Single Phase Single-Stage Transformer Less Renewable Energy System for Micro Grid Applications

Seepelli Praveen, Samalla Krishna, Katkuri Laxmi Chaitanya

Abstract— In low power renewable systems, a single phase grid-connected converter is usually adopted. This paper deals with a single stage transformer less single phase converter for micro grid applications with PV system is proposed. By using this system the maximum power tracing is possible from PV array to the micro grid. The maximum power point tracing is maintained with a logical controller. A proportional controller is used to control the current injected into the grid a single-phase, single-stage current source inverter based photovoltaic system for grid connection. A double-tuned parallel resonant circuit is designed to attenuate harmonics at the inverter dc side. It helps to improve the power quality and system efficiency. A modified carrier based modulation technique for the current source inverter is studied to magnetize the dc-link inductor and to control the switching pattern for the single phase grid-connected CSI. The operation of Single Phase Transformer-less grid connected PV system is verified by the Simulation and experimental results show the effectiveness of the proposed solution.

Index Terms—: Distributed power Generation, DC- AC power conversion ,current source inverter grid- connected converters, Single - phase systems, current source converters, Maximum power point tracing (MPT).

I. INTRODUCTION

The energy crises takes place due to the increasing of the population. Because the power requirement is increases day by day but the major drawback the present power production not fulfill the requirements. For this all the regions there is a need of renewable energy sources. The solar power is very suitable resource. In a single-stage grid-connected system, the PV system utilizes a single conversion unit to track the maximum power and interface the PV system to the grid. With this model, PV maximum power is delivered into the grid with high efficiency, small size, and low cost. to fulfill grid requirements, such a topology requires either a step-up transformer, which reduces the system efficiency and increases cost. 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, this two-stage technique suffers from reduced efficiency, higher cost, and larger size.

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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. Different single-stage topologies have been proposed. The conventional voltage source inverter (VSI)Moreover, a bulky transformer and an unreliable electrolytic capacitor are still required. The current source inverter (CSI) has not been extensively investigated for grid- connected renewable energy. The current source inverter (CSI) could be a viable 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.

The aim of this project is to improve power quality and system efficiency, a double tuned resonant circuit is studied to attenuate the second and fourth order harmonics at the inverter dc side. Carrier based PWM Technique is analyzed to generate switching pattern for the IGBT switch of CSI.

II. BASIC STRUCTURE FOR CURRENT FED THROUGH VOLTAGE SOURCE INVERTER TO THE LOAD

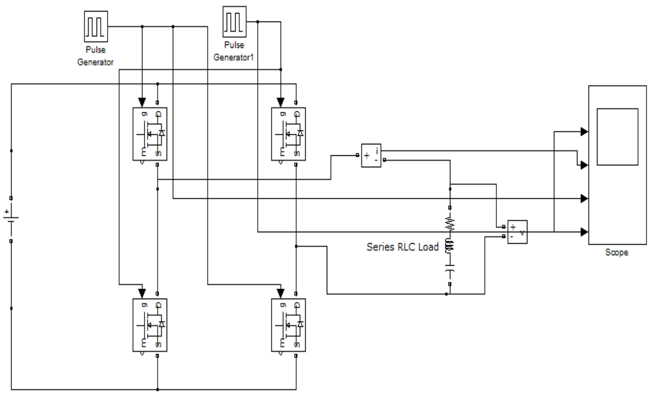

Fig. 1. Voltage source inverter

The current fed bridge inverter with a parallel resonant load is taken for analysis. In above circuit the inductance Ldc is solarge that input current remains constant and a square-wave current is impressed on the resonant-load circuit. The load voltage is nearly sinusoidal.

The IGBT switch are turned off by the reactive power supplied by the load itself, provided the inverter operating frequency is equal to the resonance frequency of the load. In this circuit no separate turn-off arrangement is required. The initial condition when IGBT S1 and IGBT S4 are switched on is

$i \mid_{t=0} = I0$ (1)

$vc \mid_{t=0} = -Vc0$ (2)

The circuit equations are

$iRL + L\frac{di}{dt} = vc$ (3)

$i + C\frac{dvc}{dt} = Iin$ (4)

Where i, vc, RL, L, C and Iin represents output inductor current, output capacitor voltage, internal resistance of inductor, ac line resonant inductor, ac line resonant capacitor and input current of current source inverter respectively.

