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Review on A Single Phase Grid Connected Five-Level Converter for Renewable Distribution System with Reactive Power Control

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Abstract: *Single phase converters are the popular choice in low-power grid connected systems. However, these converters invariably use a power transformer on the output side, which increases the system losses, cost and size. This paper discusses a five-level single phase converter topology that does not require a transformer on the output side, thereby removing the disadvantages associated with it. The converter architecture is based on a full bridge topology, with an addition of two more power switches and two diodes. The diodes are connected to the midpoint of the dc link. Since the discharging of the two capacitors is responsible for the addition of the added levels, the balancing of the midpoint voltage of the capacitors has been considered. Further, the control of the amount of reactive power fed into the grid by the converter is also considered in the control scheme. Simulation results will be used to show the effectiveness of the proposed solution.*

Keywords *—Multilevel systems, photovoltaic(PV) systems,Voltage source inverter,Common mode leakage current, five level converter, pulse width modulation(PWM), PLL, DClink.*

INTRODUCTION

Recently, solutions employing high frequency transformers, or making no use of transformer at all, have been investigated in order to reduce size, weight and cost[1] . In low power applications, international standards allow the use of grid connected power converter without any galvanic isolation, thus allowing the so-called ‘transformer less architectures[7].

The standard solution for single phase converters is the three level (unipolar) full bridge architecture. As the number of output voltage levels increases, the harmonic distortion of the injected grid current decreases, allowing the use of smaller and cheaper output filters. Moreover, multilevel topologies are usually characterized by a strong reduction of the switching voltages across the power switches, allowing the reduction of switching power losses and EM[1][7]I. This work uses a novel five-level converter based on a full bridge topology with two added power switches and two diodes connected to the mid-point of the dc link. In order to balance the mid-point voltage, a suitable PWM modulation strategy is employed[4][8].

Another important issue of grid-tied transformer less PV inverter is the ability of injecting reactive power into the utility grid[3]. Recently almost every international regulation has imposed that a definite amount of reactive power should be handled by the grid-tied PV inverter. This is due to the problems of grid voltage instability. Reactive power control of the grid, by injecting suitable reactive power into the grid will also be attempted so that the grid should attain power factor from 0.95 leading to 0.95 lagging.

I. LITERATURE SURVEY

[1]Multilevel transformer less topologies for single-phase grid-connected converters,Oscar L´opez, Remus Teodorescu,et al

Multilevel voltage source inverters synthesize the AC output terminal voltage from several levels of voltages, eliminates the need of transformer thus

reduce harmonic distortion, losses, costs, size and filter requirements Galvanic connection of the grid and the DC sources in transformerless systems introduce additional leakage currents due to the earth capacitance. Amplitude and spectrum of leakage current depends on converter topology, switching strategy, resonant circuit formed by the ground capacitance, converter, AC filter and the grid. Regarding only to ground current the half bridge neutral point clamp is the best choice. Leakage current in cascaded converter is expected to decrease when the number of levels increases. In Half bridge topology the ground voltage is constant and thus, eliminates ground current

[2]Single Phase Transformerless Photovoltaic Inverter with Reactive Power Control, Bhavik Brahmbhatt, et al

A least complex grid synchronization Approach is used for the generation of orthogonal and parallel components of the grid voltage using various computing techniques to generate a Synchronized current reference value in the current control Loop. To eliminate common mode leakage current,PV system uses half bridge and full bridge inverter with sine pwm as in this case variable common mode is not generated. Grid voltage estimator produces two components. Parallel components multiplexed with the grid voltage and orthogonal component leads the grid voltage by 90 degree, the resulting current component thus, control the active power flow similarly orthogonal component of current controls reactive power through to the Grid.

[3]Reactive power control of single phase grid tied VSI for residential PV application XiangdongZong et al

A reactive power control method is discussed for a grid tied single phase voltage sourced inverter for residential photovoltaic (pv) power integration. A low complexity grid synchronization method, decouples the active and reactive power component so that each component can be controlled independently. The reactive current component used as control command to inject or absorb reactive current. Thus, inverter independently control reactive power flow.A PR compensator tracks a sine reference current.Notch filter eliminates ripples in dc link voltages such that output grid current free from ripple component.

