Highly Efficient and Reliable PV Inverter Configuration for Leakage current elimination in a Grid connect PV System

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Abstract: Standalone PV Systems are very useful inproviding Power to the remote located electrical loads, but the stand alone system cannot supply power during all atmospheric conditions. By connecting the PV system to the local grid it can be made more reliable than the stand alone system. The grid connected PV Systems are used to provide electrical energy to the local loads and for the exchange power with utility grids. PV systems still face major difficulties and may pose some adverse effects to the system, such as overloading of the feeders, harmonics, high investment cost, low efficiency, and low reliability. In this paper, a comparative analysis of seven levels of MLI's and leakage current elimination is presented. Control scheme based on Sinusoidal Pulse Width Modulation (SPWM) is adopted due to its ease of implementation. More number of levels results in reduced THD and nearly sinusoidal output. Simulation is performed using Matlab/Simulink.

Keywords: Photovoltaic Cell, Total Harmonic Distortion(THD), PWM (Pulse Width Modulation).

I. INTRODUCTION

Utilization of renewable energy resources is the demand of today and the necessity of tomorrow. With advancement in power electronic technology, the solar photovoltaic energy has been recognized as an important renewable energy resource because it is clean, abundant and pollution free. The PV power supplied to the utility grid is gaining more and more visibility, while the world's power demand is increasing [1]. Not many PV systems have so far been placed into the grid due to the relatively high cost, compared with more traditional energy sources such as oil, gas, coal, nuclear, hydro, and wind. Solid-state inverters have been shown to be the enabling technology for putting PV systemsinto the grid. The price of the PV modules were in the past the major contribution to the cost of these systems. A downward tendency is now seen in the price for the PV modules due to a massive increase in the production capacity of PV modules [2]. The cost of the grid-connected inverter is, therefore, becoming more visible in the total system price. A cost reduction per inverter watt is, therefore, important to make PV-generated power more attractive. Solar-electric-energy demand has grown consistently by

20%–25% per annum over the past twenty years, which is mainly due to the decreasing prices of the PV products, an increasing efficiency of solar cells and manufacturing technology improvements [3]. PV inverter, the heart of the grid connected and standalone PV system, is used to convert dc power obtained from PV modules into ac power to be fed into the grid. Improving the output waveform of the inverter reduces its respective harmonic content and hence the size of the filter used and the level of electromagnetic interference (EMI) generated by switching operation of the inverter. In recent years, multilevel inverters have become more attractive for researchers and manufacturers due to their advantages over conventional three-level pulse width-modulated (PWM) inverters. They offer improved output waveforms, smaller filter size, and lower EMI, lower total harmonic distortion (THD).

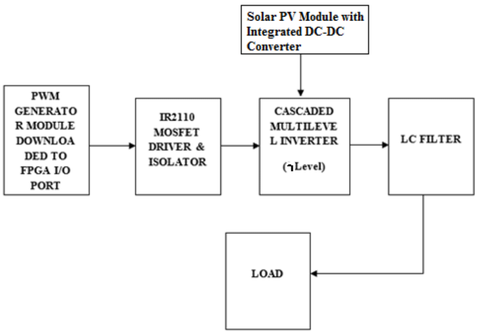

Fig1 shown above is the basic schematic model of the standalone PV system. Multilevel inverter are designed based on basic inverter model [4] which is shown in Fig.2 and its output is shown in Fig.3. Multilevel inverters can be used to interface with renewable energy and distributed energy resources because several batteries, fuel cells, PV cells, wind turbines, and micro turbines can be connected through a multilevel inverter to supply a load or the ac grid without voltage balancing problems [5]. Generally, the battery requires a large capacity transformer for connecting to the power system. As a result, the whole system becomes large, heavy and has low efficiency. Recently, a transformer less battery energy storage system based on a cascaded multilevel inverter has been proposed [6]. A cascaded multilevel inverter has a simple structure that has promoted its application at megavolt level. By using it, the whole system can be reduced in size, weight, and cost. The cascaded multilevel inverter synthesizes a desired voltage from several independent sources of DC voltage, which may be obtained from batteries, fuel cells or PV cells [7]. This DC voltage must be filtered, not only clean but also well regulated. However, if the current source is directly loaded, then the output voltage will change. Therefore, it need a DC voltage control, thus the equipment can work according to its ability.

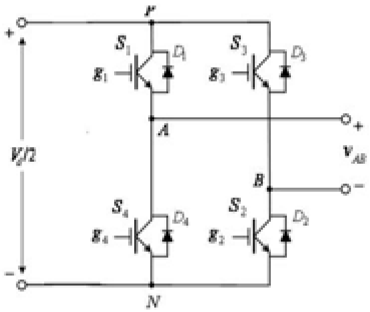

Fig.2. Basic Inverter.

