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REVIEW OF TRANSFORMERLESS INVERTER TOPOLOZIES FOR GROUND LEAKAGE CURRENTS REDUCTION IN GRID CONNECTED DISTRIBUTED SYSTEM

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ABSTRACT: Grid-connected transformer less inverters are increasingly overwhelming the market due to their higher efficiency, lower cost, lighter weight, and reduced size when compared to their transformer based counterparts. However, due to the absence of galvanic disengagement in the low voltage grid interconnections of these inverters, the PV systems become vulnerable to leakage currents flowing through the grounded star point of the circulation transformer, the earth, and the distributed parasitic capacitance of the PV modules. These leakage currents are prohibitive, since they constitute an issue for safety, reliability, protection coordination, electromagnetic similarity, and module lifetime.

I. INTRODUCTION

Solar photovoltaic (PV) systems are considered as one of the most encouraging distributed energy resources (DERs) and the grid integration of such PV systems is performed through inverters. Over most recent couple of years, there have been noteworthy development on inverter technologies and the principle reasons behind all these development are the improvements in the efficiency and the reductions in costs. The grid integration of PV units becomes more expensive when transformers are used as the expenses associated with transformers are high. Hence, it is imperative to consider transformer less inverters (TLIs) for the PV based systems synchronized with grid. The existing literature about TLIs include different designs, for example, double parallel back inverters, H5 inverters, optimized H5 (oH5) inverters, H6 inverters, high efficient and reliable inverter Concept (HERIC) [A1]. The IGBTs' fixed voltage conduction losses are utilized in the H5 inverter to enhance the efficiency, these fixed voltage conduction losses are not utilized in the topology of the H6 inverter. Nevertheless, the three switches are serially connected in the present way cause greater losses of conduction during the active stages [1]. The H6 topology despite everything contains the shoot-through problems due to the three DC-transport connected switches in a serial connection. The diodes of the MOSFET body might be activated when there is change in phase of inverter current and yield, eventually ending up being H6 inverter's yet another disadvantage [2]. This may lead to a reduction in the system's reliability and the reversal of recovery issues by body diode. Therefore, a profoundly efficient and reliable topology is proposed for inverter without transformer for illuminating these issues [3].

One of the significant issues in the transformer less grid connected PV system is the galvanic connection of the grid and Photovoltaic system, which leads to a leakage current problems. For transformer less grid-connected inverters, full-bridge (FB) inverter, neutral point clamped (NPC), active NPC (ANPC) inverter, and many other topologies, for example, H5, H6, and profoundly 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. However, these topologies are not absolutely free from leakage current or a Common mode current. The leakage current despite everything exists due to the parasitic capacitor of the switch and stray capacitance between the PV panel and ground. Thus, 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) air conditioning modules may become a trend for the future PV systems because of their greater flexibility in distributed system expansion, easier establishment due to their attachment and play" nature, lower fabricating cost from secluded and a scalable production, and higher system-level energy harnessing capabilities under shaded or PV fabricating confound conditions as compared to the single or multi-string inverter.

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II. LITERATURE REVIEW

Shayestegan et al interests on different scientific aspects of photovoltaic (PV) systems has increased over the previous decade. However, these systems are as yet undergoing further developments, and new designs are being demonstrated every year. To minimize cost, reduce size, and increase the efficiency of PV systems, the use of transformerless PV grid-connected inverters has gained the interest of the residential market. This examination describes the principle challenges in transformerless topologies just as provides a review on new single-phase grid-connected PV systems, which are categorized into six gatherings based on the number of switches required in the system. The essential operational principles of different schemes under the six categories of inverters are presented and compared in terms of leakage current, efficiency, strengths and weaknesses. Furthermore, the proposed inverter structure and a compensation strategy for eliminating leakage current have been discussed followed by a comparative report with the available ones. Consequently, our proposed system has discovered noteworthy results in PSIM environment with a reduction in leakage current as compared with those in three other different topologies.

Dutta et al explained grid-connected single-phase transformerless inverter that can operate two serially connected solar photovoltaic (PV) subarrays at their respective maximum power points while each one of them is exposed to different atmospheric conditions is proposed in this paper. As two subarrays are connected in series, the number of serially connected modules inside a subarray is reduced to half. Reduction in the number of serially connected PV modules inside a subarray leads to an overall improvement in the magnitude of power that can be abstracted from a subarray while the modules of the subarray are exposed to varied atmospheric conditions. The topological structure of the inverter ensures that the regular mode voltage does not contain high-frequency components, thereby reducing the magnitude of leakage current involved with the solar panels well inside as far as possible. An in-depth investigation of the scheme alongside the derivation of its little sign model has been carried out. Detailed reproduction studies are performed to verify its effectiveness. A 1-kW research center prototype of the scheme has been fabricated. Detailed experimental approvals have been carried out using the prototype to affirm the practicality of the proposed scheme.

