



Three Phase Transformerless Inverter for Grid Tied Renewable Application by Using Fuzzy Logic Based on P-Q Theory

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Abstract

This paper presents a three phase transformerless photovoltaic inverter for grid tied PV system. A three phase grid is connected to the photovoltaic system with maximum power point tracking (MPPT), along with fuzzy logic controller is used, the control strategy is applied based on p-q theory for better utilization of the photovoltaic system, according to this strategy during sunlight the system sends active power to the grid and at the same time compensates the reactive power of the load. In case there is no sunlight (during the night for instance), the inverter only compensates the reactive power of the load. The advantage of this strategy is the operation of the photovoltaic system the whole day.

Keywords: grid tied inverter, transformerless inverter, fuzzy logic controller

1- Introduction

Over a last two decades, renewable energy sources become very popular. In renewable energy sources Photovoltaic (PV) power system place a major role. because they generate a electricity with no moving parts and its operates quietly with no emission and it requires a little maintenance[1] [2]. Distributed grid-connected PVs are playing an very important role as the integral part of the electrical grid. However, due to the large stray capacitors between the PV panels and the ground, PV systems suffer from a high common mode (CM) current, which reduces the efficiency of the system and may cause a electric shock., transformers are commonly used to eliminate the leakage currents, in the PV system to provide galvanic isolation. However, it possesses undesirable properties including large size, high cost, and weight with additional losses [3]. Thus, removing the transformer is a great benefit for a further improvement to increase the efficiency of the system efficiency, reduce the size, and weight [4]. One of the important issues in the transformerless grid connected PV system is the galvanic connection of the grid and Photovoltaic system, which leads to a leakage current problems. For transformerless grid-connected inverters, full-bridge (FB) inverter, neutral point clamped (NPC), active NPC (ANPC) inverter [5], and many other topologies such as H5, H6, and highly efficient and reliable inverter concept (HERIC) were proposed to reduce a leakage current with disconnecting of the grid from the PV during the freewheeling modes [6]. However, these topologies are not totally free from leakage current or a Common mode current . The leakage current still exists due to the parasitic

capacitor of the switch and stray capacitance between the PV panel and ground. So, some of these topologies require two or more filter inductors are used to reduce the leakage current, which leads to a rise in the volume and cost of the system. Photovoltaic (PV) ac modules may become a trend for the future PV systems because of their greater flexibility in distributed system expansion, easier installation due to their plug and play” nature, lower manufacturing cost from modular and a scalable production, and higher system-level energy harnessing capabilities under shaded or PV manufacturing mismatch conditions as compared to the single or multi- string inverter. A number of inverter topologies for PV ac module applications had been reported so far with respect to the number of power stages, location of power-decoupling capacitors, use of a transformers, and types of grid interface. Unfortunately, these solutions are suffer from one or more of the following major drawbacks:

- (1) The limited-lifetime issue of the electrolytic capacitors for a power decoupling.
- (2) Limited input voltage range for a available panels in the market.
- (3) high ground leakage current when the unipolar pulse-width- modulation(PWM) scheme is used in a transformer-less PV system.
- (4) Low system efficiency if an additional high-frequency bidirectional converter is employed.

2. Three Phase Grid Tied Transformerless Inverter

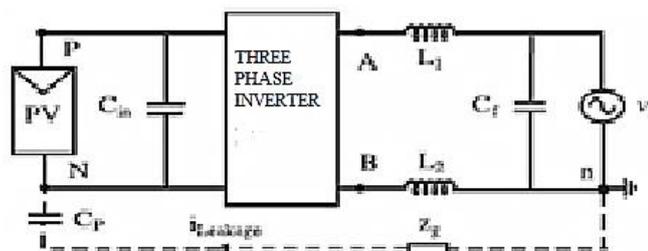


Fig. 1: Illustrates a Three-phase grid tied transformerless inverter with Common mode current path, where P is positive terminal and N is negative terminals of the Photovoltaic, respectively.