[4] A new proposal for ground leakage current reduction in Transformerless Grid-Connected Converters for Photovoltaic Plants Barater D, et al

In this paper converter topology is developed to minimize ground leakage current using unipolar PWM without increasing size of common mode filter and increasing efficiency It is based on two blocks added to full bridge converter viz. DC coupling block locks common mode voltage to Vdc/2 and No ideal compensation block Keeps Vcm constant. In FBT leakage current caused by Vcm. To avoid Vcm converter topologies used are HBT,NPC.[1]

[5]Power Control and Pulsation Decoupling in a Single Phase Grid-Connected Voltage-Source Inverter, Chi Yao Wu, et al

A power control and power pulsation decoupling method has been proposed by integrating with digital PLL. Digital PLL provides harmonic and noise rejection, better stability within wide angular and frequency variation. The method of RP control permits distributed VSI units to be used as SVC besides energy sources. DPLL methods provide various components of grid voltage and injected grid current. PR controller controls grid current and Decoupling capacitos mitigate ripple effect. A bidirectional boost buck converter used to realize power decoupling. Based on current direction it has two modes viz.Buck mode where excess power generated stored in decoupled capacitor, and Boost mode where stored energy provided to the grid.To control capacitor voltage, voltage pwm control is employed.

[6] Efficient Single Phase Transformerless Inverter for Grid-Tied PVG System With Reactive Power Control, Monirul Islam, et al

In this paper, a new high efficiency transformer less topology for grid-tied PV system is presented. The main advantages of the proposed topology can be summarized as:

1) The proposed topology does not lead itself to the reverse recovery issues which allow utilizing MOSFET switches even though when inject reactive power. Therefore, without compromising

the overall efficiency, proposed topology can inject reactive power into the utility grid.
2) The CM voltage is kept constant at the mid-point of dc bus voltage; as a result, low leakage current flows through the system which is lower than the H6-type topology[4].
3) PWM dead time is not required for the proposed topology that reduces the THD at the output**.**

[7] A Novel Five-Level Single Phase Grid Connected Converter for Renewable Distributed Systems,Giampaolo Buticchi, et al

In low-power grid connected systems (renewable or traditional energy sources) a single phase converter is usually adopted. In order to reduce losses, costs and size the keyword is removing any kind of transformer. This paper deals with a novel five level converter topology that follows this trend. The proposed converter architecture is based on a full bridge topology with two more power switches and two diodes connected to the midpoint of the DC link[1]. Since the two added levels are obtained by the discharge of two capacitors, the balancing of the midpoint voltage is taken into account.

[8] Multilevel Inverter For Grid-Connected PV System Employing Digital PI Controller,Jeyraj Selvaraj et al

This paper presented a single-phase multilevel inverter for PV application. It uses two signals viz. reference signals and a carrier signal to generate PWM switching signals. A digital PI current control algorithm is implemented to optimize the performance of the inverter. It can be experimentally shown that the THD of the five-level inverter is lower than that of the conventional three-level inverter. Additionally, both the grid voltage and the grid current are in phase at near-unity power factor.

[9] A New Single-Phase PLL Structure Based on Second Order Generalized Integrator, Mihai Ciobotaru, Remus Teodorescu et al

A new PLL method to generate orthogonal voltage systemis based on SOGI.The advantages of proposed method are Simple implementation and Strucutre is immune to frequency changes.For determining phase an orthogonal system is required.

Function of PLL structure:

- Provide unitary PF operation, synchronization of inverter output voltage with grid voltage
- Provide clean sine current reference
- To monitor grid voltage parameters amplitude and frequency

Orthogonal system Generation:

V is the input voltage, V' and qv' are orthogonal components. Thus grid voltage in filtered into two orthogonal components due to resonance frequency of SOGI.

