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A Three Phase Multi Level Converter for grid Connected PV System

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ABSTRACT

Photovoltaic energy is a wide kind of green energy. A high performance on these systems is needed to make the most of energy produced by solar cells. Also, there must be a constant adaptation due to the continuous variation of power production. Control techniques for Power Converters like the MPPT algorithm (Maximum Power Point Tracking) present very good results on photovoltaic chains. Nevertheless, losses on power elements reduce global performance and the voltage/current adaptation is not always possible. This paper presents a single-phase 11-level (5 H-bridges) cascade multilevel DC-AC grid-tied inverter. Each inverter bridge is connected to a 200 W solar panel. OPAL-RT lab was used as the hardware in the loop (HIL) real-time control system platform where a Maximum Power Point Tracking (MPPT) algorithm was implemented based on the inverter output power to assure optimal operation of the inverter when connected to the power grid as well as a Phase Locked Loop (PLL) for phase and frequency match. A novel SPWM scheme is proposed in this paper to be used with the solar panels that can account for voltage profile fluctuations among the panels during the day. Simulation and experimental results are shown for voltage and current during synchronization mode and power transferring mode to validate the methodology for grid connection of renewable resources.

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1. INTRODUCTION

Because energy resources and their utilization will be a prominent issue of this century, the problems of natural resource depletion, environmental impacts, and the rising demand for new energy resources have been discussed fervently in recent years. Several forms of renewable zero pollution energy resources, including wind, solar, bio, geothermal and so forth, have gained more prominence and are being researched by many scientists and engineers [1]-[2]. Solar cell installations involve the use of multiple solar panels or modules, which can be connected in series or in parallel to provide the desired voltage level to the inverter. The cascaded H-bridge multilevel inverter topology requires a separate DC source for each H-bridge so that high power and/or high voltage that can result from the combination of the multiple modules in a multilevel inverter would favor this topology [3]-[7]. To maximize the energy harvested from each string, a maximum power point tracking (MPPT) strategy is needed. The task of finding the optimum operation point might increase the complexity and component count as the number of isolated DC sources increase. The approach chosen to deal with the number of input sources was to monitor AC output power parameters instead of DC input measurements [8]. Traditional multilevel inverters include cascaded H-bridge inverter, diode clamped inverter, and flying capacitors inverter. This paper focuses on the single-phase 11-level (5 H-bridges) cascade multilevel inverter.

2. PV CELL

TODAY photovoltaic (PV) power systems are becoming more and more popular, with the increase of energy demand and the concern of environmental pollution around the world. Four different system configurations are widely developed in grid-connected PV power applications: the centralized inverter system, the string inverter system, the multi string inverter system and the module-integrated inverter system. Generally three types of inverter systems except the centralized inverter system can be employed as small-scale distributed generation (DG) systems, such as residential power applications. The most important design constraint of the PV DG system is to obtain a high voltage gain. For a typical PV module, the open-circuit voltage is about 21V and the maximum power point (MPP) voltage is about 16V. And the utility grid is 220 or 110Vac. Therefore, the high voltage amplification is obligatory to realize the grid-connected function and achieve the low total harmonic distortion (THD). The conventional system requires large numbers of PV modules in series, and the normal PV array voltage is between 150 and 450V, and the system power is more than 500W. This system is not applicable to the module-integrated inverters, because the typical power rating of the module-integrated inverter system is below 500W, and the modules with power ratings between 100 and 200W are also quite common. The other method is to use a line frequency step-up transformer, and the normal PV array voltage is between 30 and 150V. But the line frequency transformer has the disadvantages of larger size and weight. In the grid-connected PV system, power electronic inverters are needed to realize the power conversion, grid interconnection, and control optimization. The residential grid-connected PV system is shown in the below Figure 1.