Ahmad et al this creators fundamental concern of the grid connected transformerless photovoltaic (PV) inverters. Many single phase transformerless inverter topologies with reduced leakage current have been introduced in the previous few years. These are essentially classified based on leakage current reduction methods Galvanic confinement without-regular mode voltage (CMV) cinching and with-CMV bracing. It has been indicated that leakage current generation is profoundly dependent on CMV. CMV of the topologies without-CMV clasping oscillates and wavering amplitude depends on switches' intersection capacitances and parasitic parameters of the topology. So as to eliminate the leakage current completely, CMV must be steady all through the inverter operation. Moreover, inverter ought to likewise be capable to inject definite measure of reactive power into the grid, as demanded by the international regulations. In this investigation, reduced leakage current CMV clamped topology is proposed which can eliminate leakage current and capable of injecting reactive power into the grid. Absolute symphonious bends (THD) of injected grid current at different solar irradiance levels are additionally analyzed. So as to verify the theoretical explanations, the proposed topologies are simulated in Matlab/Simulink environment. At last, the simulated results are validated experimentally.

Siriwattanasit et al introduces the buck-help based three-switch three-state Z-source inverter for utilizing with grid-connected PV system, and it can provide double establishing for suppression problems of PV inverter system and provide support capacity. Moreover, this paper presents the performance examination between the buck-help based three-switch three-state Z-source grid-connected PV inverter and profoundly efficient and reliable inverter concept (HERIC) grid-connected PV inverter with support converter.

Ardashir et al proposes a new single-phase transformer less photovoltaic (PV) inverter for grid-tied PV systems. The topology is derived from the concept of a charge siphon circuit so as to eliminate the leakage current. It is composed of four power switches, two diodes, two capacitors, and a LCL yield filter. The neutral of the grid is directly connected to the negative extremity of the PV panel that creates a steady basic mode voltage and zero leakage current. The charge siphon circuit generates the negative yield voltage of the proposed inverter during the negative cycle. A corresponding resonant control strategy is used to control the injected current. The primary benefits of the proposed inverter are:

1) The neutral of the grid is directly connected to the negative terminal of the PV panel, so the leakage current is eliminated;

2) Its conservative size;

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3) Low expense;

4) The used dc voltage of the proposed inverter is the same as the full-bridge inverter (unlike neutral point clamped (NPC), active NPC, and half-bridge inverters)

5) Flexible establishing setup

6) Capability of reactive power flow; and

7) High efficiency. A complete description of the operating principle and investigation of the proposed inverter are presented. Experimental results are presented to affirm both the theoretical investigation and the concept of the proposed inverter. The obtained results clearly validate the performance of the proposed inverter and its commonsense application in grid-tied PV systems.

Ahmad et al improved H6 normal mode voltage (CMV) clamped topology with modified regulation strategy is proposed. The proposed topology offers low misfortune air conditioning side decoupling, complete elimination of leakage current through CMV bracing and reactive power generation ability. The proposed regulation technique facilitates the flow of current so as to generate zero voltage state during negative power flow. Complete symphonious bending (THD) of injected grid current at different solar irradiance levels is likewise analyzed. Moreover, implementation of inverter control algorithm in real time computerized test system (OP-5600) has been discussed in detail. So as to legitimize the reasonableness of the proposed topology for grid-tied PV system, recreations have been carried out in Matlab/Simulink environment and validated through an experimental setup.

Ardashir et al explained four power switches, two capacitors, two diodes, and a LC filter are uses in this topology. The negative extremity of the PV panel is connected to the neutral of the utility grid with regular line. Therefore, a typical mode voltage is consistent and leakage current is nearly zero. A unipolar Sinusoidal Pulse-Width regulation (SPWM) method is utilized to reduce the yield current ripple and requirements of filter. The significant merits of this topology are conservative size, low cost, flexible establishing arrangement and higher efficiency. The operating principle and examination of the proposed inverter are presented in details. At last, a universal prototype rated 500 W are tested to validate the proposed topology and the overall concept. The results obtained clearly affirm the performance and reasonable application of the proposed topology for grid-connected PV systems.

Sun et al proposes a novel transformerless inverter utilizing a novel idea of the freewheeling circle separation for PV system to protect the system from dangerous leakage currents, and the new topology is analyzed with operation modes. Then a reproduction utilizing Matlab/Simulink is worked for Heric topology and the new topology to verify the operation principle and compare the two performances in the aspect of leakage currents characteristics. At last, the reproduction results show that the performance in leakage currents of the proposed topology is better than HERIC topology.

Islam et al proposed a new high efficiency transformer less topology is proposed for grid-Tied PV system with reactive power control. The new topology structure and detail operation principle with reactive power flow is described. The high frequency basic mode (CM) model and the control of the proposed topology are analyzed. The inherent circuit structure of the proposed topology does not lead itself to the reverse recovery issues even when inject reactive power which allow using MOSFET switches to help the overall efficiency. The CM voltage is kept steady at mid-point of dc input voltage, results low leakage current. At long last, to validate the proposed topology, a 1 kW research facility prototype is manufactured and tested. The experimental results show that the proposed topology can inject reactive power into the utility grid with no extra current twisting and leakage current. The maximum efficiency and European efficiency of the proposed topology are measured and discovered to be 98.54% and 98.29%, respectively.

