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A Literature Survey on Transformer less Grid Connected Inverter Circuits Used in Solar Photovoltaic Systems- Using Different Filters

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***Abstract*—In this survey paper discuss the In this present work a grid associated PV system without utilization of transformer. The required power for grid is accomplished and can be transfer without utilization of transformer. The MPPT effectively obtain wanted voltage at Maximum Power Point. The system utilizes CSI which is further drive via carrier based PWM. The high value inductor (L) can be decreased by two fold tuned resonant filter. Resonant filter also eliminated harmonics. The THD with Inductor is 1.86 and with Double tuned filter 1.36. All outcomes are simulated in MATLAB/SIMULINK..**

Keywords*— *Space-Time Trellis Code (STTC), Filter, Inter-Carrier Interference, Bit Error Rate (BER), Signal To Noise Ratio (SNR) And Wireless Fading Channe.

I. INTRODUCTION

As one of the most effective ways to fight against these environmental concerns, photovoltaic (PV) technology has experienced significant development and huge cost improvements over the past decade.

Particularly in recent years, driven by the rising demand for electricity and the increasing competitiveness of solar PV energy, PV capacity has expanded exponentially in some regions[11]. According to data from the Renewable 2017 Global Status Report, additions to the worldwide PV capacity during 2016 reached 75 GW with an increase of 48% compare to 2015, which is greater than the cumulative world capacity five years earlier[12].

Among this amount over 34 GW were contributed from China, representing nearly half of the global additions.

A. An Overview Of Grid-Connected Pv Inverter System

The control functions are implemented to ensure the grid-connected PV inverter system injects a sinusoidal current to the grid at the highest possible conversion efficiency.

More specifically, the outer loop, for DC voltage control, balances the active power between the DC side and the grid side by maintaining the voltage across the DC link capacitor at a specific reference level Meanwhile the Current controller and grid synchronization work together as an inner loop to regulate the output sinusoidal current, allowing for the PV inverter and the grid to work in unison[13].

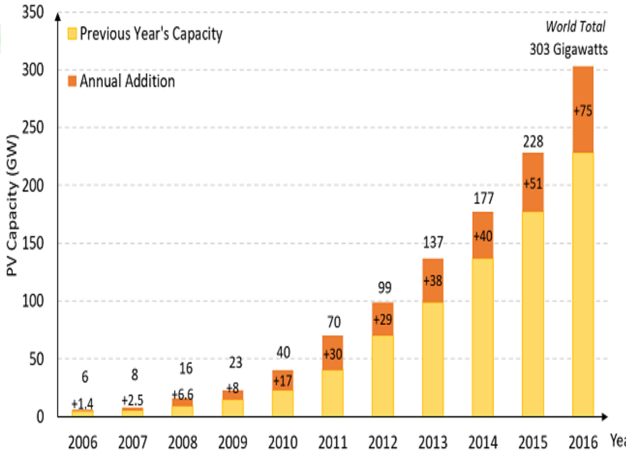

Fig 1.1 World solar PV capacity and annual additions between 2006 and 2016

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These control functions including output current control and grid synchronization techniques, are discussed in detail in this pepar.

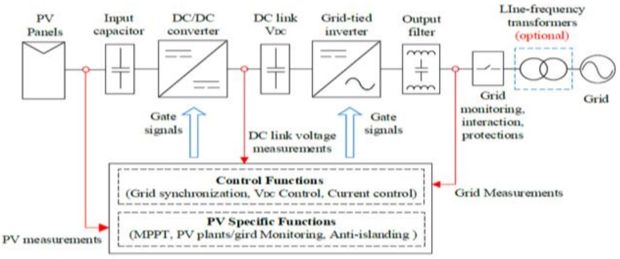

Fig 1 An overview of generic two-stage grid-connected PV inverter system

B. Objectives and Scope of the Research

The specific objectives of the thesis are listed as follows:

To review the advantages and disadvantages of published DC measurement or suppression techniques along with remaining technical challenges and research barriers.