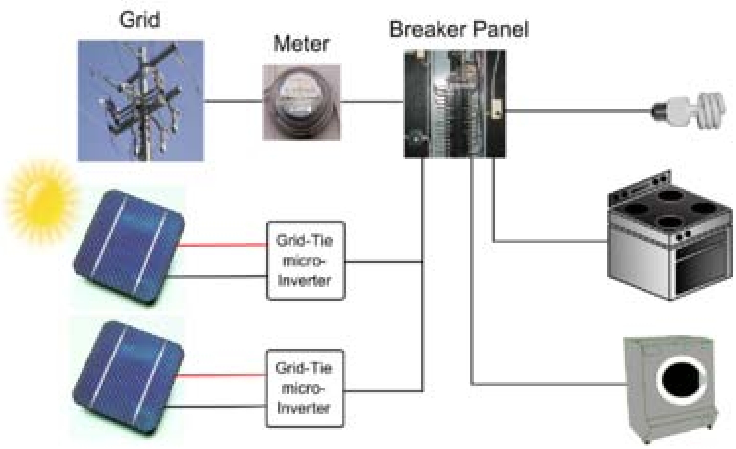

Figure 1. Diagram of a residential grid-connected PV system

A grid connected system is connected to a large independent grid (typically the public electricity grid) and feeds power into the grid. Grid connected systems vary in size from residential (2-10kWp) to solar power stations. This is a form of decentralized electricity generation. In the case of residential or building mounted grid connected PV systems, the electricity demand of the building is met by the PV system. Only the excess is fed into the grid when there is an excess. The feeding of electricity into the grid requires the transformation of DC into AC by a special, grid-controlled inverter.

3. PROPOSED CONCEPT

This paper presents a single-phase 11-level (5 H-bridges) cascade multilevel DC-AC grid-tied inverter as shown in the Figure 2. Each inverter bridge is connected to a 200 W solar panel. OPAL-RT lab was used as the hardware in the loop (HIL) real-time control system platform where a Maximum Power Point Tracking (MPPT) algorithm was implemented based on the inverter output power to assure optimal operation of the inverter when connected to the power grid as well as a Phase Locked Loop (PLL) for phase and frequency match. A novel SPWM scheme is proposed in this paper to be used with the solar panels that can account for voltage profile fluctuations among the panels during the day. Because energy resources and their utilization will be a prominent issue of this century, the problems of natural resource depletion, environmental impacts, and the rising demand for new energy resources have been discussed fervently in recent years.

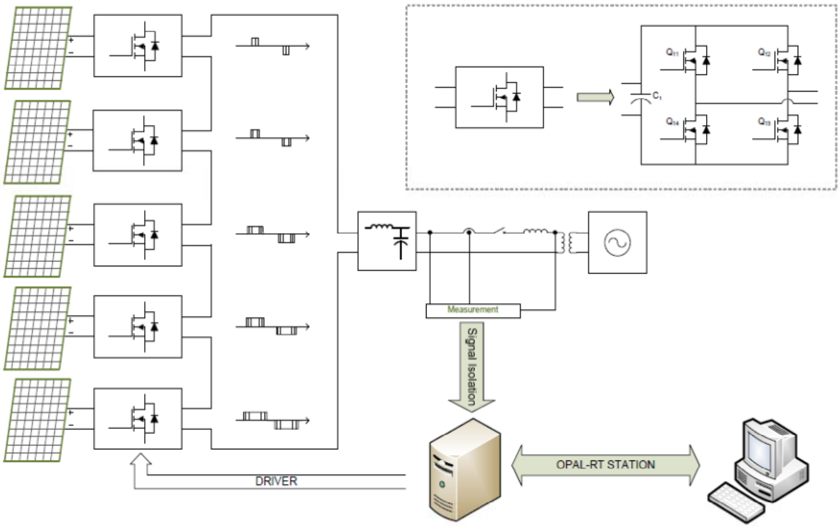

Figure 2. Multilevel inverter system overview

An overview of the system is shown in Figure. The core component of this inverter design is the four-switch combination shown in Figure. By connecting the DC source to the AC output by different combinations of the four switches, Q_{11}, Q_{12}, Q_{13}, and Q_{14}, three different voltage output levels can be generated for each DC source, $+V_{dc}$, 0, and $-V_{dc}$. A cascade inverter with N input sources will provide (2N+1) levels to synthesize the AC output waveform. The DC source in the inverter comes from the PV arrays, and the switching signals come from the multicarrier sinusoidal pulse width modulation (SPWM) controller. The 11-level inverter connects five H-bridges in series and is controlled by five sets of different SPWM signals to generate a near sinusoidal waveform [9]-[11].

