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Single Phase single stage transformer less Grid connected PV system

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Abstract - A single-phase, single-stage H-Bridge inverter-based photovoltaic system for grid connection is proposed. The system utilizes transformer-less single-stage conversion and interfacing the photovoltaic array to the grid. The ZCD Synchronizer is used to provide fundamental signal of frequency from conventional grid.

The drawbacks of existing grid connected PV systems, it is noticeable that the efficiency and path of the two-stage grid-connected system are not attractive. Therefore, single-stage inverters have gained attention, especially in low voltage applications.
***Keywords**: Zero cross detector (ZCD), Maximum power point tracking (MPPT), Photovoltaic (PV).*

I INTRODUCTION

1.1 Grid-Connected PV System Topologies:

A grid-connected PV system comprises at least the following parts: solar module, inverter and utility grid. Fig. 2 illustrates a grid-connected PV system based on a two-stage grid-connected power converter. The technical literature on power converters for grid connected PV systems is extremely wide. Depending on the characteristics of the PV system (input and output voltage levels, rated power, electrical isolation) several converter topologies may be used. Along the past years many authors have proposed many different converters for PV applications. PV applications for residential use are rapidly growing towards the usage of module-integrated converters (MIC) generally in the power range bellow 500 w.

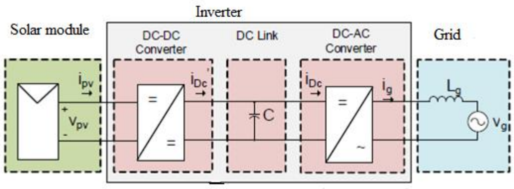

Fig 1.1 General structure of a grid-connected pv system & internal structure of a single-phase inverter.

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. 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.

From the above mentioned drawbacks of existing grid connected PV systems, it is clear that the efficiency and track of the two-stage grid-connected system are not attractive. Therefore, single-stage inverters have gained attention, especially in low voltage applications. 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.

The PV modules output is typically DC. Hence, a DC/AC conversion with boosting stage is mandatory. Conventional Voltage Source Inverters (VSI), referred to as buck inverters, are probably the most common power converter topology employed in such systems. Intrinsically, the peak AC output voltage of VSIs is always lower than the input DC voltage. To consider the VSI topology in the grid connected PV systems, the low output voltage of the PV panels requires a pre-boosting stage in order to match the grid connection requirements. A two-stage power conversion system is thus typically used. Two common configurations are mostly employed.

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The first configuration uses an intermediate DC-DC boost converter before the DC-AC grid interface inverter (as in Fig.1.2a). This adds significant complexity and hardware to the power conversion system. Alternatively, the second configuration uses an output transformer to not only step up the inverter output voltage but also to avoid the injection of DC components into the grid (as in Fig.1.2b).

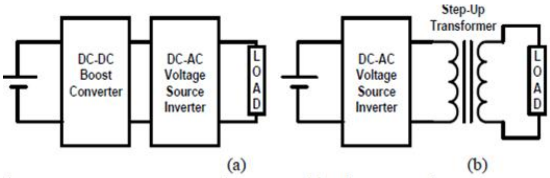

Fig 1. 2 Two stage power conversion system (a)using DC-DC boost converter & (b)using output step-up x'er.

The current source inverter (CSI) has not been extensively investigated for grid- connected renewable energy systems. However, it could be a practical alternative technology for PV distributed generation grid connection for the following reasons:

1) The dc input current is continuous which is important for a PV application;

2) System reliability is increased by replacing the shunt input electrolytic capacitor with a series input inductor;

3) The CSI voltage boosting capability allows a low-voltage PV array to be grid interface without the need of a transformer or an additional boost stage.

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.