To study controller performance against power quality issues including DC and harmonic mitigation in grid-connected PV inverter systems[14]. To develop cost-effective solutions to be used to suppress, or compensate for, DC current injection in the grid-connected transformer less inverter. To develop simulation models and experimental test rigs in order to validate the proposed DC suppression methods.

II. LITERATURE SURVEY

Sudipto Monda et.al.(2023) **-** A single-phase five-level SC based transformer less inverter is proposed for grid-tied PV systems. The proposed transformer less inverter has voltage boosting capability by utilizing only a single SC ensuring five-level output voltage. The common mode voltage of the proposed transformer less inverter is found quite stable and thus the leakage current is found around 15.33mA in simulation and 17.1mA in hardware validation. The overall power loss and heat distribution among all the power switches are also found satisfactory for the proposed transformer less inverter. The total power loss is found around 6.42W at rated power and the efficiency is found around 98.3% which is higher than those of the many existing transformer less inverter topologies. The injected grid current THD for the proposed transformer less inverter is found 1.03% for a SC of 3300µF which ensures improved power quality of the inverter while feeding PV power to the grid [01].

Parimalasundar Ezhilvannan et.al. (2023) - several factors have been considered and adjusted to create a PV network that is a part of the grid and produces the most electricity possible. When used with an accurate PV model, the system's performance employing the maximal power point tracking approach, may be raised. Also necessary is the employment of a controller in between device and the electrical grid for power control as well as for synchronizing with the grid. Simulating is done using MATLAB/Simulink with the MPPT technique and the PV grid attached to it. Both the Photovoltaic system's dynamic and stable state characteristics may be enhanced by the MPPT approach that was simulated in this work. The level of planning the maximum power point tracking successfully, according to simulation results. Additionally, this study demonstrates that the suggested control scheme provides a straightforward method for examining performance of applications utilising utility interfaces [02].

Shaik Nyamathulla et.al. (2023) **-** This review paper presented an overview of the grid-connected multilevel inverters for PV systems with motivational factors, features, assessment parameters, topologies, modulation schemes of the multilevel inverter, performance parameters, and the selection process for specific applications. In this review paper, the findings of a comprehensive reliability analysis of fundamental multilevel inverters are studied and the reliability of three basic multilevel inverters was evaluated. Two distinct methodologies for reliability testing multilevel inverters were presented in this review paper (exact and approximate) [03].

A. M. Mahfuz-Ur-Rahman et.al. (2022) - A new current peak point tracking third harmonic injected bus clamping pulse width modulation (CPPTTHBCPWM) technique for effective active and reactive power control in a transformer less H5 solar photovoltaic inverter. The proposed technique reduces the switching loss compared to that of the traditional switching technique by using a new reference signal and eliminating unwanted gate pulses. The proposed CPPTTHBCPWM technique ensures better utilization of the dc bus voltage, lowers the total harmonic distortion, and lowers the converter loss compared to the conventional modulation techniques. The proposed modulation technique also reduces the thermal stress in the switching devices and increases the power converter lifetime. The proposed modulation technique is simulated in MATLAB/Simulink environment and validated in the laboratory using a reduced-scale prototype test platform [04].

Safa Haq et.al. (2021) **-** Due to global warming and shortage of fossil fuels, the grid-connected solar photovoltaic (PV) system has gained significant popularity all over the world. The modular multilevel cascaded (MMC) inverter is the natural choice for step-up transformer and line filter less direct medium voltage grid integration of solar PV systems. However, power quality and loss are the important issues while connecting the PV system to the medium voltage grid through MMC inverter. Modulation technique is the key to maintain output power quality, e.g., total harmonic distortion (THD) and to ensure low switching and conduction losses. In this paper, an advanced modulation technique named “triangle saturated common mode pulse width modulation (TSCMPWM)” control is proposed for a 3-phase 5- level MMC inverter-based grid-tied PV system. Compared to traditional modulation techniques, the proposed TSCMPWM control offers the lowest voltage THD as well as lower inverter power losses [05].