II. OBSERVATIONS AND IDENTIFICATION FROM LITERATURE REVIEW

Benefits of using transformerless PV system:

1. Usually much lighter in weight than inverters with transformers.
2. Have higher efficiency ratings.
3. Capable of dual MPPT inputs, depending on manufacturer
4. Lower cost and size,higher efficiency
5. Embodied energy.
6. They can generate output voltages with extremely low distortion and lower dv/dt.
7. They draw input current with very less distortion.
8. They generate smaller common mode (CM) voltage, thus reducing the stress in motor bearings
9. They can operate with a lower switching frequency.

PHASE LOCKED LOOP

- It can be used control the reactive power of the grid
- For synchronization of grid output voltage with that of grid and monitoring grid voltage parameters as amplitude and frequency.
- It provides unitary power factor operation.

Unipolar PWM method can be used to control the mid point voltage of the dc link.

Research objective has been decided

i. Grid synchronization and control

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ii. Grid-side controller, which can have the following tasks:

- active power generated to the grid should be controlled;
- reactive power transfer between the DPGS and the grid should be taken care of;
- dc-link voltage needs to be controlled;
- high quality of the injected power should be ensured.

III. RESEARCH PROBLEM STATEMENT

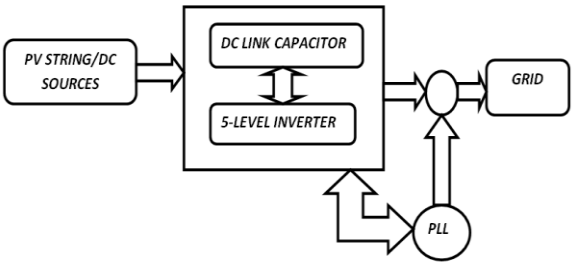


Fig:(1)

Utilization of a custom five-level inverter for interfacing a renewable energy source with the grid. The five-level converter provides an output with less harmonic distortion, minimizes the common- mode leakage current and improves the efficiency[7]

- To **synchronize** the inverter output **voltage** with that of the grid.
- To **Balance** the input side dc link capacitors, responsible for synthesizing the five-level output voltage
- To handle the output **reactive power** of the converter so as to control the reactive power of the Grid

IV. PROPOSED METHODOLOGY AND SYSTEM DESCRIPTION

Five-level single-phase topology

As shown in Fig(2)[7], the main work is to utilize a custom five-level inverter for interfacing a renewable energy source with the grid. The five-level converter provides an output with less harmonic distortion; minimizes the common- mode leakage current and improves the efficiency.

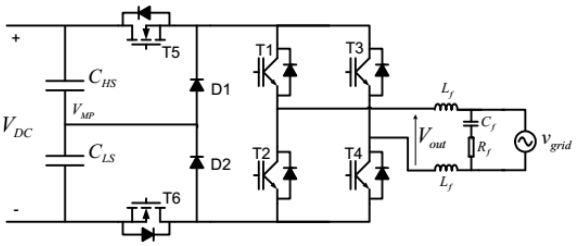
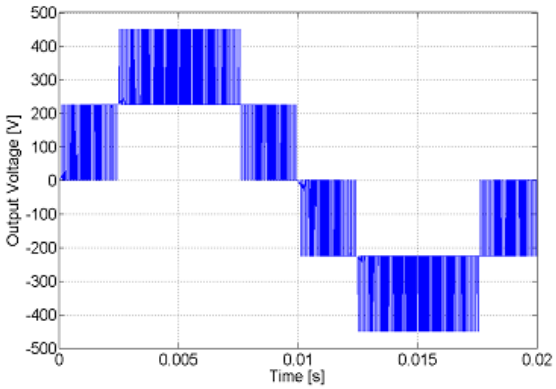


Fig: (2)

Fig. (3)[7] shows the output voltage waveform of the inverter over a full cycle corresponding to the grid voltage period. Fig. 3 shows the modulation index waveform in steady state conditions, along with definition of the four different PWM zones. The definitions of the PWM zones, depending on the modulation index m, are also listed in Table I.



