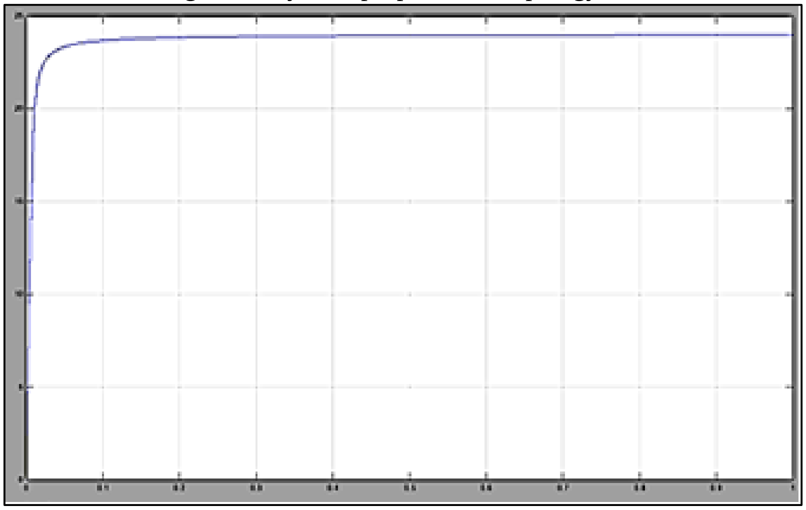

Fig. 4: Output from solar panel

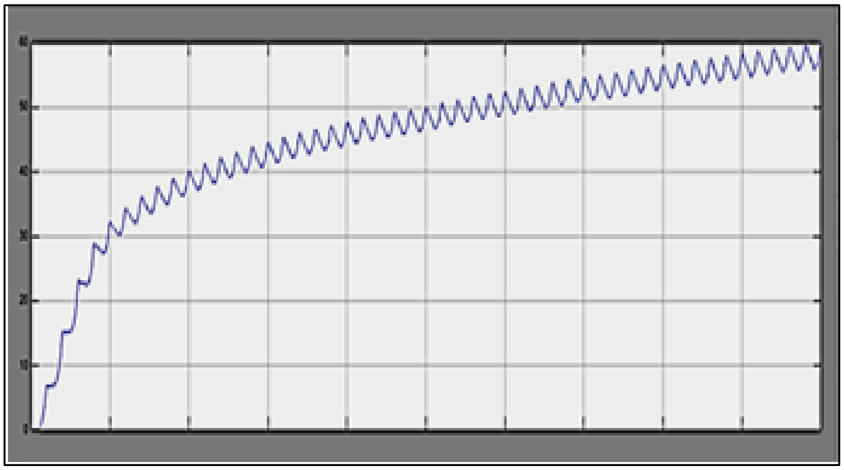

Fig. 5: Output waveform of Boost converter

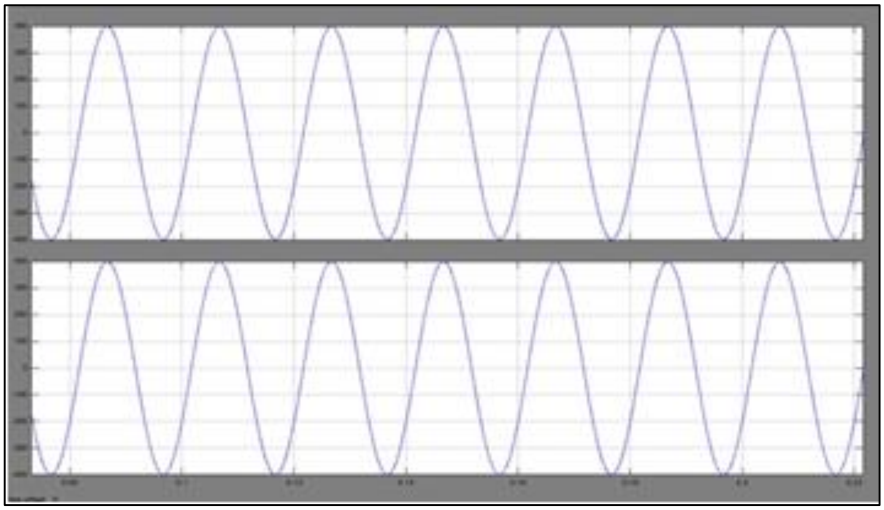

Fig. 6: Output waveform from H8 inverter (Voltage to be injected to the grid)

V. Conclusion

This paper reviewed and investigated the performance of 3- phase transformerless PV inverters combined with PWM techniques to reduce the leakage currents. The output waveform of H8 inverter is ripple free. When compared to previous inverter topology like H6 inverter, the leakage current is reduced. The output waveform is the proof that leakage current is reduced considerably. The control scheme is very much simple compared to existing systems.

