ISSN(ONLINE):2278 - 3814

Volume-12, Issue-10, October 2023
JOURNAL OF COMPUTING TECHNOLOGIES (JCT)
International Journal
Page Number: 01-07

A Literature Survey on Different Transformer less Solar PV Array Systems

[1]Pawan Kumar, [2]Alka Thakur
[1]M.Tech Student Electrical Power System, [2]Assistant Professor
[1,2]Department of Electrical Engineering (EE)
[1, 2]School of Engineering (SOE), SSSUTMS, Sehore, (M.P), INDIA
[1]pawansharma08239@gmail.com, [2] electricalhod06@gmail.com

Abstract— In this survey paper discuss the different transformer less pv systems. In the current generation transformer less is an important part in electrical power supply system. In this survey paper discuss the different transformer less pv systems. In the last decade there are many research work proposed different transformer less pv systems. In this review paper discuss based transformer less with different transformer less pv systems. Also discuss the comparative analysis of in transformer less with different transformer less pv systems.

Keyword:- Photovoltaic System (PV), AC voltage, Capacitor Power Supplies (CPS), MOV (Metal Oxide Varistor), Transformer Less PV Inverters, etc.

I. INTRODUCTION

PV systems are becoming more prevalent due to their advantages over conventional power generations. By harvesting energy from PV panels, they can provide a sustainable solution for the power generation. Typically, solar energy can be harvested by a grid-connected PV inverter with or without the transformer [35]. Basically, the transformer is heavy, bulky, costly, and suffers from the power loss. Also, the control performance would be affected by the transformer depending on the winding configurations, which is often overlooked in literature [37]. Therefore, the transformer less PV inverters has received more and more attention in both academic and industrial fields. However, there are technical challenges to deal with before connecting them into grid [38]. One of the technical issues is to reduce the leakage current, which is mainly due to the lack of galvanic isolation. The leakage current has the adverse impact on the grid current, potential human safety and the EMI problems [33].

Therefore, the VDE 0126-1-1 specifies that the PV systems must be disconnected from the grid on the condition that the leakage current is beyond 300 mA[31-32].

In order to cope with this problem, many insightful single phase topologies have been proposed such as H5, H6, Heric and so on [22], The basic goal is to achieve constant common-mode voltage for eliminating the leakage current, and meanwhile output the three-level PWM waveform, instead of two-level one, in order to reduce the power loss and alleviate the filter size towards the high power density and low cost [24]. Theoretically, the constant common-mode voltage can be achieved with the abovementioned topologies. In practice, however, the common mode voltage is time-varying depending on the junction capacitor of the power switches [25][27].

One possible solution is installing the additional capacitors paralleled to the respective power switches to match the value principle of the junction capacitors. The idea is interesting and insightful, but the junction capacitances of practical switches are generally nonlinear and hard to be matched accurately [20]. Also, the switching losses would be increased by the additionally paralleled capacitors. Another solution is integrating the clamping branch in the previous topology [21].

In this way, the common-mode voltage would be constant all the time, in order to eliminate the leakage current. From the abovementioned single-phase topologies, there is a well-known conclusion that the clamping topology is better than the unclamping one in terms of leakage current reduction[16-17][19]. However, is these conclusions correct for three-phase dc by pass ones? So far this has not yet been explored, and is the motivation to cover this gap [18].

The objective of this paper is to investigate the impact of clamping and unclamping dc-bypass switches on the leakage current reduction capability of three-phase transformer less inverters. The rest of the paper is organized as follows. Section II provides the literature survey of transformer less PV system. Section III presents the types of transformer less power supply. Finally, discuss transformer less low cost dc power supply resistive &

capacitive in Section IV. At last focus on conclusion and references.

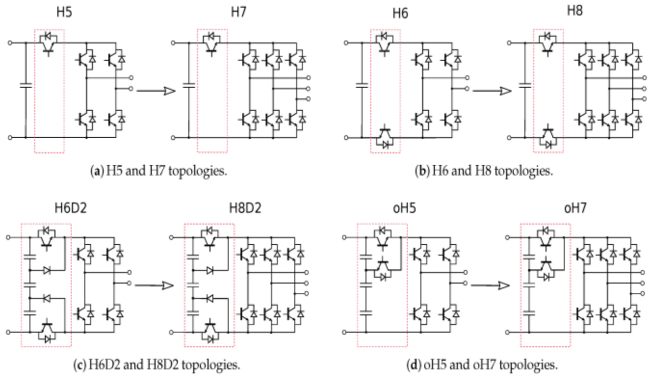

Fig 1 Different single-phase and three-phase dc-bypass inverters. (a) H7; (b) oH7; (c) H8; (d) oH8