III. IRCUIT TOPOLOGY

In micro 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.

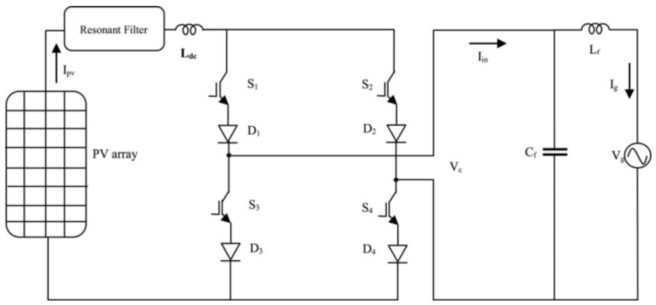

Fig. 2. Single-phase grid connected current source inverter

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.

IV. DOUBLE-TUNED RESONANT FILTER

In a single-phase CSI, the power electronics devices are used to reduce the harmonics, 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.

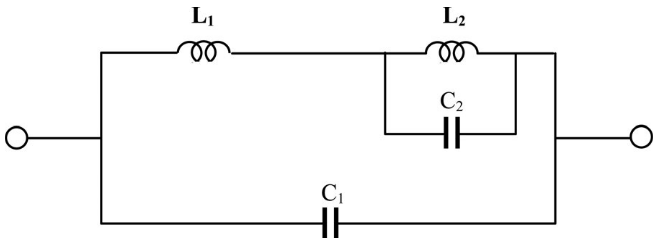

Fig. 3. Proposed double tuned filter

the impedance of *C*1 and the total impedance of *L*1, *L*2 and *C*2 should have equal values of opposite sign. For simplicity, assume component resistances are small, and thus can be neglected in the calculation.

$ZC1 + Zt = 0.$ (5)

From (5), the capacitances are represented by the following equations:

$$C1 = \frac{(L2C2 - \frac{1}{\omega 2})}{(\omega 2L1L2C2 - L1 - L2)} \quad (6)$$

$$C1 = \frac{(-L2)}{(\frac{L2}{C1}\omega 2L1L2)} + \frac{1}{\omega 2L2} \quad (7)$$

Where *C*1 and *C*2 are the resonant filter capacitances, *L*1 and *L*2 are the resonant filter inductances, *ZC*1 is *C*1 impedance, *Zt* is the total impedance of *L*1, *L*2 and *C*2, and ω is the angular frequency of the second- or fourth-orders harmonics. After selecting the inductance values, which are capable of allowing the maximum $\frac{di}{dt}$ at rated current, the angular frequency of the second harmonics in (6) and the angular frequency of the fourth harmonic in (7) are used. The desired capacitances are calculated by numerically solving (6) and (7). The filter is capable of eliminating both the second- and fourth-order harmonics. In order to obtain the relationship between the resonant inductances (*L*1 and *L*2), (5) and (6) are solved for *C*1.

$$C_1 = \frac{\sqrt{L_1(L_1\omega_1^4 + L_1\omega_2^4 - 2L_1\omega_1^2\omega_2^2 - 4L_2\omega_1^2\omega_2^2)} + L_1\omega_1^2 + L_1\omega_2^2}{2L_1^2\omega_1^2\omega_2^2 + 2L_1L_2\omega_1^2\omega_2^2} \quad (8)$$

From (8), to avoid complex numbers in the solution, the relationship between *L*1 and *L*2 should be

$L2 \leq 1.778\, L1$ (9)

To select the optimum values for the proposed filter components, the effects of varying resonant circuit inductance are analyzed. It can be shown that *C*1 is not significantly affected when varying *L*1 and *L*2, whereas *C*2 is affected mainly by *L*2. As *L*2 decreases, the value of *C*2 increases.