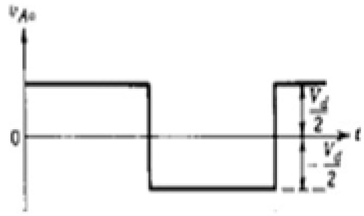

Fig.3. Output waveform.

III Photovoltaic system

A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solarcells are the building blocks of photovoltaic modules, otherwise known as solar panels.

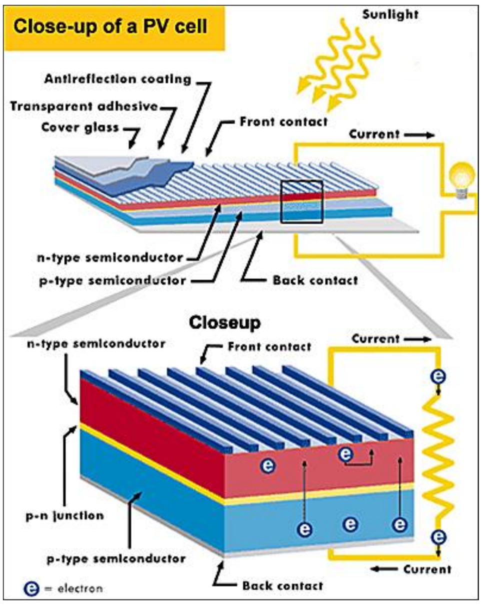

Figure4: Solar cell

Photons of light with energy higher than the band-gap energy of PV material can make electrons in the material break free from atoms that hold them and create electron and hole pairs. These electrons however, will soon fall back into holes causing charge carriers to disappear. If a nearby electric field is provided, those in the conduction band can be continuously swept away from holes toward a metallic contact where they will emerge as an electric current. The electric field with in the semiconductor itself at the junction between two regions of crystals of different type, called a p-n junction. The PV cell has electrical contacts on its top and bottom to capture the electrons.

When the PV cell delivers power to the load, the electronsflow out of the n-side into the connecting wire, through the load, and back flows in the opposite direction from electrons.

IV Modelling of PV Array

PV arrays are built up with combined series/parallel combinations of PV solar cells, which are usually represented by a simplified equivalent circuit model such as the one given in Figure3.

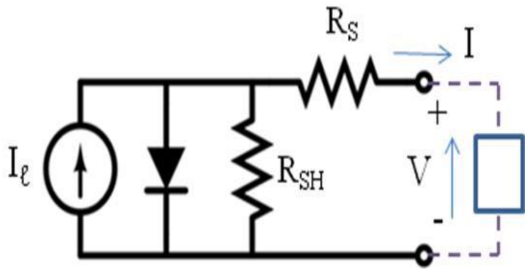

Figure5: Equivalent circuit for a PV cell

The PV cell output voltage is a function of thephotocurrent that mainly determined by load current depending on the solar Irradiation level during the operation.

$$Vc = \frac{AkT_c}{e} ln\left(\frac{I_{ph} + I_0 - I_c}{I_0}\right) - R_s I_c$$

Where the symbols are defined as follows:

e: electron charge (1.602 × 10-19 C).

k: Boltzmann constant (1.38 × 10-23 J/*P*o*P*K).

Ic: cell output current, A.

A: curve fitting factor used to adjust the I-V characteristics of the cell

Iph: photocurrent, function of irradiation level and junction temperature (5 A).

I0: reverse saturation current of diode (0.0002 A).

Rs: series resistance of cell (0.001 Ω).

Tc: reference cell operating temperature (20 °C).

Vc: cell output voltage, V.

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If the temperature and solar irradiation levels change, thevoltage and current outputs of the PV array will follow this change. Hence, the effects of the changes in temperature and solar irradiation levels should also be included in the PV array model.

V. BASIC STRUCTURE

The cascaded H-Bridge inverter is composed of several H-bridgeconverters in cascade connection as given in Fig. 6. This topology uses separate dc sources and high quality multilevel waveforms can be achieved with comparatively lesser components. The voltage levels at the output □m’ in a cascade inverter is defined by m = 2n+1, where □n’ is the number of dc sources. Hence ‘4n’ power switches are required to synthesize all possible combinations. This results in harmonic reduction in the synthesized current which reduces the size of the output filters [11].