Phani Kumar Chamarthi et.al.(2021) -Among the traditional MLIs, the cascaded H-bridge (CHB) MLI accommodates lower voltage rated input dc sources, which

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reduce the voltage stress across the devices. However, the CHB MLI requires multiple PV sources as separate dc-link voltage sources, which create more paths for leakage currents. Therefore, it is a challenging task to deal with the leakage currents in the case of CHB MLIs. In this article, a novel three-phase transformer less inverter topology for grid-connected solar PV application is introduced. This proposed that the inverter topology has six switches per phase, and it has the combined advantages of dc-bypass and ac-bypass circuit configurations. A new modulation strategy is developed for the proposed topology; it is based on a sine triangle pulse width modulation technique combined with the dedicated logic functions. The gate pulses for all switches are provided by using these dedicated logic functions [06].

Ali Salem et.al. (2021) -A flying capacitor buck–boost transformerless inverter was proposed for single-phase grid-connected PV systems. The proposed topology differs from the similar types in the literature by its ability to charge the flying capacitor continuously, even in the negative power cycle (active). Thus, it can minimize the size of the flying capacitor and prevents an inrush current when charging the flying capacitor due to the existence of the inductor in the buck–boost circuit. The performance of the proposed inverter was verified using a PSIM simulation, which showed that the results are consistent with the theoretical analysis that was carried out. In general, the proposed transformer less inverter eliminates the leakage current, reduces the losses, and reduces the flying capacitor size and filtration requirement due to unipolar SPWM modulation. The efficiency of the proposed inverter was evaluated at 2 kW rated power using theoretical calculations and simulation results, and showed a CEC efficiency of 97.29% and 98.33%, respectively. However, it may suffer buck–boost circuit losses at powers greater than 2 kW; in particular, the switching losses [07].

Guo, X., Wang, et.al. (2019) -This paper has presented the theoretical analysis and experimental evaluation about the impact of clamping and unclamping dc-bypass switches on the leakage current reduction capability for three-phase transformer less PV inverters.The new insights have revealed that, different from the well-known conclusion for single-phase dc-bypass transformer less PV inverters, the unclamping three-phase dc by pass topology is better than the clamping one in terms of leakage current reduction. In addition, H8 is better than H7, due to the reduced common-mode voltage amplitude, which is beneficial to leakage current attenuation. In summary, the unclamped H8 is the best choice among four dc-bypass topologies for the leakage current reduction. Future research is towards soft-switching three-phase Hx (x=6,7,8,…) topologies, inspired by the soft-switching single-phase H6 topology [08].

Sabry, A. H., et.al. (2019, March) - Multi-level transformer less inverters are widely used in grid-tied PV systems since they characterized by higher efficiency and lower cost.In this context, new topologies, modulation, and control schemes were presented to solve problems of a common-mode voltage and leakage current.This work proposes a transformer less five-level inverter with zero leakage current and ability to reduce the harmonic output content for a grid-tied single-phase PV system. The neutral of the grid links to a common on which the negative and the positive terminals of the DC-link are connected via parasitic capacitors that can eliminate the leakage current [09].

***Li, X., Xing et.al. (2018)* –** In this paper present the CMRCC and leakage current suppression for the transformer less three-level T-type PV inverter system are discussed and verified with the proposed method. The improved CMCC model is proposed, which reveals that the CMRCC is induced with ILCL filter. The CMRCC causes inverter-side current oscillation, leakage current increment and system instability. Based on the improved model, a hybrid control strategy is presented to realize CMRCC suppression. Besides, DM circuit resonance current reduction and NP voltage balance are achieved using CVF and P controllers. The performance of the proposed scheme is compared with other methods. Finally, the steady-state and transient simulation and experimental results demonstrate the effectiveness of CMRCC and leakage current suppression with the proposed method [10].

III. TRANSFORMER LESS & PV SYSTEM

Photovoltaic Power Station

A photovoltaic power station, also known as a solar park or solar farm, is a large-scale photovoltaic system (PV system) designed for the supply of merchant power into the electricity grid.

They are differentiated from most building-mounted and other decentralized solar power applications because they supply power at the utility level, rather than to a local user or users.