A single-stage boost inverter is proposed, it can generate an AC output voltage with larger magnitude than the input DC voltage depending on the instantaneous duty cycle. The single-stage boost inverter is used as a grid-tied inverter to extract the DC power output from the PV array and inject a high quality AC current into the grid. Control of the CSI is comparatively simpler in grid-connected applications, as CSI can buffer the output from grid voltage fluctuations, generates a predetermined magnitude of current to the grid and can thus achieve a high power factor. Its output current is less dictated by the grid voltage. Moreover, it has inherent short circuit protection and the advantage of rapidness in system control. Due to the interaction between the rectified voltage appeared on the dc side of the grid-connected CSI and the buffer inductor, the input current on the dc side inherently consists of second order harmonic of the grid frequency. This harmonic component will be modulated by the PWM signal that results in generating low-order harmonics at the output and thus injecting into the grid. In order to suppress the source of the harmonics (i.e., the harmonic current on the dc side), the dc inductor is usually of large value so that the dc input current can be kept constant and the output current waveform is purely determined by the PWM signals. A literature survey on the application of CSI in PV system applications shows an ongoing attempt to take advantage of the points of strength of this topology while identifying the weaknesses and trying to rectify them.

II LITERATURE REVIEW

In [1], a single-stage single-phase grid-connected PV system-based on a CSI is proposed. A doubled-tuned parallel resonant circuit is proposed to eliminate the second- and fourth order harmonics on the dc side. Moreover, a modified carrier based modulation technique is proposed to provide a continuous path for the dc-side current after each active switching cycle.

The control structure consists of MPPT, an ac current loop, and a voltage loop. In a single-phase CSI, the pulsating instantaneous power of twice the system frequency generates even harmonics in the dc-link current. These harmonics reflect onto the ac side as low order odd harmonics in the current and voltage. Undesirably, these even harmonics affect MPPT in PV system applications and reduce the PV lifetime. In order to mitigate the impact of these dc-side harmonics on the ac side and on the PV, the dc link inductance must be large enough to suppress the dc-link current ripple produced by these harmonics. Practically, large dc-link inductance is not acceptable, because of its cost, size, weight, and the fact that it slows MPPT transient response. To reduce the necessary dc-link inductance, a parallel resonant circuit tuned to the second-order harmonic is employed in series with the dc-link inductor. The filter is capable of smoothing the dc-link current by using relatively small inductances. Even though the impact of the second-order harmonic is significant in the dc-link current, the fourth-order harmonic can also affect the dc-link current, especially when the CSI operates at high modulation indices. Therefore, in an attempt to improve the parallel resonant circuit, this paper proposes a double-tuned parallel resonant circuit tuned at the second- and fourth-order harmonics.

In [2], a single-phase full bridge inverter with high-frequency transformer that can be used as part of two stage converter with transformer less single-stage converter for grid connected PV application is proposed. From the literature review of module-integrated converter (MIC) topologies it is observed that, many converter topologies may be employed & many kind of MIC inverters can be found in the literature using half-bridge, full-bridge, buck-boost, flyback structures. In the proposed system the H-bridge inverter is connected to the grid through the output filter composed of L & C.With a closed-loop current controller, the circuit can behave as controlled current source connected to the grid. The high-frequency square voltage produced by the H-bridge is applied to the transformer, whose secondary applies a stepped-up square wave to the inductor. The voltage is then modulated in order to control the inductor current, which must be sinusoidal and synchronized with the grid voltage.

The filter design is critical issue in the inverter performance. A current controller is used to produce a sinusoidal current synchronized with grid voltage at the output of the RC filter. Many type of current controllers for grid-connected inverters have been proposed in the literature. Controllers PI or PID are most widely used. The author designs the proportional & resonant (P+RES) compensator, which is an alternative to the steady state error of PI & PID compensator. The P+RES compensator does not require coordinate transformation nor require PLL (phase-locked loop) synchronization, hence can be easily implemented in single-phase systems. The resonant controller achieves zero steady-state error, it means a unity power factor at the micro-inverter output.