4. MATLAB/SIMULINK RESULTS

Here the simulation is carried out by two cases 5.1 and 5.2. Three Phase Cascaded 11 level Inverter connected to grid without PV Cells. 2. Three Phase Cascaded 11 level Inverter connected to grid with PV Cells. All these Cases A carrier shifting PWM Technique is used.

5. SIMULATION RESULTS

5.1. Three Phase Cascaded 11-level Inverter Connected to Grid without PV Cells

The simulation results are shown in the Figure 3 and 4.

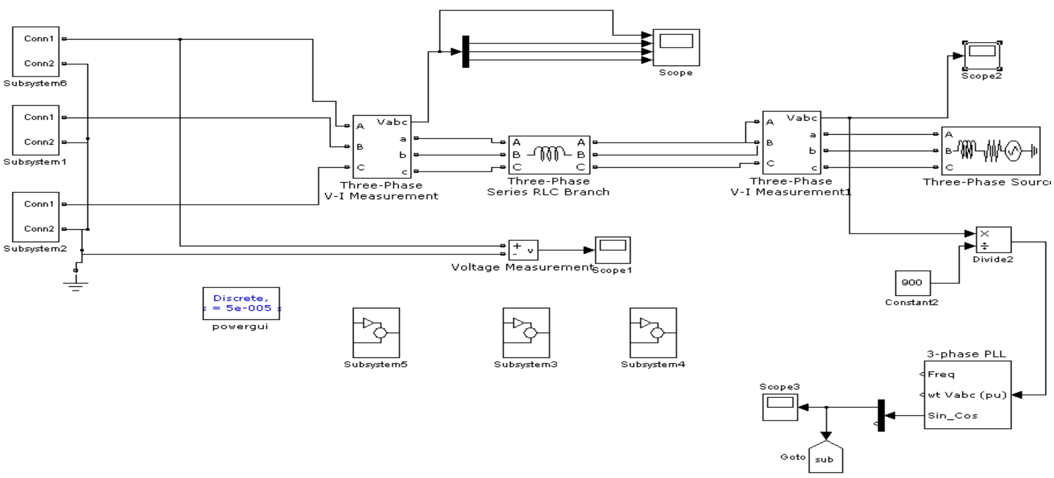

Figure 3. 11 level Output Voltage of cascaded Multilevel Inverter

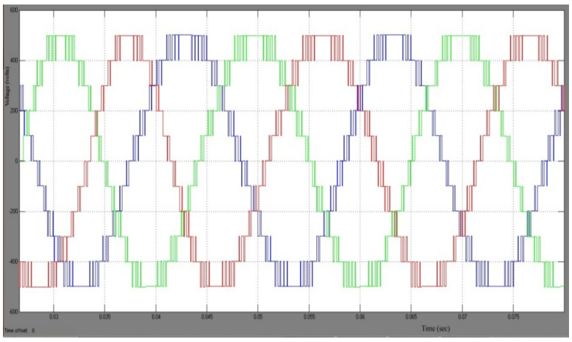

Figure 3(a). Grid Voltage without PV cell

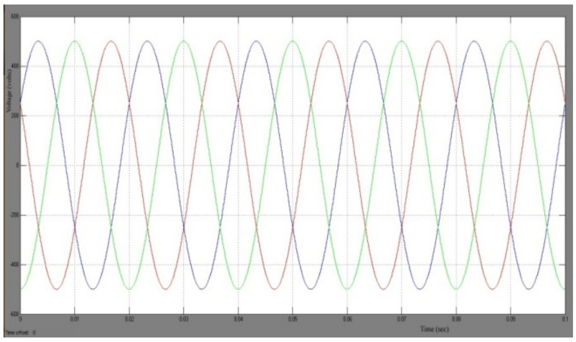

Figure 3(b). Grid Voltage without PV cell

5.2. Three Phase Cascaded 11 Level Inverter Connected to Grid with PV Cells

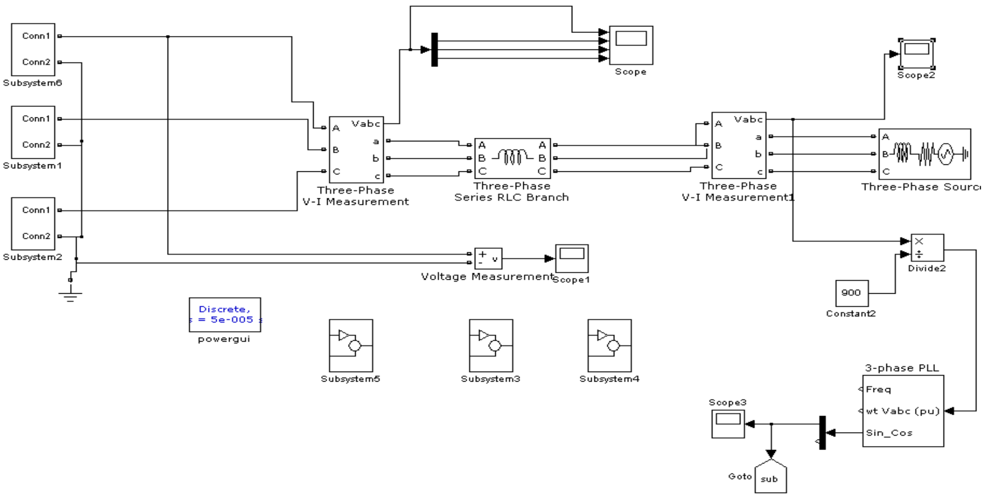

Figure 4. Output voltage of three phase Cascaded 11 level inverter with PV cells

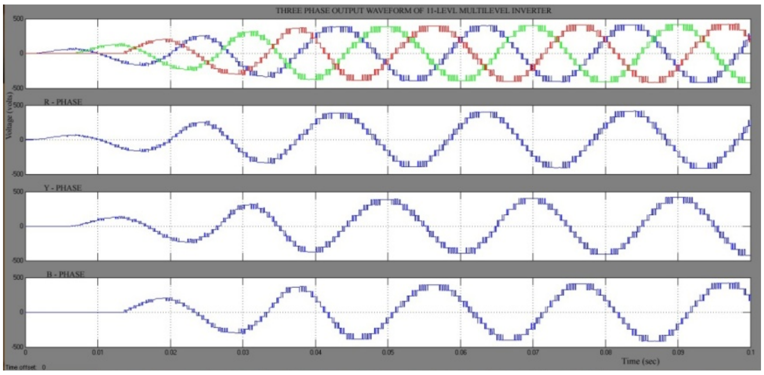

Figure 4(a). Output voltage of three phase Cascaded 11 level inverter with PV cells

6. CONCLUSION

This paper presented a Single Phase and three phase eleven-level cascade H-bridge inverter, which uses PLL and MPPT with separate solar panels as DC sources to interact with the power grid. A SPWM approach was presented to deal with the uneven power transferring characteristics of the conventional SPWM modulation technique. This technique proved to be successful due to the irradiance profile and the use of capacitors to smooth the voltage fluctuation.

The system was driven at 2kHz because of speed constrains of the control platform, which required bulk filter components. Grid connection results were shown using the proposed MPPT algorithm. Future work includes the use of a DSP platform to increase switching frequency and reduce filter requirements. The entire PV system structure and its interaction with the grid through PLL and MPPT algorithms were shown by the simulation results.

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