Selmi et al explained key stage of photovoltaic (PV) systems is the inverter connected at the chain's end. Inverters dedicated to PV systems could be classified into two significant topologies: (I) those equipped by a transformer and (ii) those without a transformer, the purported: transformer less inverters (TIs). The latter were recognized to be more efficient in terms of energy efficiency and compactness. In spite of these performances, the integration of TIs in PV systems is compromised by some weaknesses, for example, the dissemination of a leakage current due to the absence of the galvanic confinement. This work considers a new single phase TI topology dedicated to PV systems. Beyond its energy efficiency ability and its invalid zero-intersection bending,

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it has the merit to eradicate the leakage current. Following, the examination of its operating sequences, the proposed TI topology is simulated so as to feature its effectiveness.

Cho et al proposes an improved single-phase transformerless inverter with high power density and high efficiency for grid-connected photovoltaic systems. The proposed inverter is comprised of the double paralleled-buck inverter and two helper circuits for the zero-current turning turn-off of the diodes. The double paralleled-buck inverter and assistant circuits are joined by two coupled inductors. To achieve high power density, the proposed inverter operates at high exchanging frequency of 40 kHz. This leads to lower filter inductors and lower conduction losses of the filter inductors than conventional full-bridge inverters. Moreover, two assistant circuits reduce the exchanging losses caused by high exchanging frequency operation. Furthermore, the proposed inverter provides the low normal mode leakage current, which satisfies the criteria given by VDE-0126-1-1. Accordingly, the proposed inverter achieves the maximum efficiency of 99%. The operation principle of the proposed inverter is analyzed and verified. Experimental results for a 1 kW prototype are obtained to show the performance of the proposed inverter.

Islam et al focuses on the transformerless topologies, which are classified into three fundamental gatherings based on the decoupling method and leakage current characteristics. Different topologies under the three classes are presented, compared and evaluated based on leakage current, component appraisals, advantages, and disadvantages. An examination of demand for the inverter, the utility grid, and the PV module are presented. A performance correlation in MATLAB/Simulink environment is done among different topologies. Additionally an investigation has been presented to select a better topology. At long last, based on the examination and recreation results, a correlation table has been presented. Furthermore, some significant experimental parameters have been summarized.

Chen et al review of the state-of-the-craftsmanship transformerless inverter topologies and the related pulsewidth balance (PWM) method, this paper proposes a group of transformerless inverter topologies with asymmetric phase-legs. PWM adjustment and inverter operating modes are then detailed, experiment results demonstrate the legitimacy of proposed inverter topology.

Gupta et al proposed H-4 bridge topology is adopted to implement the proposed design where tally of power devices is limited to four. One leg of the bridge operates at high exchanging frequency while the other leg operates at line frequency, this regulation technique reduces the exchanging losses. This additionally obviates the requirement of quick recovery against parallel diodes across power devices for low frequency leg. Use of fewer devices and computerized control (instead of simple control) has led to reduced expense and size. Exchanging and conduction losses are further reduced by utilizing MOSFETs with very low on state resistance. A novel control scheme has been implemented to eliminate the DC offset at the yield. A profoundly reliable over current and shoot-through protection is implemented through computerized control. The advanced control algorithm implemented enhances the reliability of operation at high power level. Ideal design of PCB and high frequency filters with SMD components contribute to high power density. A 3 kW prototype has been developed and tested for different reactive loads.

Kumar et al putting forth an attempt to suggest suitable transformer less inverter topology based on examination of leakage current. The PV inverter system connected to grid, is simulated for different transformer less inverter topology. Leakage current obtained from recreation result is compared to the standard standards. The control method is applied with the end goal that high efficiency and solidarity power factor is maintained. Moreover a simple control structure is studied for two stage conversion.

Buticchi et al adopted in low-power and domestic applications. So as to improve the efficiency, while keeping the absolute expense of the system low, the converters are typically designed without a protection transformer. Recently, these converters have witnessed an increased interest due to the widespread dispersion of renewable energy sources. So as to ensure the compliance with the international regulation for the grid connection, the Total Harmonic Distortion (THD) of the grid current must be maintained below specific thresholds indicated by the guidelines. Therefore, LCL filters allow to acquire a greater symphonious attenuation than a simple inductive filter. This paper proposes a deadbeat current control, specifically tailored for this application, which can ensure ideal reference tracking, rejection of the grid voltage disturbance and low computational effort. Reenactment and experimental results show the effectiveness of the proposed arrangement.

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III. CONCLUSION

Several single-phase transformer less PV inverter topologies are analyzed about the efficiency and the leakage current. To reduce exchanging losses, the number of switches which operates with the high-frequency ought to be reduced and to reduce conduction losses, the number of switches in the current way ought to be reduced during the inverter operates. Likewise, there ought to be no high-frequency voltage in the parasitic capacitor to achieve the low leakage current. The relation between leg voltages and the leakage current is derived through the proposed high-frequency model.

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