In [3], the single-stage boost inverter is used as a grid-tied inverter to extract the DC power output from the PV array and inject a high quality AC current into the grid. a modified modulation scheme is proposed to enhance the boosting capability of the boost inverter and to improve the THD of the grid injected current. To overcome the asymmetrical output voltage problem, this paper proposes a modified modulation scheme for the grid connected three phase boost inverters that reduces the DC offset of each converter which in turn reduces the stress on both the capacitors and the switching devices as well as enhances the boosting capability of the boost inverter itself. The most attractive feature of this modified scheme apart the other modulation schemes is that it allows both upper and lower half cycles of the AC output voltage to be generated within the same boosting ratio (gain), which results in symmetrical sine wave with reduced THD of the grid injected current with respect to the other modulation schemes. This modified modulation is inspired from the dead band PWM inverters, where one leg of the inverter is clamped for a certain period of time in each cycle, resulting in a dead band region where switching is inhibited. In a three phase circuit, keeping one leg of the inverter inactive will not result in loss of controllability but will reduce the effective switching frequency. The proposed modulation implies that one of the inverter legs is not switching for 120° over the period giving a constant voltage each sinusoidal one third cycle which results in a 33% reduction in the average switching frequency compared to conventional modulation technique. In this paper, a sliding mode controller is designed and applied to control the output voltages of the proposed three phase boost inverter.

In [4], the proposed system is equipped with PV array, battery storage, and a single-phase VSI, which has a new circuit configuration and PWM method. The VSI output current is controlled by both of the firing angle α and the modulation index MI. The VSI circuit consists of the normal single-phase bridge circuit and an additional arm. The two auxiliary self turns- off devices of the arm avail to adopt a composite PWM control, which contributes to reduce the ripple in the AC output current. The series resonance circuit absorbs the double-frequency AC components included in the DC pulsated current.

In [5], a technique for single phase CSI's oscillating power effect mitigation is proposed. The presented technique utilizes an additional PR controller as a harmonic compensator (HC) on the grid current to minimize its third order harmonic component. This PR controller is tuned at three times the grid frequency and works independent from the fundamental grid current PR controller, hence named 3HC-PR technique. The proposed technique is based on cancellation of the 3rd harmonic component from the inverter's grid current using harmonic cancellator based proportional-resonant controller, hence named (3HC-PR). An additional PR controller, tuned at three times the grid frequency, is introduced to the system's main PR controller which is tuned at the grid fundamental frequency. Also, the proposed system is simple in its implementation utilizing conventional SPWM with constant amplitude symmetrical saw-tooth carrier.

In [6], a single-phase, single-stage [no extra converter for voltage boost or maximum power point tracking (MPPT)], doubly grounded, transformer-less PV interface, based on the buck–boost principle, is presented. The configuration is compact and uses lesser components. Only one (undivided) PV source and one buck–boost inductor are used and shared between the two half cycles, which prevents asymmetrical operation and parameter mismatch problems. Total harmonic distortion and dc component of the current supplied to the grid is low, compared to existing topologies and conform to standards like IEEE 1547. A brief review of the existing, transformer-less, grid-connected inverter topologies is also included. It is demonstrated that, as compared to the split PV source topology, the proposed configuration is more effective in MPPT and array utilization. Design and analysis of the inverter in discontinuous conduction mode is carried out. Single-phase, single-stage, transformer-less grid-connected PV interfaces, capable of resolving the double grounding problem, have been reviewed. Most of the existing transformer-less topologies achieve double grounding by using a split PV source. Such topologies, when operating under nonuniform conditions, face problems such as inefficient 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 PV–grid 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 components. The THD and dc component of the injected grid current are much lower as compared to other topologies. In addition, due to its inherent nature, it can work over a wide input voltage range.

In [7], analysis of the development of a method for the mathematical modeling of PV arrays is presented. The objective of the method is to fit the mathematical I–V equation to the experimental remarkable points of the I–V curve of the practical array. The method obtains the parameters of the I–V equation by using the following

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nominal information from the array datasheet: open circuit voltage, short-circuit current, maximum output power, voltage and current at the MPP, and current/temperature and voltage/temperature coefficients. This paper has proposed an effective and straightforward method to fit the mathematical I–V curve to the three (V, I) remarkable points without the need to guess or to estimate any other parameters except the diode constant a. This paper has proposed a closed solution for the problem of finding the parameters of the single-diode model equation of a practical PV array. This paper has presented in detail the equations that constitute the single-diode PV I–V model and the algorithm necessary to obtain the parameters of the equation. In order to show the practical use of the proposed modeling method, this paper has presented two circuit models that can be used to simulate PV arrays with circuit simulators. This paper provides all necessary information to easily develop a single-diode PV array model for analyzing and simulating a PV array.