RESONANT FILTER INDUCTOR , L1	(mH)	10
RESONANT FILTER INDUCTOR , L2	(mH)	5
RESONANT FILTER CAPACITOR , C1	(μF)	125
RESONANT FILTER CAPACITOR , C2	(μF)	250

Table I. DESIGN VALUES OF RESONANT FILTER

V. MODIFIED CARRIER BASED PULSE WIDTH MODULATION

Use Modified carrier-based pulsewidth modulation (CPWM) is proposed to control the switching pattern for the single-phase grid-connected CSI. In order to provide a continuous path for the dc-side current, at least one top switch in either arm and one bottom switch must be turned ON during every switching period. In conventional sinusoidal pulsewidth modulation (SPWM), the existence of overlap time as the power devices change states allows a continuous path for the dc current. However, the overlap time is insufficient to energize the dc-link inductor, which results in increased THD. Therefore, CPWM is proposed to provide sufficient short-circuit current after every active switching action. CPWM consists of two carriers and one reference.

Fig. 4 shows the reference and carrier waveforms, along with the switching patterns. The carrier with the solid straight line shown in Fig. 4 is responsible for the upper switches, while the dashed line carrier is responsible for the lower switches and is shifted by 180.

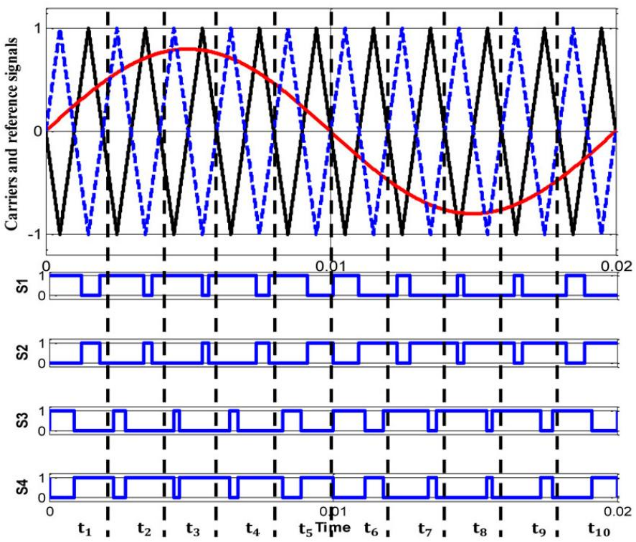

Fig. 4. Proposed carriers-based PWM along with switching sequence for one fundamental frequency

VI. PROPOSED SYSTEM CONTROL TECHNIQUE

To design a grid-connected PV system using a CSI, the relationship between the PV output voltage and the grid voltage is derived as follows. By neglecting inverter losses, the PV output power is equal to the grid power.

VPVIPV = ½*I g, peak*V g, peak cos θ (10)

where θ is the phase angle, VPV and IPV are the PV output voltage and current, respectively, while V g, peak and I g, peak are the grid peak voltage and current, respectively. The grid current is equal to the PV output current multiplied by the inverter modulation index M .

I g, peak = M *IPV (11)

Substituting (10) into (11), assuming unity power factor, the equation describing the relationship between the PV output voltage and the grid voltage is

VPV =1/2*M*V g, peak (12)

Therefore, in order to interface the PV system to the grid using a CSI, the PV voltage should not exceed half the grid peak voltage. The CSI is utilized to track the PV MPP and to interface the PV system to the grid. In order to achieve these requirements, three control loops are employed, namely MPPT, an ac current loop, and a voltage loop. To operate the PV at the MPP, MPPT is used to identify the optimum grid current peak value. Any conventional MPPT technique can be used. However, to prevent significant losses in power, the tracking technique should be fast enough to handle any variation in load or weather conditions. Therefore, a fuzzy logic controller (FLC) is used to quickly locate the MPP.

VII. SIMULATION MODEL DESIGN OF PROPOSED CIRCUIT / RESULTS

In order to validate the theoretical analysis, closed loop operation of single phase current source inverter grid connected using photovoltaic system is simulated on MATLAB/Simulink. The simulated closed loop system has taken the circuit parameter values are shown in table II. The system control mainly consists of an Agilent modular solar array block to emulate PV system operation, a phase-locked loop (PLL) block to ensure synchronization between grid current I g and voltage V g respectively. The Double Tuned Resonant Filter to attenuate the harmonics is presented in dc side of CSI. Modified Carrier based PWM block is presented with a 4-kHz switching frequency to provide a sufficient short circuit current after every switching action and to track the maximum power point and also to interface the PV system to the grid.