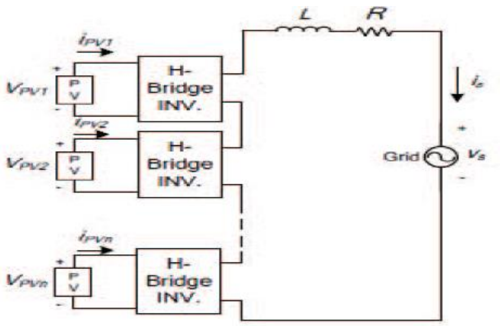

Fig. 6. Structure of a Cascaded H Bridge MLI for a grid connected PV system

A cascaded multilevel inverter uses set of series connectedfull-bridge inverters with separate DC sources in a modular setup to create the stepped waveform. A full bridge inverter is in itself a 3 level cascaded multilevel inverter and every module added in cascade to that extends the inverter with two more voltage levels, which then increases the number of steps in the waveform. A typical 5-level for a single phase leg is shown below. One can observe from here that it requires 8 switches. For a 7-level inverter model, it uses 12 switches, whereas the proposed model uses only 9.

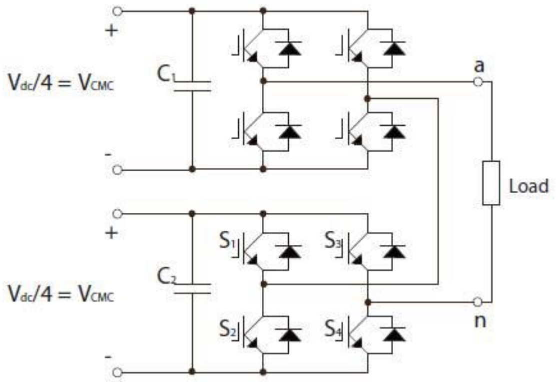

Figure 7. Typical 5-level cascaded multilevel inverter circuit.

The traditional two or three levels inverter does not completely eliminate the unwanted harmonics in the output Waveform. Therefore, using the multilevel inverter as an alternative to traditional PWM inverters is investigated. Cascaded H-bridge multilevel inverters typically use IGBT switches.

VI. Simulation Results

The simulation model of Reduced Switches Cascaded 7- level MLI of designed using MATLAB/SIMULINKSoftware. The gating signals for the inverter are generatedby using multicarrier modulation technique. The circuit was simulated with RL load. The simulation parameters are shown in below table 2here in this section simulation results and observations ofPhotovoltaic Application based 7- level Cascaded MLI with Reduced No. of Switches is presented. The different parameters (like voltage, current, THD) are observed.

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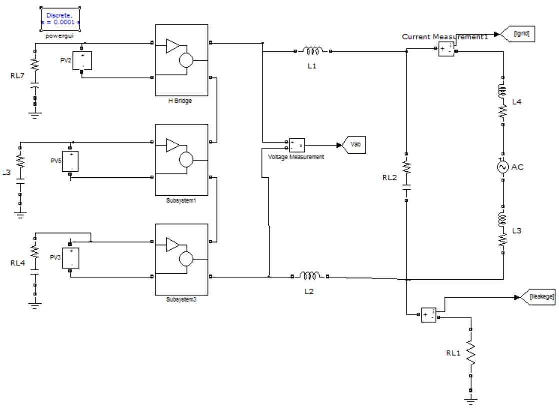

Figure 8 shows the MATLAB Model of Photovoltaic based 7- level Cascaded MLI with reduced no. of switches

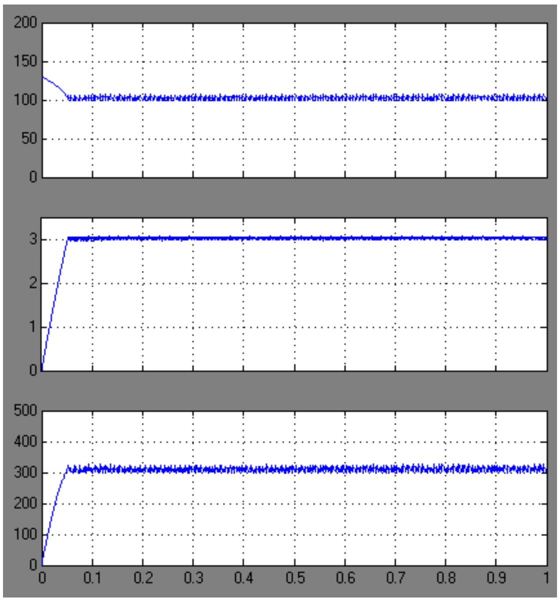

Figure 9 Simulation waveforms of the PV Panel 1 Voltage (V), Current (A), and Power (W).

