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Study and Analysis of a Single Stage Transformer-less Inverter for Grid Connected PV Systems by using CSI

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ABSTRACT: In this paper, a single-phase, single-stage current source inverter-based photovoltaic system for grid connection is proposed. The system utilizes transformer-less single-stage conversion for tracking the maximum power point and interfacing the photovoltaic array to the grid. The maximum power point is maintained with a fuzzy logic controller. A proportional-resonant controller is used to control the current injected into the grid. To improve the power quality and system efficiency, a double-tuned parallel resonant circuit is proposed to attenuate the second- and fourth- order harmonics at the inverter dc side. A modified carrier based modulation technique for the current source inverter is proposed to magnetize the dc-link inductor by shorting one of the bridge converter legs after every active switching cycle. Simulation and practical results validate and confirm the dynamic performance and power quality of the proposed system.

Index Terms: Current source inverter (CSI), grid-connected, maximum power point tracking (MPPT), photovoltaic (PV)

I. INTRODUCTION

The sun is the primary energy source that subsequently creates substantial diversity of renewable energy sources on the Earth. However, solar energy that can be collected directly on the Earth's surface still accounts for the largest amount of renewable energy compared to all other renewable sources. Therefore, using solar energy could be sufficient for securing the future energy requirements. In addition, direct solar energy can be converted directly to electricity using devices called Photovoltaic (PV) cells. This leads to a simpler system for solar-PV electricity production for small-scale (typically 1 kW –50 MW) electric power generators that produce electricity at a site close to customers or that are tied to an electric distribution system generally refers as Distributed generation (or DG).

In distributed generation applications, the PV system operates in two different modes; grid-connected mode and island mode. In the grid-connected mode, maximum power is extracted from the PV system to supply maximum available power into the grid. Single- and two-stage grid-connected systems are commonly used topologies in single- and three-phase PV applications.

In a single-stage grid-connected system, the PV system utilizes a single conversion unit (dc/ac power inverter) to track the maximum power point (MPP) and interface the PV system to the grid. In such a topology, PV maximum power is delivered into the grid with high efficiency, small size, and low cost. However, to fulfill grid requirements, such a topology requires either a step-up transformer, which reduces the system efficiency and increases cost, or a PV array with a high dc voltage. And inverter control is complicated because the control objectives, such as MPP tracking (MPPT), power factor correction, and harmonic reduction, are simultaneously considered.

On the other hand, a two-stage grid-connected PV system utilizes two conversion stages: a dc/dc converter for boosting and conditioning the PV output voltage and tracking the MPP, and a dc/ac inverter for interfacing the PV system to the grid. In such a topology, a high-voltage PV array is not essential, because of the dc voltage boosting stage. However, this two-stage technique suffers from reduced efficiency, higher cost, and larger size. From the aforementioned drawbacks of existing grid connected PV systems, it is apparent that the efficiency and footprint of the two-stage grid-connected system are not attractive.

Therefore, single-stage inverters have gained attention, especially in low voltage applications. The current-source inverter (CSI) has the potential of becoming a preferred topology for interfacing a PV system to the ac power grid for the following reasons.

1) CSI provides a smooth dc-side current, which is a desirable feature for PV modules.

2) The energy storage element of a CSI has a longer lifetime than that of a VSI.

3) CSI has an inherent voltage boosting capability, which allows integration of PV panels of lower output voltages and reduces the requirements of the step-up interface transformer.

4) With the evolution of reverse-blocking (RB) IGBT switches, the series diodes will be eliminated, resulting in a considerable reduction in the cost and conduction losses.

II. LITERATURE REVIEW

The grid connected solar PV system requires the power converters. This power converter is used to convert the direct current from the PV plant to the desired values of AC with the highest possible efficiency and provide quality power to the utility grid.

The function power converters in grid connected PV system include DC-AC conversion, output power quality assurance, maximum power point tracking, and system controls. Focusing on the requirement of PV grid connected system, this section analysis the work carried out so far in the area of grid connected inverter, and control structure of grid connected inverter system. This investigation provides a great deal of insight into where improvement is required in the grid connected PV system**.**

A. Grid Connected Inverters

A Power loss comparison of the single-stage and two-stage grid connected PV power conversion system. This study shows that power losses in both the techniques are similar because losses due to MPPT in single-stage are more or less equal to losses in two-stage systems. But single-stage power conversion systems have the advantages of low cost, reduced system size, and reduced switching loss resulting in increased efficiency. However, the authors have not concentrated on the common mode leakage current problem, and harmonic distortion in the grid current [1].