The generic expression utility-scale solar is sometimes used to describe this type of project.

The solar power source is via photovoltaic modules that convert light directly to electricity.

However, this differs from, and should not be confused with concentrated solar power, the other large-scale solar generation technology, which uses heat to drive a variety of conventional generator systems[15].

The solar power source is via photovoltaic modules that convert light directly to electricity. However, this differs from, and should not be confused with concentrated solar power, the other large-scale solar generation technology, which uses heat to drive a variety of conventional generator systems.

Both approaches have their own advantages and disadvantages, but to date, for a variety of reasons, photovoltaic technology has seen much wider use in the field.

As of 2019, concentrator systems represented about 3% of utility-scale solar power capacity.

In some countries, the nameplate capacity of a photovoltaic power stations is rated in megawatt-peak (MWp), which refers to the solar array's theoretical maximum DC power output.

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However, Canada, Japan, Spain and the United States often specify using the converted lower nominal power output in MWAC, a measure directly comparable to other forms of power generation.

IV. PROPOSED METHOD

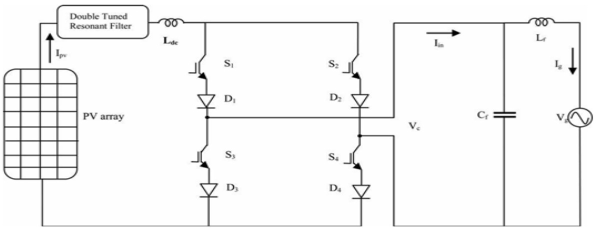

Fig. 2 Main Diagram

C. Double Tuned Resonant Filter

Introduction

In a single-phase Current Source Inverter (CSI), the output is not pure sinusoidal. It is Pulsating. It generates even harmonics in the dc-link current. Second these even harmonics affect Maximum Power Point Tracker (MPPT) on PV side. This may be reducing Photovoltaic (PV) life. In order to reduce the effect of these dc-side harmonics on the ac side and on the PV[17][18].There is a two solution proposed. One is to use the large value inductance must used. These large value inductance is capable reduce the dc-link current ripple produced by these harmonics. Here we used the inductor of value 300mH.But practically this large value inductance is not possible. Because it added cost, size, weight & may be losses also.

Second To reduce the value of large inductor, a double tuned parallel resonant filter is introduced[22]. This Double Tuned Resonant Filter, generally placed in series with the inductor of low value. This filter is capable of smoothing the dc-link current by using small inductor. 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 Current Source Inverter (CSI) operates at high modulation indices.

The basic of Double Tuned Resonant Filter is shown in figure 3

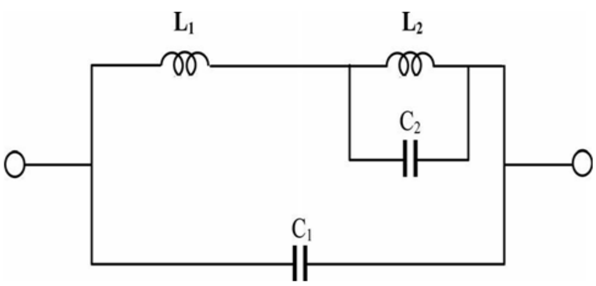

Fig.3 Double Tuned Resonant Filter

In this section, the design parameters of filter has been discussed. Firstly to eliminate the desired harmonics, 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 simplification, assume component resistances are small, and thus negligible for calculation purpose.

Now

$$Z_{c1} + Z_t = 0 \qquad (1)$$

Capacitances are given by,

$$C_1 = \frac{L_2C_2 - 1/\omega^2}{\omega^2 L_1 L_2 C_2 - L_1 - L_2} \qquad (2)$$

$$C_2 = \frac{-L_2}{L_2/C_1 - \omega^2 L_1 L_2} + \frac{1}{\omega^2 L_2} \qquad (3)$$

Here C1 and C2 are the resonant filter capacitances, L1 and L2 are the resonant filter inductances, ZC1 is C1 impedance, Zt is the total impedance of L1, L2 , and C2 respectively.