II. LITERATURE REVIEW

Gallaj, et.al (2023), Author are presented a new transformer-less grid-tied seven-level inverter is presented which its input dc power supply is a PV panel. The proposed topology uses an interleaved dc-dc boost converter for achievement of a flexible dc-link amplitude at the dc-link side. The output voltage of the interleaved dc-dc boost converter is adjusted to the requirements of the grid voltage. The MPC control method is applied to control of the inductor current and the voltage of the flying capacitor. Furthermore, by applying a proper loop control of MPC for the output voltage, the reference inductor current will have a suitable value which leads to improvement of the dynamic response of the output voltage. Consequently, there will not exist any additional current injected to the grid in the wake of an appropriate control. The THD of the proposed inverter is lower than 2.1% and the leakage current of the PV panel is about 9.3 mA. The overall efficiency of the proposed topology is nearly 96.2% for a 900 W laboratory prototype. By applying the MPC controller, the active/reactive power of the inverter is managed independently with flexibility. The synchronization function is utilized for controlling the power; thus, the PLL block is not required for the grid voltage management. According to obtained results, the control of the proposed topology is simple with flexibility at different power levels [01].

Alam,et.al,(2023), Author are analysis performance analysis of different transformer less inverter topologies has been carried out in terms of leakage current generated by different topologies. In the paper, the HERIC inverter topology and its SPWM modulation strategy has been presented and the simulation results are compared with H4 and H5 inverter topology and other studies conducted on conventional topology. As compared to conventional H4, H5 topology, HERIC topology provides satisfactory performance in terms of leakage current and efficiency. In order to verify the topology, simulation results are provided. As per international standards and grid compliance codes, the achieved value is very low and acceptable [02].

Srivastava, et.al, (2022), Author are study a new 9L4x SC-based PV inverter with a common ground configuration has been introduced in this article for transformer less grid-tied application. Therefore, it is suitable for integration of low-voltage producing PV panels with the transformer less grid operation. However, a much higher input voltage is needed for half-bridge, NPC inverter, full-bridge-based inverter, and some other contemporary multilevel inverter for the same grid voltage condition. Hence, this PV inverter causes low voltage stress on switches and filter inductors; consequently, inductor core losses and switch losses are reduced. Another advantage of low voltage input is that the rating of the components gets reduced, and further, their cost will be less. The proposed PWM strategy balances all three capacitors' voltages at their base value. Therefore, it proved self charging ability without the help of any complex algorithm or any feedback control for voltage balancing. The proposed inverter is capable of handling reactive power with the grid's lagging/leading pf condition. The inverter is designed in such a way that total conducting switches for different voltage level generation is minimum. This technique helped to increase the efficiency of the inverter. A comparative analysis with contemporary nine-level inverter and some experimental results are shown for the verification of the correctness and feasibility of the proposed inverter [03].

Alam et.al, (2022), Researcher are Comparative analysis is presented here of recent developments in transformer-less inverter systems used for grid-connected PV Systems. A comparison of inverter topologies is based on CMVs, leakage currents, semiconductor losses, efficiency, and total harmonic distortion (THD). Its advantages include small power losses, small size, and low cost. Here are a few of the key conclusions of the study: Using galvanic isolation and CMV clamping, optimized H5 and passively clamped H6, and an active clamped HERIC, leakage currents can be eliminated. Decoupled AC topologies are more efficient than DC topologies. When solar radiation is 1000 Watts/m2, the THD is nearly the same for all topologies. Due to the high number of active switches on the current path, passive clamped H6 and H6 suffer from high device losses Several different transformer-less inverter topologies for grid-connected PV are discussed in this paper. Academic and industrial researchers can utilize this paper to select an appropriate transformer-less inverter topology [04].