In order to eliminate the leakage current, the Common mode voltage (CMV) (v_{cm}) must be kept constant during all operation modes according to it. The V_{cm} with two inductor filters (L_1, L_2) is calculated as follows:

$$V_{cm} = V_{An} + V_{Bn} + (V_{An} - V_{Bn}) \frac{(L_2 - L_1)^2}{L_2 + L_1} \quad (1)$$

Where V_{An} and V_{Bn} are the voltage difference between a midpoint A and B of the inverter to the dc bus minus terminal N, respectively.

If $L_1 \neq L_2$ (asymmetrical inductor), V_{cm} is calculated according to (1) and the leakage current appears due to a varying Common mode voltage. If $L_1 = L_2$ (symmetrical inductor), V_{cm} is simplified to

$$V_{cm} = V_{An} + V_{Bn} = \text{constant} \quad (2)$$

3. Proposed topology and modulation strategy proposed three phase grid tied inverter

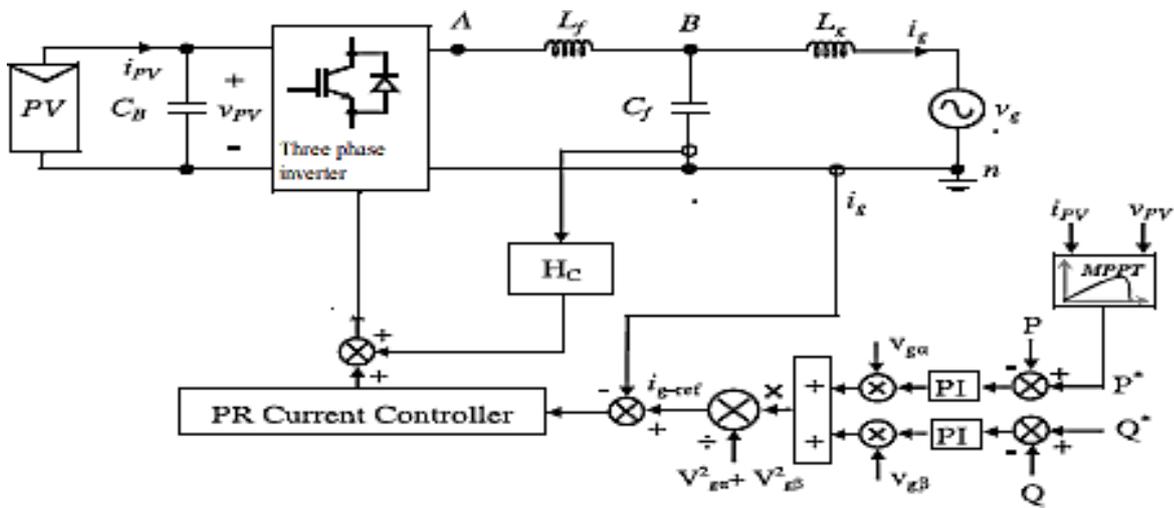


Fig. 2: proposed Three phase grid tied inverter based on PQ theory

The control strategy of the proposed grid-tied three-phase inverter is shown in Fig. 2. It contains two cascaded loops the first loop is an inner control loop, which has the responsibilities to generate a sinusoidal current and the outer control loop is implemented for the current reference generation, where the power is controlled. A proportional resonant (PR) controller provide an infinite gain at the resonant frequency (f_{res}) and can eliminate the steady state error when tracking a sinusoidal signal, which is an index of power quality. Due to these features, the PR controller is selected instead of the PI controller in the current control loop in this topology [7]. The transfer function of this controller can be found as follows.

$$(S) = KP + 2KrS^2 + \omega^2 \tag{3}$$

Where K_P is the proportional gain K_r is the fundamental resonant gain, and ω is the resonant frequency.