Table. II DESIGN SPECIFICATION AND CIRCUIT PARAMETERS

ITEM			VALUE
PV OPEN CIRCUIT VOLTAGE	V_{oc}	(V)	80
PV SHORT CIRCUIT CURRENT	I_{sc}	(A)	15
PV ARRAY RATED POWER	P_R	(W)	500
RESONANT FILTER INDUCTOR	L1	(mH)	10
RESONANT FILTER INDUCTOR	L2	(mH)	5
RESONANT FILTER CAPACITOR	C1	(μF)	125
RESONANT FILTER CAPACITOR	C2	(μF)	250
DC LINK INDUCTOR	L_{dc}	(mH)	5
SWITCHING FREQUENCY	F_s	(kHz)	4
AC LINE INDUCTOR	L	(mH)	1
AC LINE CAPACITOR	C	(mF)	400
GRID VOLTAGE	V_{grms}	(V)	110

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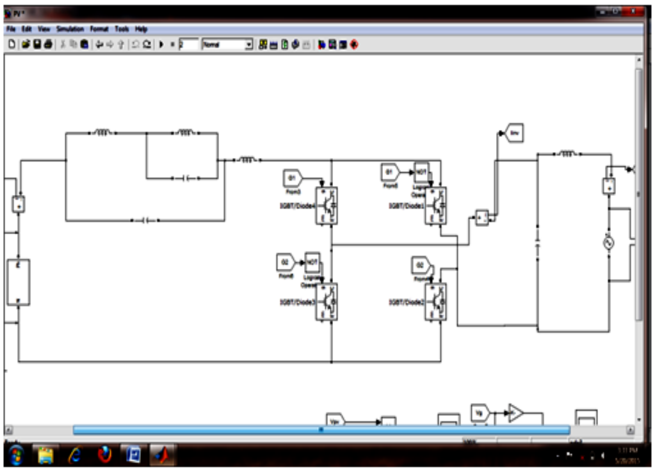