Chamarthi, et. al (2021), Authors presented verified through simulations and experimental study the leakage current suppression of the 3-? CHB inverter topology (see Fig. 1) for the PV-fed grid-connected system. It had been found that the conventional CHB inverter was unable to suppress the leakage current effectively. On the other hand, the proposed 3-? CHB MLI topology (see Fig. 2), through its developed modulation strategy, suppressed the leakage current significantly. It had also been observed that the suppressed leakage current was well within the standard (VDE 0126-01-01). Furthermore, it can be observed that the proposed methodology was simple and easily implementable. Hence, the proposed methodology was very suitable for 3phase, PV-fed grid-connected transformer less inverter applications. Furthermore, it can be noted that with the increase in power level of input PV source, the value of parasitic capacitance also increases. It can be observed from the results that even for higher parasitic capacitance value of 300 nF, the peak value of leakage current was well within the VDE 0126-01-01 standard. Therefore, the proposed topology and its modulation strategy can be used for higher power generation. The two extra switches (S5i and S6i; i=a, b, c) in the proposed topology do not operate throughout the cycle. Hence, the total losses of the proposed topology were not affected considerably. The experimental efficiency of the laboratory prototype was observed to be 96.5% at a 3-kW power level, which is well matching with the theoretical value. In total, the proposed CHB inverter topology showed a better tradeoff compared to existing transformer less inverter topologies in terms of the number of power devices, total sum of switches voltage rating, leakage current, and efficiency [05].

Majumdar, et.al, (2021), Author are study a basic single-phase 17-level boost inverter-based PV system is designed for a transformer-less grid-connected system. The proposed inverter is able to limit the eakage current to 22 mA, which is much lesser than the acceptable limit of 300 mA as per the German standard. The modified SPWM technique further makes the leakage current independent of the inverter switching frequency. The ripple voltage across the capacitors is much smaller, which reduces the overall losses and improves the inverter efficiency even at increased output power. Comparative studies have proved that the performance of the proposed MLI is better than most of the other similar kinds of MLIs. A d-q-based closed-loop current control is implemented for the grid-tied system using DS1103-based digital controller to control the active power transfer from the PV to the grid. Experimental results are presented to verify the simulation results. Moreover, the closed-loop system remains stable after the transient is over [06].

Rahimi, et.al, (2020), Researcher are Due to its high leakage current, the traditional three-phase FB inverter is not a suitable topology for TL grid-connected PV system. This paper employed a Filter Clamped Inverter (FCI) that solves the leakage current issue in a three phase TLPV systems. The FCI does not need any additional switches compared to three phase FB inverters. Unlike the FB inverter, in FCI, the parasitic capacitor voltage is not dependent to the CMV; thus, the leakage current is significantly reduced. Through analysis and simulation, the effectiveness of the FCI topology in reducing the leakage current is validated. The leakage current reduction that is achieved by FCI well satisfies the 300 mA limit governed by VDE 0126-1-1 standard [07].

Guo, X., (2019) – This paper reviews 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 dcby 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., (2019) - 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. The proposed topology, with its inherent circuit structure, leads to boost the overall efficiency. Simulation and experimental results show almost zero leakage current and a high-quality output when maintaining balanced capacitor voltages on the DC-link input. The experimental results show 1.07% THD and 96.3 % maximum efficiency when injecting a power of 1.1 kW that verify the performance of the proposed inverter with PV sources.**[09]**

Li, X., (2018) - In this paper, 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. Other LCL filters, such as

LLCL filter and LCCL filter, have stronger attenuation capability for switching harmonics in the grid-side current. The CMRCC and leakage current suppression with these filters will be future work.**[10]**

Rajeev,et.al., (2018) - A novel B–B derived micro inverter topology that eliminates the ground leakage current and guarantees negligible dc injection into the grid is proposed for transformer-less GCPVS.DCM operation ensures reset of the input inductor current in each switching cycle, soft switching of the main switch (S1) and easier control as the right-half-plane zero is not encountered in the plant model. It has been experimentally validated that the topology is capable of boosting the input voltage up to 2–2.5 times with a current THD less than 5% and dc injection, less than 0.5% of the rated current. Measured efficiency of the laboratory close to the rated power is comparable with other transformer-less B–B derived topologies of the same power level.**[11]**

Valderrama, (2017) – In this present multilevel transformer less topology and its modulation technique were proposed. The topology was based in the conventional H-bridge inverter with an auxiliary circuit. The latter consisted of a bidirectional switch formed by two IGBTs or MOSFETs and two diodes. The bidirectional switch was connected between the middle point of the first leg in the H-bridge and the middle point of the input split capacitor, i.e., a T-type leg. The other leg is kept unchanged. Therefore the topology was referred as asymmetrical T-type. The proposed topology provided five output voltage levels, which turns out to be an important advantage regarding other commercial single phase topologies. Besides, to control the power flowing from the DC source to the load, a PWM modulation strategy based on a sinusoidal multicarrier technique was proposed. Both inverter and PWM were aimed to overcome the leakage current issue in low power transformer less PV systems applications.**[12]**