A review in which they have focused on inverter technologies for connecting photovoltaic (PV) modules to a single-phase grid. Various inverter topologies are presented, compared, and evaluated against demands, lifetime, component ratings, and cost. Finally, some of the topologies are pointed out as the best candidates for either single PV module or multiple PV module applications [2].

The conventional voltage source inverter (VSI) is the most commonly used interface unit in grid-connected PV system technology due to its simplicity and availability In this paper, a novel maximum power point tracking algorithm based on the perturb-and-observe (P&O) technique is introduced [3].

A single-phase cascaded H-bridge converter for a grid-connected photovoltaic (PV) application. The multilevel topology consists of several H-bridge cells connected in series, each one connected to a string of PV modules. The topology offers advantages such as the operation at lower switching frequency or lower current ripple compared to standard two-level topologies [4].

A single-phase seven-level inverter for grid-connected photovoltaic systems, with a novel pulse width-modulated (PWM) control scheme. A digital proportional-integral current-control algorithm was implemented to keep the current injected into the grid sinusoidal [5].

B. Control structure of Grid Connected PV System

As power output of the PV plant largely depends on the solar irradiation and temperature, the wide variation of these parameters result in high voltage ripple in the Dc-link which propagates to the utility grid and cause power quality problem due to non-sinusoidal current injection to the grid. These wide variations in the input result in high input ripple in DC side which will propagate through the inverter to AC side and cause poor power quality and current harmonic injection into the grid. As per IEEE 1547 THD of the grid voltage/current should be maintained below 5%. In grid connected PV system, DC link voltage control and inverter output current control are necessary. Maximum power point tracking (MPPT) techniques are employed in grid connected PV power conversion systems. The main objective of MPPT is to extract the maximum available power from the PV plant under constant and changing environmental conditions. This section mainly deals with the previous work carried out in the area of maximum power point tracking algorithms.

A Proportional Resonant (PR) controller, tuned at the third harmonic, is utilized to minimize the oscillating power effect from the grid side, and hence acts as a harmonic cancellator (HC). The proposed technique features: (i) simple implementation, (ii) easy tuning, and (iii) superior steady state elimination [10].

Nonlinear pulse-width modulation (NPWM) proposed to improve harmonic mitigation. NPWM is based on applying computational operations, such as a band-pass filter, a low-pass filter, a phase-shifter block, and various division operations to extract the second-order harmonic component from the dc-link current [11].

Proposes that, the single-phase PWM current source inverter has many advantages for utility-interactive PV systems. It is suitable especially for the non insulated type utility-interactive topology which is widely used for residential photovoltaic generating systems. But this type of inverter has a significant disadvantage, that is to say, output current of the inverter has large harmonic components when its smoothing reactor is not large enough to eliminate the ripple component of its current. This paper presents the power oscillating effect is mitigated by using a modification of the carrier signal on pulse amplitude modulation (PAM) [12].

New fuzzy-logic controller for maximum power point tracking of photovoltaic (PV) systems is proposed. PV modeling is discussed. Conventional hill-climbing maximum power-point tracker structures and features are investigated. The new controller improves the hill-climbing search method by fuzzifying the rules of such techniques and eliminates their drawbacks. Fuzzy-logic based hill climbing offers fast and accurate converging to the maximum operating point during steady-state and varying weather conditions compared to conventional hill climbing [13].

III. PROBLEM FORMATION

-The conventional voltage source inverter (VSI) is the most commonly used interface unit in grid connected PV system technology due to its simplicity and availability.

-However, the voltage buck properties of the VSI increase the necessity of using a bulky transformer or higher dc voltage.

-Moreover, an electrolytic capacitor, which presents a critical point of failure, is also needed. Several multilevel inverters have been proposed to improve the ac-side waveform quality, reduce the electrical stress on the power switches, and reduce the power losses due to a high switching frequency.

-However, the advantages are achieved at the expense of a more complex PV system. Moreover, a bulky transformer and an unreliable electrolytic capacitor are still required.

-Unlike the three-phase grid-connected CSI, the single-phase system has even harmonics on the dc side, which affect MPPT, reduce the PV lifetime, and are associated with odd-order harmonics on the grid side

-The conventional solution to the dc current oscillation is to use a large inductor, which is capable of eliminating the even-order harmonics. Practically, the CSI inverter produces high dc current therefore; an inductor with a large value is usually bulky and large in size. Thus, this technique is practically unacceptable.

IV. DESCRIPTION OF THE PROPOSED SYSTEM

The review of the existing topologies, However, to fulfill grid requirements, such a topology requires either a step-up transformer, which reduces the system efficiency and increases cost, or a PV array with a high dc voltage.