ω is the angular frequency of the second or fourth-orders harmonics.(whatever we consider).

By solving Equation (2) and (3),we can obtain the value of capacitances. The filter is capable of eliminating both the second and fourth order harmonics.

Now, to obtain the value of inductances L1 and L2,we can get values as

$$L2 \leq 1.778L1 \qquad (4)$$

To eliminate the no. of harmonics from system, the Capacitances C1,C2.....Cn given as

$$C_1 = L_1\omega_1 + \frac{1}{\omega_1 C_1} + Z_t = 0$$

Due to some limitation of Sinusoidal Pulse Width Modulation, the Modified Carrier Based Pulse Width Modulation is introduced. In Sinusoidal Pulse Width Modulation the pulses nearer the peak of sine wave do not change significantly with the variation of modulation index. Second thing that the carrier signal is applied to whole cycle[21].

Its increases no. of switching devices and also increases switching losses. To overcome above situation Carrier based Pulse Width Modulation is presented. Its provides continuous path for the dc side current[19][20]. There is one switch either in top or bottom must be ON during every switching period. This can be also achieved in Sinusoidal Pulse Width Modulation (SPWM). In SPWM, due to overlap time. It allows continuous path for dc side current. Overlap time is occur when power devices change it states. This overlap time is not sufficient for energizing dc link inductor. This may be result in increasing Total Harmonic Distortion (THD).

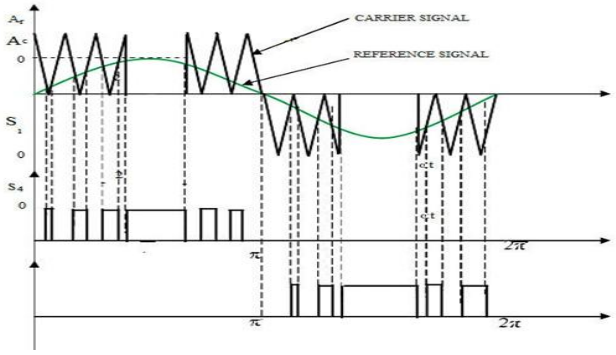

Fig. 4 Carrier Based Pulse Width Modulation

V. CONCLUSION AND FUTURE WORK

This survey paper discusses the advanced modulation technique for transformer less grid-connected inverter circuits used in solar photovoltaic (PV) systems offers several advantages and improvements over traditional modulation techniques. This technique addresses some of the key challenges associated with transformer less inverters, such as leakage current, common-mode voltage, and low efficiency. The advanced modulation technique utilizes advanced control algorithms to achieve high-quality power conversion and grid synchronization. By employing advanced pulse-width modulation (PWM) techniques, the inverter can effectively control the output voltage and current, ensuring a stable and reliable power supply to the grid. One of the significant benefits of this modulation technique is the mitigation of leakage current issues. Leakage current, caused by the parasitic capacitance between the PV panels and the ground, can be a safety concern and may lead to power quality issues. The advanced modulation technique minimizes the leakage current by controlling the switching patterns of the inverter, resulting in improved system safety and reduced power losses. Furthermore, the advanced modulation technique addresses common-mode voltage problems that can occur in transformer less inverters. Common-mode voltage refers to the voltage difference between the inverter's positive and negative terminals with respect to ground. By implementing advanced control algorithms, the technique effectively reduces the common-mode voltage, enhancing the system's overall performance and reliability. In terms of efficiency; the advanced modulation technique optimizes the power conversion process, resulting in higher overall system efficiency. By minimizing power losses and improving the utilization of the PV system's energy, the technique enables maximum power extraction from the solar panels and increases the overall energy yield of the system. Overall, the advanced modulation technique for transformer less grid-connected inverter circuits used in solar PV systems represents a significant advancement in power electronics and renewable energy systems. Its ability to address challenges related to leakage current, common-mode voltage, and efficiency makes it a promising solution for grid-connected PV systems, contributing to the widespread adoption of solar energy and a more sustainable future.

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