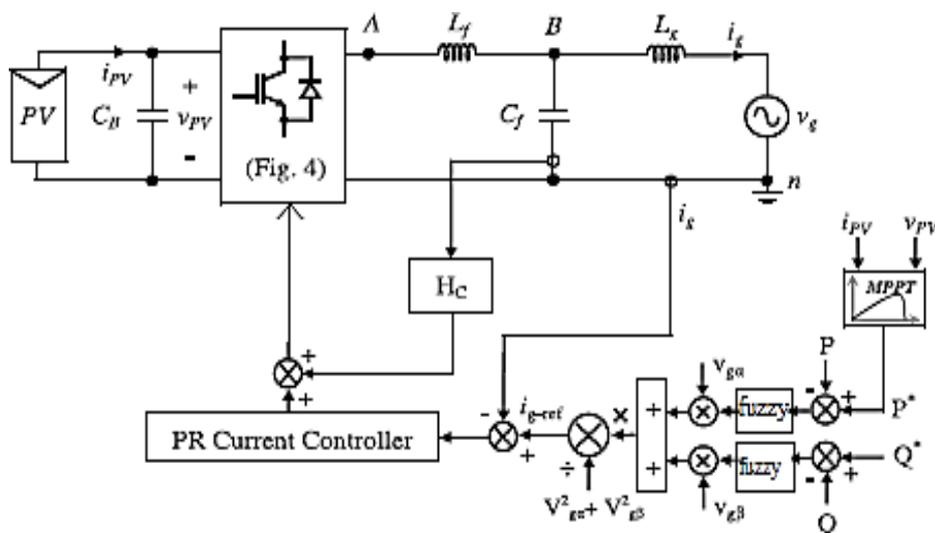


Fig. 3 : Figure shows the Three phase grid tied inverter based on fuzzy logic

The power control loop requires orthogonal signal generation systems to create quadrature components ($v_{g\alpha}$, $v_{g\beta}$ and $i_{g\alpha}$, $i_{g\beta}$) corresponding to the grid voltage v_g and grid current i_g , and then it generates a current reference, which is to be used in the inner current control loop. According to the single-phase PQ theory [8], [9], the current reference can be produced by regulating the active and reactive powers. The active power (P) and reactive power (Q) for the proposed topology can be calculated by [10].

$$P = V_{g\alpha}i_{g\alpha} + V_{g\beta}i_{g\beta} \tag{4}$$

$$Q = V_{g\alpha}i_{g\beta} - V_{g\beta}i_{g\alpha} \tag{5}$$

Where, $V_{g\alpha}$, $V_{g\beta}$, $i_{g\alpha}$, $i_{g\beta}$ are the α and β components of grid voltage and grid current, respectively. The active power and reactive power reference (P^* and Q^*) can be tuned by the operators {R-3} or in the control unit, When the MPPT control is activated. The current reference can be computed in the $\alpha\beta$ – reference frame, which simplifies the overall control. Fuzzy logic is connected in between MPPT and PR controller. Fuzzy logic is used in order to eliminate the leakage current [11].

TABLE 1: PARAMETER VALUES SIMULATIONS

Parameter	Value	Parameter	Value
Power rating (P)	500 W	Capacitance (C_1)	220 μ F, 500 V
Input voltage (V_{dc})	400V	Capacitance (C_2)	330 μ F, 500 V
Output voltage (v_{Bn})	220 V (RMS)	L filter (L_f)	4 mH
Input capacitor (C_B)	470 μ F, 500 V	C filter (C_f)	2.2 μ F
Power switches ($S_1 - S_4$)	C2M0080120D, SiC MOSFET	L_g	2 mH
Diodes (D_1, D_2)	C3D10060A Schottky Diode	Switching frequency (f_s)	24 kHz