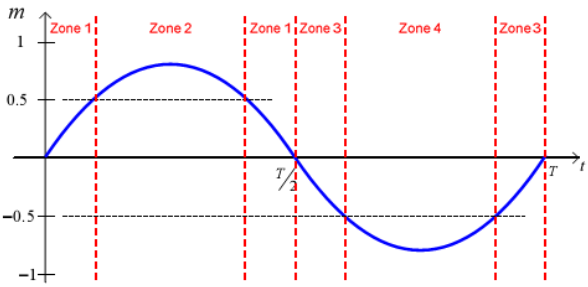


Fig:(3)

TABLE I
OUTPUT VOLTAGES DEPENDING ON MODULATION INDEX m

Zone	m	Output Voltages
Zone 1	$0 < m < 0.5$	$+V_{MP}$ and 0
Zone 2	$0.5 < m < 1$	$+V_{MP}$ and $+V_{DC}$
Zone 3	$-0.5 < m < 0$	0 and $-V_{MP}$
Zone 4	$-0.5 < m < -1$	$-V_{MP}$ and $-V_{DC}$

During the positive half-cycle, the transistors T1 and T4 are ON and T2 and T3 are OFF. In Zone 1,

T5 is OFF and T6 commutates at the switching frequency, while in Zone 2 T5 commutates at the switching frequency and T6 is ON. During the negative half-cycle, the full bridge changes configuration, with T1 and T4 OFF and T2 and T3 ON. With similarity to Zone 1 and 2, in Zone 3 T5 commutates while T6 is OFF, and in Zone 4 T5 in ON and T6 commutates.

Fig. 4[7] shows the gate signals for the five-level modulation strategy. The advantage of this strategy is that only two transistors commutate at high frequency, while the four transistors of the full bridge commutate at line frequency.

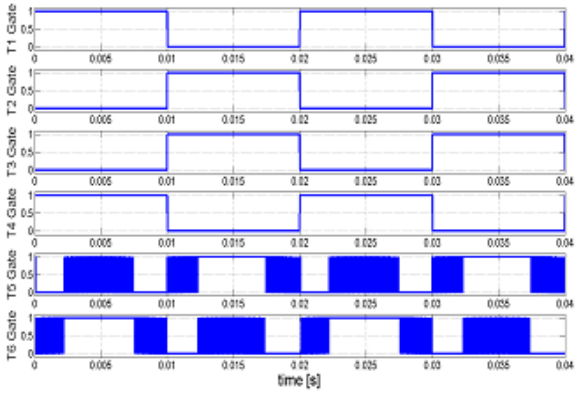


Fig. 4 PWM Gate Signals for the Five-Level Modulation Strategy

Mid-point Voltage Balancing and Reactive Power Control

The mid-point voltage balancing can be obtained by ensuring that the discharge times of the high-side and low-side capacitors are the same[7]. A suitable control scheme will be utilized to ensure that the voltages on the two capacitors are kept equal. This will be ensured, in turn, by maintaining the discharge times of the two capacitors same over a complete grid-cycle.

A PLL will be used to synchronize the inverter output voltage with the grid-voltage[5][9]. It is proposed to keep a slight phase displacement between the inverter output voltage and the grid voltage, so that the inverter is able to feed both active as well as reactive power to the grid. A suitable control scheme will be devised and implemented to control the amount of reactive power that is fed to the grid.

V. CONCLUSION

The present papers discusses various aspects of using transformerless system. The proposed work deals with a novel five-level topology for single-phase grid connected converters[7]. The PWM modulation strategy for the converter was chosen in order to obtain the minimum number of commutations to maximize efficiency[4][8]. The converter topology uses the mid-point voltage of the dc link to provide two more output voltage levels, decreasing switching power losses and EMI. The balancing of the mid-point voltage will be taken into account and a suitable control scheme, able to compensate system asymmetries, will be developed.[4][6] The control scheme will also control the reactive power injected into the grid so as to maintain the power factor at the grid as close to unity as possible[5][9].

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