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Review of Transformer less PV system in a multilevel grid connected inverter

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ABSTRACT

This paper presents work done in a Transformer less PV system in the multi grid connected inverter in which a single-phase transformer less grid-connected photovoltaic converter based on two cascaded full bridges with different dc-link voltages. The converter can synthesize up to different voltage levels with a single dc bus, since one of the full bridges is supplied by a flying capacitor. The multilevel output reduces harmonic distortion and electromagnetic interference. A suitable switching strategy is employed to regulate the flying-capacitor voltage, improve the efficiency (most devices switch at the grid frequency), and minimize the common-mode leakage current with the help of a novel dedicated circuit (transient circuit). Simulations and experiments confirm the feasibility and good performance of the proposed converter.

Keyword: Leakage current, multilevel system, PV system, flying capacitor.

I.INTRODUCTION

Grid connected photovoltaic (PV) converters represent the most widespread solution for residential renewable energy generation. While classical designs of PV converters feature a grid frequency transformer, which is a typically heavy and costly component, at the interface between the converter and the electrical grid, researchers are now considering transformer less architectures in order to reduce costs and weight and improve efficiency. Removing the grid frequency transformer entails all the benefits above but worsens the output power quality, allowing the injection of dc current into the grid [1], [2] and giving rise to the problem of ground leakage current [3], [4]. Although the active parts of PV modules might be electrically insulated from the ground-connected mounting frame, a path for ac ground leakage currents generally exists due to a parasitic capacitance between the modules and the frame and to the connection between the neutral wire and the ground, usually realized at the low-voltage/medium-voltage (LV/MV) transformer [3]. In addition to deteriorating power quality, the ground leakage current increases the generation of electromagnetic interference and can represent a safety hazard, so that international regulations pose strict limits to its magnitude. This issue must be confronted in all transformers less PV converters, regardless of architecture. In particular, in full-bridge-based topologies, the ground leakage current is mainly due to high frequency variations of the common-mode voltage at the output of the power converter [4]. Several solutions can be found in literature aiming at the reduction of the common-mode voltage harmonic content [5]–[7]. Once the grid frequency transformer is removed from a PV converter, the bulkiest wound and reactive components that remain are those that form the output filter used to clean the output voltage and current from high frequency switching components. Further reduction in cost and weight and improvement in efficiency can be achieved by reducing the filter size, and this is the goal of multilevel converters. Multilevel converters have been investigated for years [8], but only recently have the results of such researches found their way to commercial PV converters. Since they can synthesize the output voltages using more levels, multilevel converters outperform conventional two- and three-level converters in terms of harmonic distortion. Moreover, multilevel converters subdivide the input voltage among several power devices, allowing for the use of more efficient devices. Multilevel converters were initially employed in high-voltage industrial and power train applications. They were first introduced in renewable energy converters inside utility-scale plants, in which they are still largely employed [9]–[13]. Recently, they have found their way to residential-scale single-phase PV converters, where they currently represent a hot research topic [14]–[29]. CFB converters have also been proposed for stand-alone applications [17], [22]. CFBs give developers many degrees of freedom for the control strategy. Together with the aforementioned sequential permutation and with phase shifting [19], artificial neural networks [23] and predictive control [24] have been proposed to minimize harmonic distortion and achieve maximum power point tracking (MPPT). A CFB made up of n full bridges (and at least $4n$ power switches) can synthesize $2n + 1$ voltage levels when the supply voltage is the same for each full bridge. Custom architectures can generally provide more output levels with a given number.

II.RELATED WORK

G. Buticchi, L. Consolini, and E. Lorenzani [1]- a low-cost nonlinear sensor for an accurate detection, free from offset problems, of the dc voltage component present in the grid voltage has been proposed. The detection of the dc voltage component was used to realize an active filter of the dc current component. The proposed solution is outlined, and then the stability issue is addressed by means of a simplified model. Experimental results confirmed that the simplified model closely approximates the real system.

G. Buticchi and E. Lorenzani [2]- a method to detect the dc current component flowing into the distribution power transformer with a precise measurement of the dc voltage component at the transformer winding has been presented. A magnetic sensor has been developed and implemented in a closed-loop control system to achieve a high sensitivity and guarantees a good linearity with a high rejection ratio to grid voltage variations. Simulation and experimental results confirm the effectiveness of the proposed approach.