SIMULATIONS

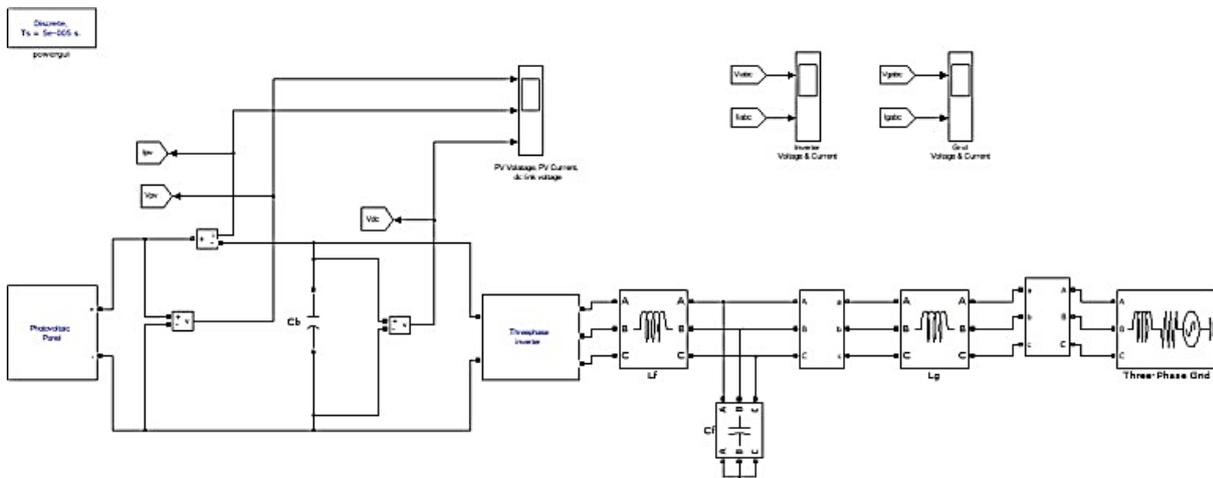


Fig 4: Three phase grid tied inverter based on p-q theory

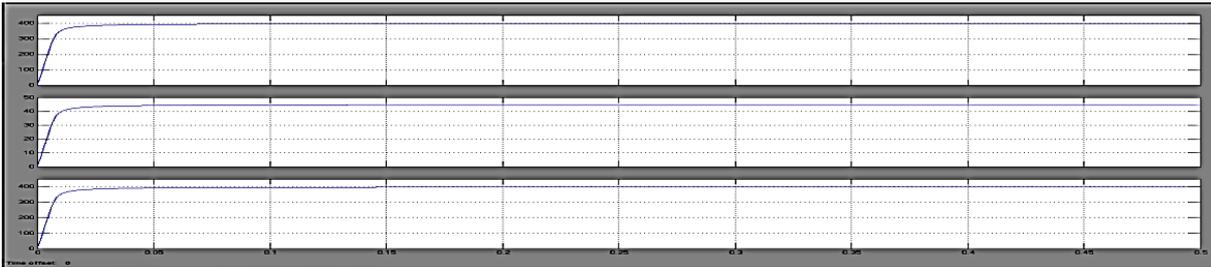


Fig. 5: waveform shows the PV voltage, current and DC link voltage

Figure 5 waveform shows the PV voltage, PV current and DC link voltage x axis represents time in seconds and y axis represents voltage in volts. The PV voltage and DC link voltage are in same phases and voltages are same. In PV current waveforms x axis represents time in seconds and y axis represents currents in Amps. The PV voltage and DC link voltage are same i.e, 400v and current is 40 Amps.