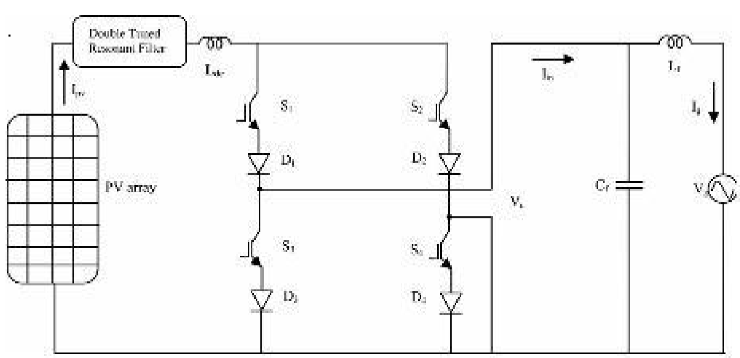

Fig. 1. Single-phase grid connected current source inverter.

High-voltage systems suffer from hotspots during partial shadowing and increased leakage current between the panel and the system ground though parasitic capacitances. Moreover, inverter control is complicated because the control objectives, such as MPP tracking (MPPT), power factor correction, and harmonic reduction, are simultaneously considered.

On the other hand, a two-stage grid-connected PV system utilizes two conversion stages: a dc/dc converter for boosting and conditioning the PV output voltage and tracking the MPP, and a dc/ac inverter for interfacing the PV system to the grid. In such a topology, a high-voltage PV array is not essential, because of the dc voltage boosting stage. However, this two-stage technique suffers from reduced efficiency, higher cost, and larger size. In this project single phase CSI topology and control systems are introduced to minimize the aforementioned problems. A grid-connected PV system using a single-phase CSI is shown in Fig. 1. The inverter has four insulated-gate bipolar transistors (IGBTs) (S1–S4) and four diodes (D1–D4). Each Diode is connected in series with an IGBT switch for reverse blocking capability. A doubled-tuned parallel resonant circuit in series with dc-link inductor *L*dc is employed for smoothing the dc link current. To eliminate the switching harmonics, a *C–L* filter is connected into the inverter ac side.

The Block diagram of grid connected PV system using a CSI is illustrated in fig. 2. whole solar power conversion system consists of a PV array, a double tuned resonant filter, and a PWM-based single-phase CSI, Grid, low pass filter, PLL, MPPT.

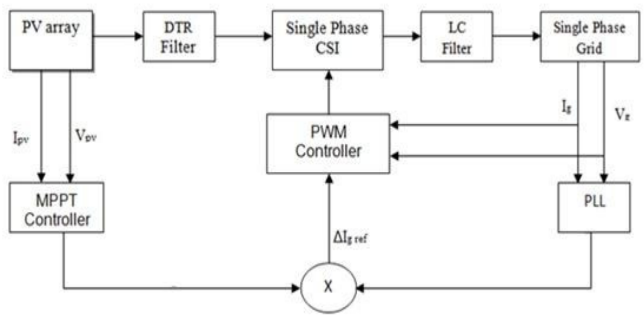

Fig. 2. Block diagram of grid connected PV system using a CSI**.**

The inputs of the MPPT block are measurements from the PV Array(I_{PV} V_{PV}). The output of the MPPT block is then modified the shape of the reference PV AC current magnitude by multiplying PLL output producing the error signal. PLL(phase locked loop) is to provide a reference phase signal synchronized with AC systems. The error signal is the input of the voltage and current control loop in which measured ac current of grid is then compared with the reference signal and error will be sent to the pr controller. The output of the voltage and current control loop is then sent to the PWM block to generate the pulses for PV inverter. The inverter output is filtered by Low pass LC filter and then injected to the utility grid.

V. CONCLUSION & FUTURE SCOPE

A novel PV integrated grid-tied transformer-less inverter has been presented in this paper. This inverter is an attractive option for single phase transformer-less grid-tied systems because of zero leakage current and negligible DC injection in to the grid. Other advantages of the proposed inverter are low current ripple, boosting of input voltage, requirement of low value of capacitor across the PV panel, and low THD in the inverter output current. However, since the PV and the grid are not isolated, safety issues need to be addressed. Design of the energy storage elements, loss and efficiency calculations and simulation results have been presented in the paper. A 250W experimental prototype is built and tested and the results obtained agree with the simulation and analytical studies. This confirms the practical feasibility of the proposed inverter topology for grid connected applications

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