H. Xiao and S. Xie [3]- the ground current in a 1.5-kW PV installation is measured under different conditions and used to build a simulation model. The installation includes a string of 16 PV panel, a full-bridge inverter, and an LCL filter. This model allows the study of the influence of the harmonics injected by the inverter on the ground current

I T. Kerekes, R. Teodorescu, P. Rodridguez, G. Vazquez, and E. Aldabas, [7]- a converter topology able to minimize the ground leakage current also in the case of unipolar pulse width modulation without increasing inductive common mode filter size and preserving efficiency has been presented. Simulations and experimental results show the feasibility of the proposed solution.

C. Townsend, T. Summers, and R. Betz [10]- a control and modulation structure based on Model Predictive Control (MPC) is described. The scheme inherently controls the DC link voltages while also providing the ability to modify any of those voltages to meet MPPT requirements. This avoids the cost and added complexity of extra DC/DC converters that are typically required to keep the DC link voltages uniform. Simulation and experimental results are presented that confirm the correct operation of the proposed approach.

G. Buticchi, E. Lorenzani, and G. Franceschini [14]- a converter architecture based on a full-bridge topology with two additional power switches and two diodes connected to the midpoint of the dc link has been proposed. Since the two added levels are obtained by the discharge of the two capacitors of the dc link, the balancing of the midpoint voltage is obtained with a specific pulse width modulation (PWM) strategy. Simulation and experimental results show the effectiveness of the proposed solution.

I. Abdalla, J. Corda, and L. Zhang [18] the novelty of the proposed system is the use of a fully FLC (not requiring any optimal PWM switching-angle generator and proportional-integral controller) and the use of an H-bridge power-sharing algorithm. Most of the required signal processing is performed by a mixed-mode field-programmable gate array, resulting in a fully integrated System-on-Chip controller. The general architecture of the system and its main performance in a large spectrum of practical situations are presented and discussed. The proposed system offers improved performance over two-level inverters, particularly at low-medium power

J. Chavarria, D. Biel, F. Guinjoan, C. Meza, and J. Negroni [19] an energy-balance control strategy for a cascaded single-phase grid-connected H-bridge multilevel inverter linking *n* independent photovoltaic (PV) arrays to the grid is presented. The control scheme is based on an energy-sampled data model of the PV system and enables the design of a voltage loop linear discrete controller for each array, ensuring the stability of the system for the whole range of PV array operating conditions. The control design is adapted to phase-shifted and level-shifted carrier pulse width modulations to share the control action among the cascade-connected bridges in order to concurrently synthesize a multilevel waveform and to keep each of the PV arrays at its maximum power operating point. Experimental results carried out on a seven-level inverter are included to validate the proposed approach.

G. Grandi, C. Rossi, D. Ostojic, and D. Casadei [21] a novel scheme for three-phase grid-connected photovoltaic (PV) generation systems is presented in this paper. The scheme is based on two insulated strings of PV panels, each one feeding the dc bus of a standard two-level three-phase voltage-source inverter (VSI). The inverters are connected to the grid by a three-phase transformer having open-end windings on the inverter side. The resulting conversion structure performs as a multilevel power active filter (equivalent to a three-level inverter), doubling the power capability of a single VSI with given voltage and current ratings. The multilevel voltage waveforms are generated by an improved space-vector-modulation algorithm, suitable for the implementation in industrial digital signal processors. An original control method has been introduced to regulate the dc-link voltages of each VSI, according to the voltage reference given by a single maximum power point tracking controller. The proposed regulation system has been verified by numerical simulations and experimental tests with reference to different operating conditions

S. Daher, J. Schmid, and F. Antunes [22] a new high-efficiency topology for transformer less systems has been proposed , which does not generate common-mode currents and topologically guarantees that no dc is injected into the grid. The proposed topology has been verified in a 5-kW prototype with satisfactory results.

III.CONCLUSION

This paper has proposed a multilevel grid-connected transformer less PV converter based on a CFB topology with two full bridges, one of which is supplied by a floating capacitor.

A suitable PWM strategy was developed in order to improve efficiency (most power devices commutate at low frequency) and, with the help of a specific TC, minimize the ground leakage current.

The proposed PWM strategy can regulate the voltage across the flying capacitor. Simulations were performed to assess the ability to regulate the flying-capacitor voltage in a wide range of operating conditions.

Extensive simulations and experiments confirm the results of the theoretical analysis and show the good performance of the converter as far as ground leakage current and harmonic distortion are concerned. Despite the use of traditional power devices for the laboratory prototype, the experimentally measured efficiency was fairly good. The proposed converter can continuously operate at arbitrary power factors, has limited boosting capability

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