Fig. 5. Proposed system in Matlab Simulink model design

VIII. SIMULATION RESULTS

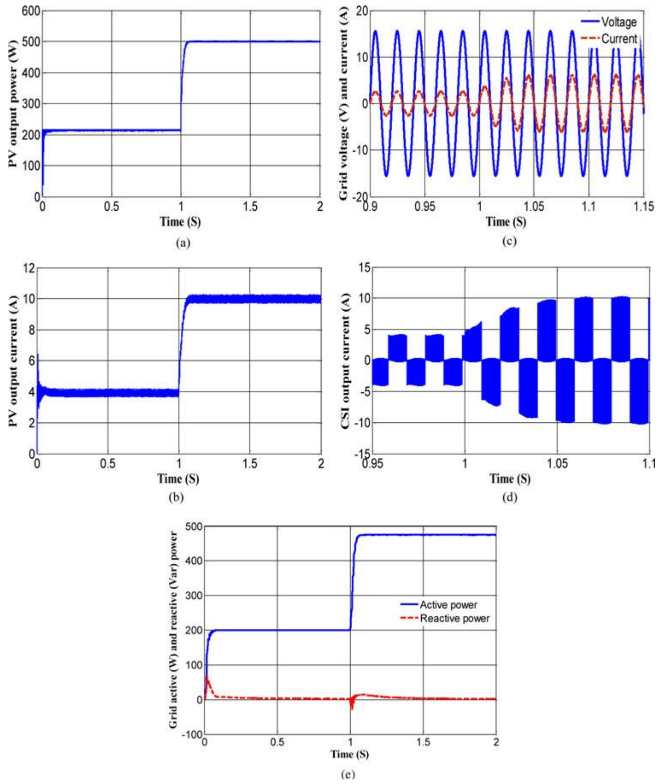

Fig. 6. Proposed simulation results

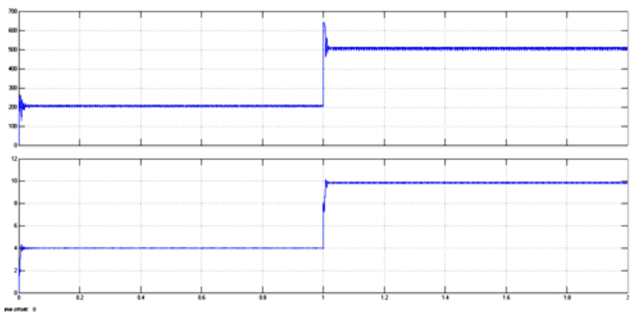

Fig. 7. PV output power and output current

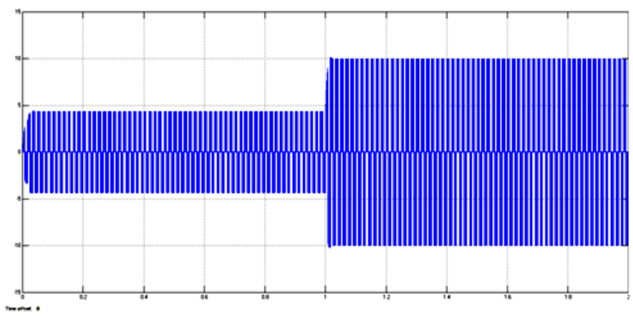

Fig. 8. CSI output current

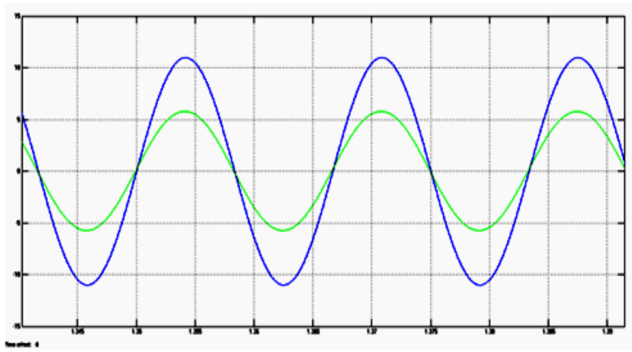

Fig. 9. Grid voltage

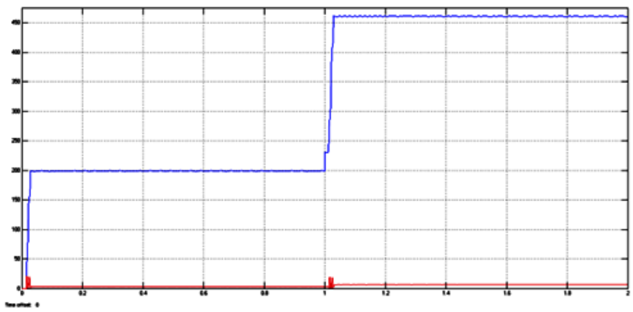

Fig. 10. Grid active and reactive power

IX. ADVANTAGES

1. Reduced harmonic.
2. Less EMI.
3. Smaller & Cheaper filter.
4. Reduced switching power losses.
5. Power factor improvement

X. CONCLUSION

A single-phase single stage transformer-less grid-connected photovoltaic system has been studied that can meet the grid requirements without using a high dc voltage or a bulky transformer. Since the system consists of a single-stage, the PV module power is delivered to the grid with high efficiency, low cost, and small footprint. A modified carrier-based modulation technique has been presented to provide a short circuit current path on the dc side to magnetize the inductor after every conduction mode. Moreover, a double-tuned resonant filter has been designed to suppress the second- and fourth-order harmonics on the dc side with relatively small inductance.

The operation of Single Phase Transformer-less grid connected using photovoltaic system is verified by the simulation using MATLAB/Simulink software. The simulation results are also presented

FUTURE SCOPE

The system can be developed to high level that can further reduce the distortion. As the structure of this project itself implies that it can be very simple and very efficient one. Solar power plant is emerging trend to extract the electrical power. In future this design may more help to invert the power and directly fed to the grid.

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