Kafle, Y. R. (2017, March) - Three inverter topologies were compared in terms of efficiency, CMV and leakage current. The H-bridge inverter with UPWM exhibited a high frequency CMV swing between ±Vdc producing potentially high leakage currents, and therefore is not suitable for applications as a transformer less PV inverter. In case of BPWM, low leakage current and constant CMV is achieved so it can be used as transformer less PV inverter application however it has low efficiency. Both the HERIC and H5 inverters had low leakage current. Based on expected efficiency and measured leakage current, the HERIC topology is the preferred of the three investigated for use as a transformer less PV inverter.**[13]**

Guo, X., (2016) - This is presented the theoretical analysis and experimental verification of a cascaded topology based on the H5 inverter and modulation strategy to reduce the leakage current for single-phase transformer less PV systems. Compared with the filter based solution, the proposed topology based solution needs to add small active switching devices instead of bulky passive components. There is no need to design the parameter of bulky and heavy filters. The experimental results indicate that the conventional single-phase cascaded H-bridge topology fail to reduce the leakage current. On the other hand, the proposed topology and new modulation strategy can ensure that the stray capacitor voltage is free of any high frequency components. Therefore, the leakage current can be significantly suppressed well below 30 mA, as specified in the standard VDE-0126-1-1. Therefore, it is attractive for single-phase transformer less PV systems **[14]**.

III. TYPES OF TRANSFORMERLESS POWER SUPPLY

One of the major challenges during a circuit design is to generate low-voltage DC from AC to power the circuit. There are many methods to convert AC voltage into DC. The most common method is the use of a step-down transformer to reduce 230V AC to a lower value AC. This is then rectified and made ripple-free by using a transformer less power supply.

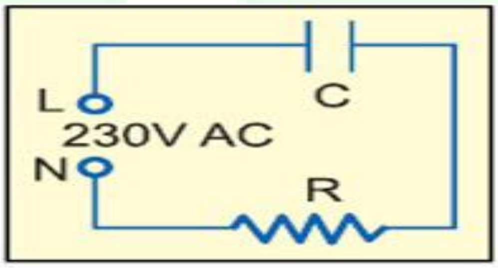

Fig. 2: AC through a series capacitor and resistor

Even though the transformer-based power supply is efficient in providing sufficient current, it consumes much space and makes the gadget bulky. Cost of the transformer is also high. To power low current demanding logic circuits and microprocessor circuits, transformer less power supply is an ideal solution. These power supplies have distinct advantages and disadvantages. These are cost-effective and consume less space, so the gadget becomes handy. But the low current efficiency makes them non-ideal to satisfy high current requirements of most circuits. Moreover, there is no isolation from the mains.

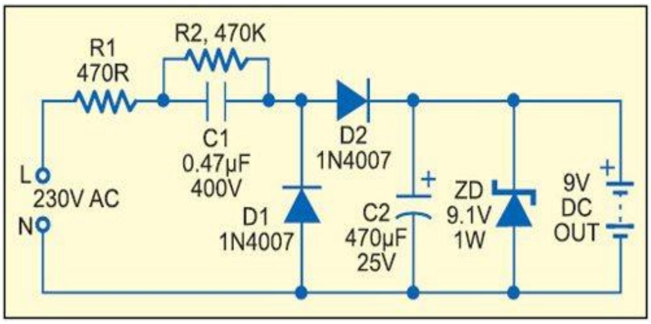

Fig. 3: Capacitive power supply

The two basic types of transformer less power supplies are capacitive and resistive. Capacitive type is more efficient since its heat dissipation and power loss are very low. Resistive type power supply, on the other hand, dissipates more heat, so the power loss is quite high. If a circuit requires very low current of a few mill amperes, transformer less power supply is an ideal solution. Before designing a transformer less power supply, some facts about AC dropping through a capacitor or resistor are to be considered.

VI. TRANSFORMERLESS LOW COST DC POWER SUPPLY RESISTIVE & CAPACITIVE

One on the major part of our electronics products is the DC Power Supply that converts mains AC voltage to a lower DC voltage. Usually we use a step down transformer to reduce mains AC voltage to desired low voltage AC and then convert it to DC or we use Switched Mode Power Supplies. But in both cases cost is very high and it takes considerable amount of space. Another Low Cost alternative for Transformer and Switcher based power supply is Transformer Less Power Supply. There are basically two types of Transformer Less Power Supplies.