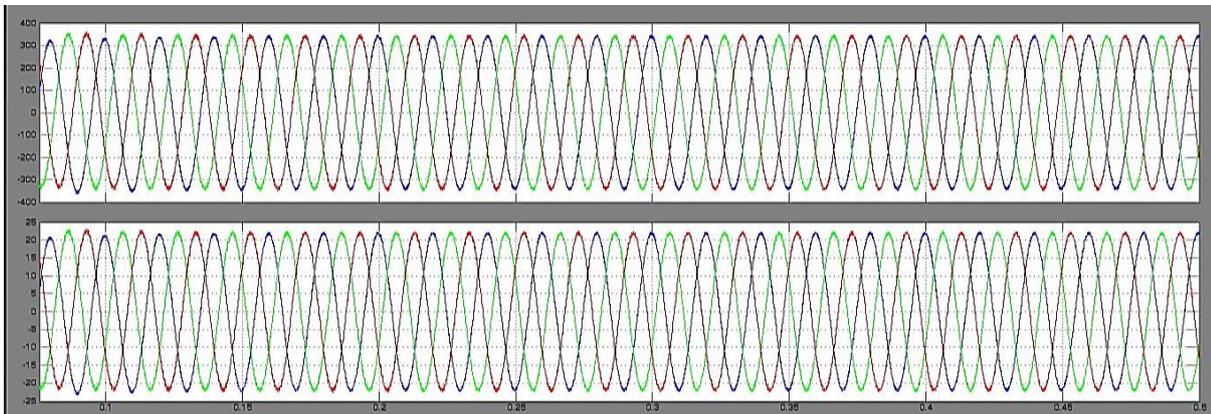


Fig. 6: waveform shows the Inverter voltage and current

FIG 6 waveforms shows the inverter voltage and inverter currents For inverter voltage X axis represents time in seconds and Y axis represents voltage in volts, inverter voltage is also known as VAN. whereas for the inverter currents X axis represents time in seconds and Y axis represents current in Amps. The magnitude of inverter voltage is 400V and currents is 23Amps.

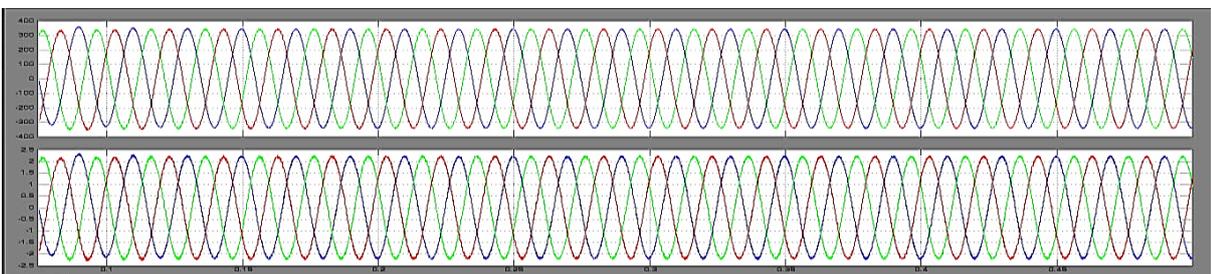


Fig. 7: waveform shows the Grid voltage and current

The Fig. 7 represents the proposed grid current of the inverter X represent Time in seconds and Y axis represent the voltage in volts . From Fig.7 it is observed that the grid voltage has the same phase as the grid current. From Fig.7, it is clear that the output voltage of the proposed inverter are highly sinusoidal with low harmonic distortion .The output voltage is 400v and output current is 2.3 amps.