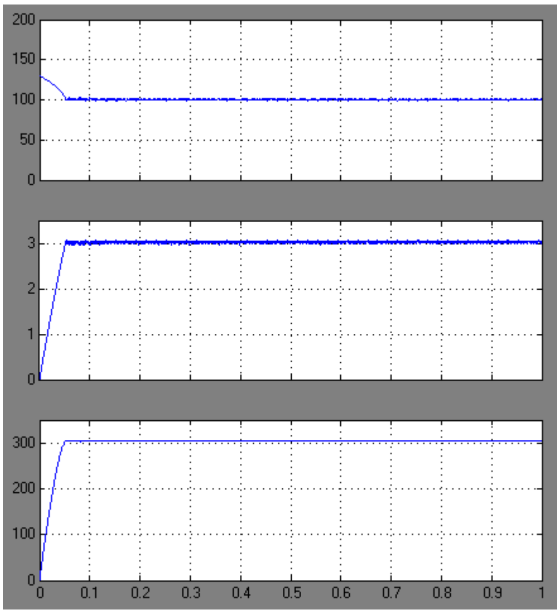

Figure 10 Simulation waveforms of the PV Panel 2 Voltage (V), Current (A), and Power (W).

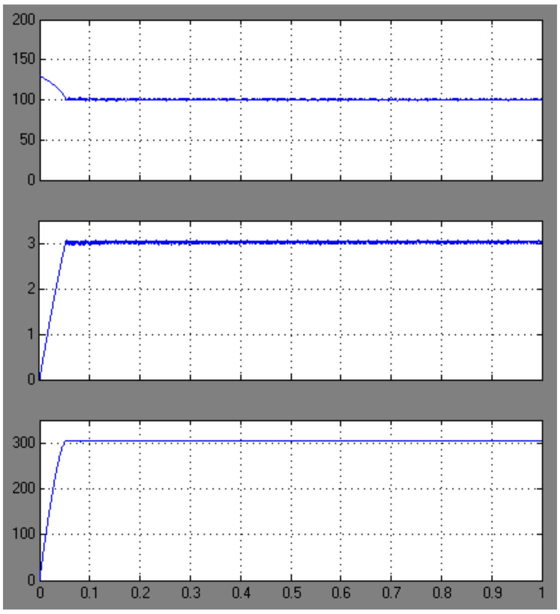

Figure 11 Simulation waveforms of the PV Panel 3 Voltage (V), Current (A), and Power (W).

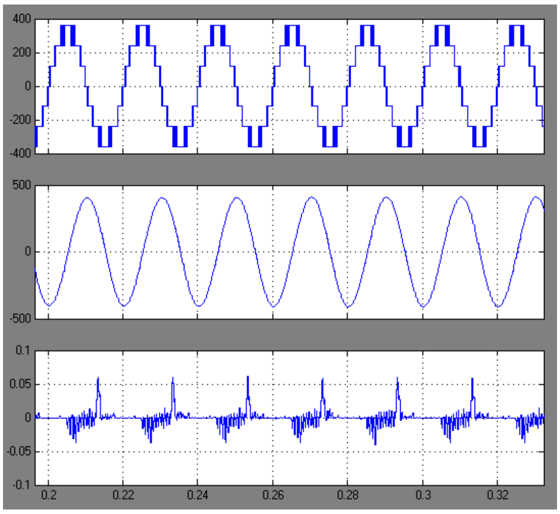

Figure 13 Simulation waveforms of the Output Voltage (V), Output Current (A), and Leakage Current (A).

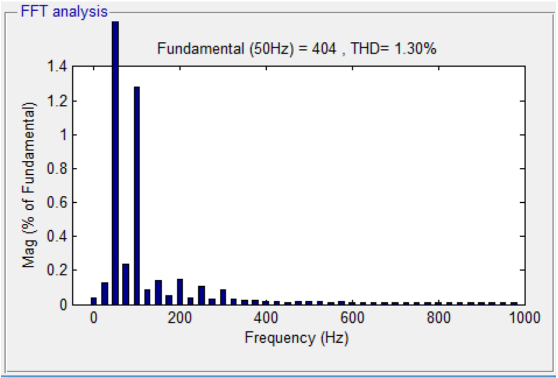

Figure 14 Total Harmonic Distortion of the Output Inverter Current in %

VII. Conclusion

Photovoltaic based applications are increasing day by day. Since most of the electrical application are in AC, so some efficient Power Electronics DC to AC converters are required for converting photovoltaic DC output to AC. In this paper a Photovoltaic application based 7-levelCascaded MLI has been shown to produce an increased stepped output with less number of semiconductor switches, and due to which controlling the overall circuit becomes less complex, the size and installation area reduces.A single phase Photovoltaic Array fed Cascaded H-Bridge MLI with Reduced number of Semiconductor Switches is simulated in MATLAB / SIMULINK environment. It is inferred with the help of simulation results the Multicarrier PWM techniques produced a lower THD than with PWM technique involving the comparison between triangular and constant values.

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