- Capacitive
- Resistive

Capacitive Transformer Less or Capacitor Power Supply - The main difference between them is, in resistive transformer less power supply excess energy is dropped as heat across a voltage dropping resistor while in capacitor power supplies voltage is dropped across a voltage dropping capacitor so there is no energy loss or heat dissipation.

Capacitor Power Supplies we use a Voltage Dropping Capacitor in series with the phase line. An ordinary capacitor should not be used in these applications because Mains Spikes may create holes in dielectric of ordinary capacitors and the capacitor will fail to work. This may destroy the device by rushing current from the mains. Thus we use X Rated Capacitor with required voltage is used for this task. X Rated Capacitors rated for 250, 400, 600 V AC and higher are available. Reactance of the voltage dropping capacitor should be greater than the load resistance to keep constant current through the load.

Circuit Diagram

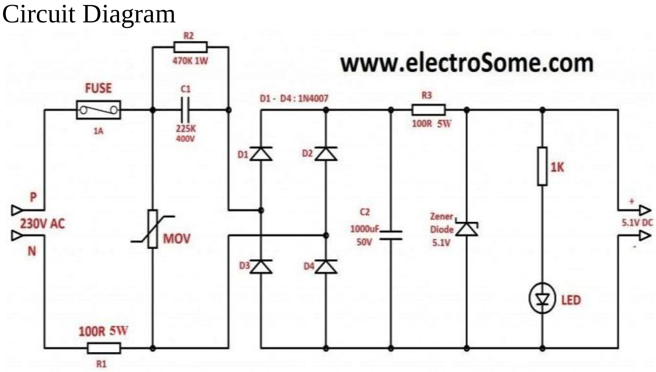

Fig 4 Capacitive Transformer Less Power Supply – Circuit Diagram

As shown 4 A fuse may be used to avoid damages due to short circuit and a MOV (Metal Oxide Varistor) also may be connected as shown above to avoid problems due to voltage transients. The resistor R1 is used to limit the high current that may occur during power on. Capacitor C1 225K (2.2μF) is used as the Voltage Dropping Capacitor. A Bleeder resistor is connected parallel to it for discharging the capacitor when the supply is switched off. Diodes D1 – D4 is wired as Bridge Rectifier and the capacitor C2 is used to filter the pulsating DC. Zener Diode is used to regulate the filtered DC or you can use IC Voltage Regulator for better results. Resistor R3 is used to limit the current through the Zener Diode.

Resistive Transformer Less Power Supply – Resistive Transformer Less Power Supply is similar to Capacitor Power Supply except that instead of Reactance it uses resistance to limit current. Thus here excess energy is dissipated as heat across the Voltage Dropping Resistor.

Circuit Diagram

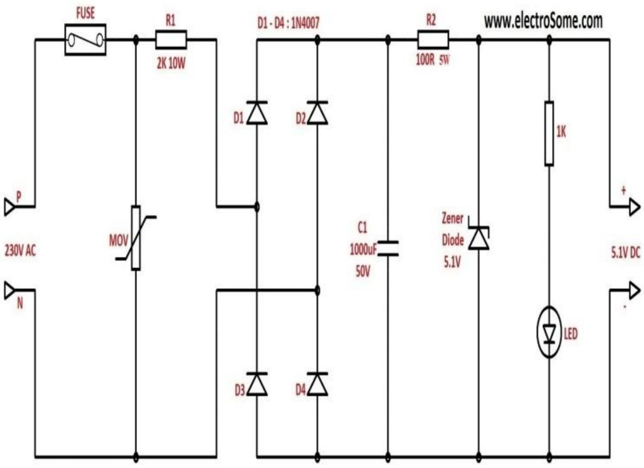

Fig 5 Resistive Transformer Less Power Supply Circuit Diagram

Care should be taken while selecting Voltage Dropping Resistor since the excess power is dissipated across it. Calculate power by multiplying Voltage and Current.

V. CONCLUSION AND FUTURE SCOPE

In this survey paper discuss on different transformer less with different transformer less pv systems. The important outcomes of this paper are shown in the section of comparative analysis.

In this survey paper observe that the based on transformer less is the major problem in transformer less. Also most of the design on transformer less with different transformer less pv systems.

In future design a better on transformer less with different transformer less pv systems. That can improve all these problems in this communication area. In future try to design transformer less on transformer less With transformer less with different transformer less pv systems.

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