In [8], the work focuses on inverter technologies for connecting photovoltaic (PV) modules to a single-phase grid. The inverters are categorized into four classifications: 1) the number of power processing stages in cascade; 2) the type of power decoupling between the PV module(s) and the single-phase grid; 3) whether they utilizes a transformer (either line or high frequency) or not; and 4) the type of grid-connected power stage. 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. This review has covered some of the standards that inverters for PV and grid applications must fulfill, which focus on power quality, injection of dc current sin to the grid, detection of islanding operation, and system grounding. The demands stated by the PV modules have also been reviewed; in particular, the role of power decoupling between the modules and the grid has been investigated. The next part of the review was a historical summary of the solutions used in the past, where large areas of PV modules were connected to the grid by means of centralized inverters. This included many shortcomings for which reason the string inverters emerged. A natural development was to add more strings, each with an individual dc–dc converter and MPPT, to the common dc–ac inverter, thus, the multi-string inverters were brought to light. This is believed to be one of the solutions for the future. Another trend seen in this field is the development of the ac module, where each PV module is interfaced to the grid with its own dc–ac inverter.

III Experimental Setup-:

A DC Source (Bus), as a PV cell of was taken. As shown in fig 5.1.The proposed modulation is based on Simple PWM strategy. By using H-bridge inverter topology the output of PV cell is given to the load. The four IGBT switches are used will operate simultaneously in a pair, i.e. in positive half T1 & T2 will conduct, T3 & T4 conduct then output voltage will be negative. The decoupling capacitor across PV cell is used to eliminate the Harmonics. The switching signal is generated from, comparator (VTRI) is used to switch on the IGBT T2 & T4 simultaneously to generate PWM.

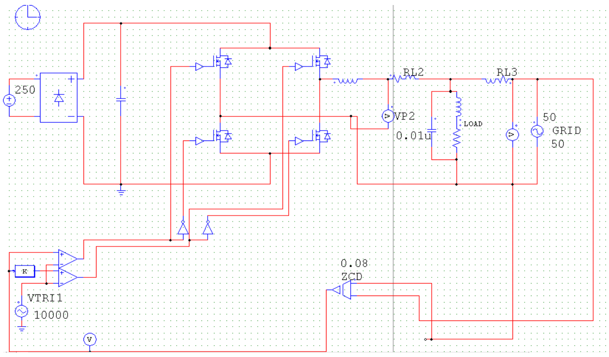

Fig: 5.1 Experimental setup

IV Simulation Results

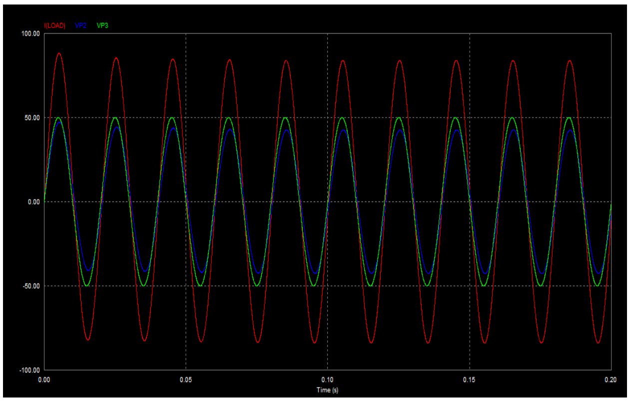

Fig.5.2 Simulation result

The result shows the waveforms of grid-voltage, inverter-voltage, and load-current. The inverter-voltage is synchronized with grid-voltage, i.e the frequency & amplitude of both the waveforms are same.which approximately matches with the inverter with transformer.

V Conclusion

In this paper, general structure of a grid-connected PV system & internal structure of a single-phase inverter & the power conversion stages of inverter is shown. The transformer less grid connected PV system was praposed.The proposed strategy uses simple PWM technology with H-bridge inverter, whose output is as shown in fig 5.2. From the output it can be clear that a PV system with transformer less inverter can easily interface with conventional grid.

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