References

[1] Marcelo C. Cavalcanti, Alexandre M. de Farias, “Modulation Techniques to Eliminate Leakage Currents in Transformerless Three-Phase Photovoltaic Systems” , IEEE Transactions on Industrial Electronics, vol. 57, NO. 4, APRIL 2010.
[2] Francisco D. Freijedo, Alejandro G. Yepes, “Three Phase Inverter Topologies for Grid-Connected Photovoltaic Applications”, ," IEEE Transactions on Industrial Electronics, vol. 60, pp. 3602-3618, 2014
[3] Shameem Ahmad, Md. Tanvir Rashid “A Technical Comparison Among Different PV-MPPT Algorithms to Observe the Effect of Fast Changing Solar Irradiation” , IEEE International WIE Conference on Electrical and Computer Engineering, pp. no. 155-158, 2015 April.
[4] Amresh Kumar Singh, Ikhlaq Hussain “An Improved P&O MPPT Algorithm for Single Stage Three-Phase Grid Integrated Solar PV System”, IEEE Transactions on Industrial Electronicsvol. 81, APRIL 2016.
[5] Ahmad Syed, S.Tara Kalyani, “Three-Phase Eight Switch Inverter with Reduced Common mode voltage for Transformerless Photovoltaic Systems”, International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT), vol.64, pp.no. 2840-2844, 2016 March
[6] R. R. Karasani, V. B. Borghate, P. M. Meshram, H. M. Suryawanshi, and S. Sabyasachi, "A Three-Phase Hybrid Cascaded Modular Multilevel Inverter for Renewable Energy Environment," IEEE Trans. Power Electron., vol. 32, no. 2, pp. 1070-1087, 2017.
[7] E. Afshari, G. R. Moradi, R. Rahimi, B. Farhangi, Y. Yang, F. Blaabjerg, and S. Farhangi, "Control Strategy for Three-Phase Grid Connected PV Inverters Enabling Current Limitation under Unbalanced Faults," IEEE Trans. Ind. Electron., vol. PP, no. 99, pp. 1-10, 2017.
[8] E. S. Sreeraj, K. Chatterjee, and S. Bandyopadhyay, “One- cyclecontrolled single-stage single-phase voltage-sensorless grid-connected pv system,” IEEE Trans. Ind. Electron., vol. 60, no. 3, pp. 1216-1224, Mar. 2013.
[9] T. Kerekes, R. Teodorescu, M. Liserre, C. Klumpner, and M. Sumner, “Evaluation of three-phase transformerless photovoltaic inverter topologies,” IEEE Trans. Power Electron., vol. 24, no. 9, pp. 2202- 2211, Sept. 2009.
[10] H. AbdEl-Gawad and V. K. Sood; “Overview of connection topologies for grid-connected PV systems,” in proc. IEEE Canadian conf. on Electrical and Computer Engineering, Toronto, ON, 2014, pp. 1-8.
[11] C. Noeding, M. Kazanbas, S. Araujo and P. Zacharias, “Towards High Power Ratings: Prospects and Challenges of SiC Technology, ” in proc. Int. Exhib. and Conf. for Power Electron., Intelligent Motion, Renewable Energy and Energy Management, Nuremberg, Germany, 2015, pp. 1-6.
[12] D. Ronanki and P. Parthiban, “PV-Battery Powered Direct Torque Controlled Switched Reluctance Motor Drive,” in proc Asia-Pacific Power and Energy Engineering Conf., Shanghai, 2012, pp. 1-4.
[13] J. Young-Hyok, J. Doo-Yong, K. Jun-Gu, K. Jae-Hyung, L. Tae-Won, and W. Chung-Yuen, “A real maximum power point tracking method for mismatching compensation in PV array under partially shaded conditions, ”EEE Trans. Power Electron., vol. 26, no. 4, pp. 1001-1009, Apr. 2011.