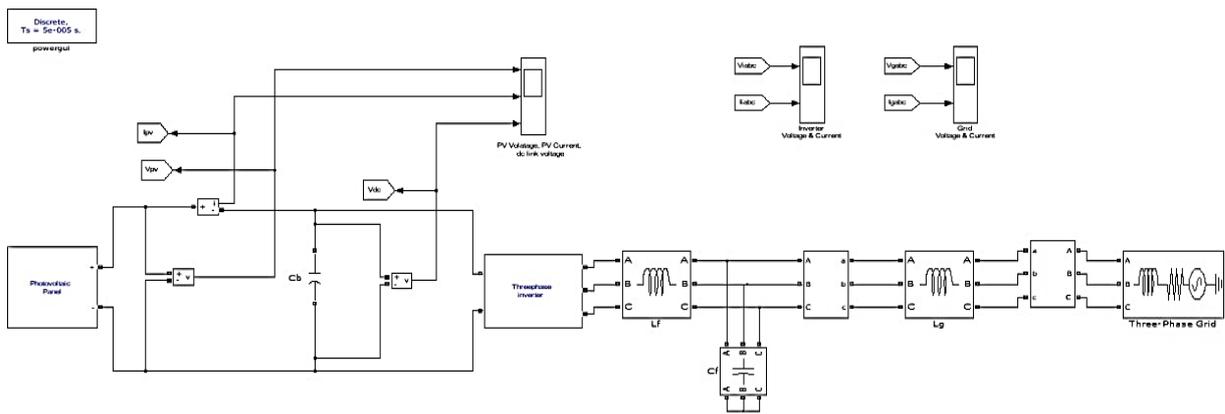


Fig. 8 : the three phase transformerless inverter by using fuzzy logic

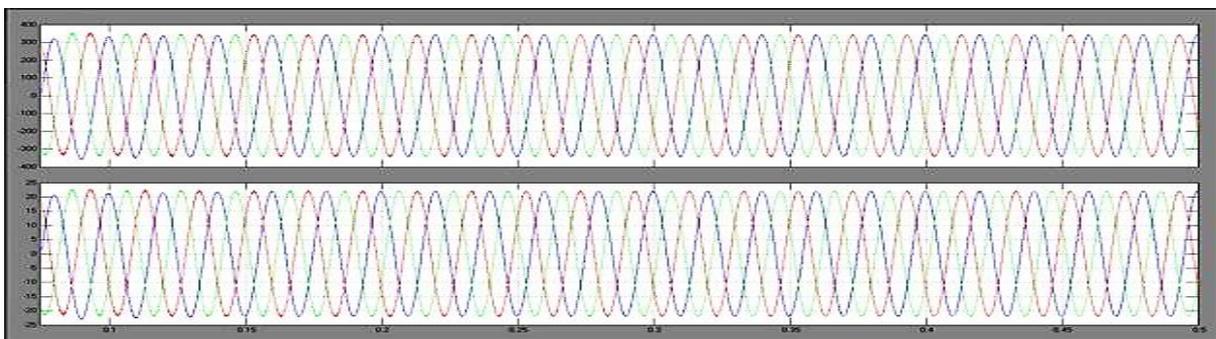


Fig. 9: waveform shows the Inverter voltage and current by using fuzzy logic

FIG 9 waveforms shows the inverter voltage and inverter currents by using fuzzy logic. voltage X axis represents time in seconds and Y axis represents voltage in volts, inverter voltage is also known as VAN. whereas for the inverter currents X axis represents time in seconds and Y axis represents current in Amps. The magnitude of inverter voltage is 400V and current is 23Amps

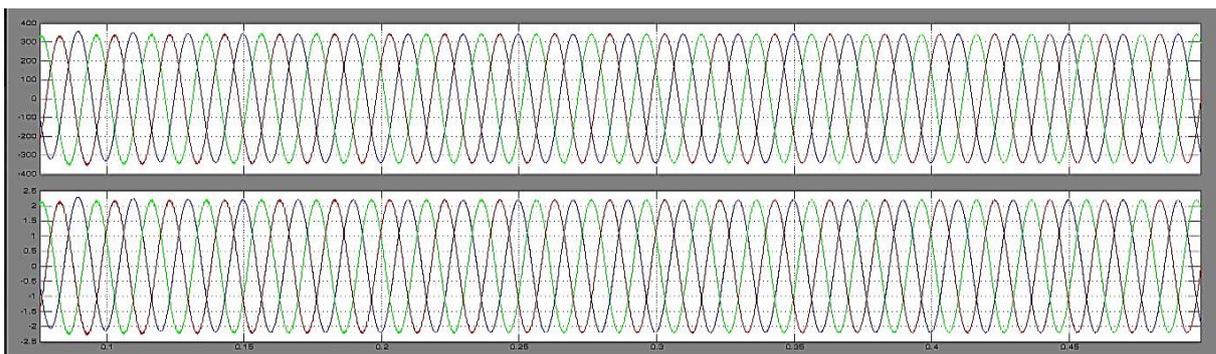


Fig. 10: waveform shows the grid voltage and current by using fuzzy logic

The Fig. 10 represents the grid current of the inverter by using fuzzy logic X represent Time in seconds and Y axis represent the voltage in volts . From Fig.10 it is observed that the grid voltage has the same phase as the grid current. From Fig.10, it is clear that the output voltage of the proposed inverter are highly sinusoidal with low harmonic distortion .The output voltage is 400v and output current is 2.3 amps by using fuzzy logic.

Conclusion

This paper proposed a new Three-phase transformerless inverter for the grid-tied PV system.. The proposed topology has also the ability to deliver reactive power into the grid. In addition, the proposed topology can be realized with a minimum number of components; hence, a higher power density can be achieved with the lower design cost. Compared to other existing transformerless topologies, the performance depicted by the proposed inverter is good. fuzzy logic control is used for reducing the steady state error.

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