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High Efficiency Single-Phase Transformer-less Inverter for Photovoltaic Applications

Inversor monofásico de alta eficiencia sin transformador para aplicaciones fotovoltaicas

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Abstract

Photovoltaic (PV) inverters have a very important role in the energy market, therefore they must possess excellent characteristics regarding cost and reliability. The PV structure most often used in the conversion stage of solar energy system includes a *Low Frequency Transformer* (LFT) which provides galvanic isolation, but on the other hand reduces the overall efficiency and increases the total size and cost of the system. An alternative to reduce the size of the system and the losses, is to use a *High Frequency Transformer* (HFT), the problem in this case is that additional power stages must be included in the system. The additional stages increase the power losses in the conversion process, as a consequence the efficiency of the system is reduced. Therefore the tendency is to remove the transformer in order to increase the efficiency and reduce the cost. A security problem regarding common mode currents arise when the LFT or HFT is omitted. In this paper an inverter topology to deal with the problem of the common mode currents is proposed. Numerical results are performed in order to prove the performance of the topology regarding efficiency and Common Mode Voltage (CMV) issues.

Keywords:

- photovoltaic systems
- common mode voltage
- leakage current
- efficiency
- parasitic capacitance

Resumen

Los inversores fotovoltaicos (FV) tienen un importante rol en el mercado de la energía debido a sus excelentes características en relación con el costo y la confiabilidad. La estructura más usada en la etapa de conversión de un sistema de energía solar incluye un transformador de baja frecuencia (TBF) el cual proporciona aislamiento galvánico, pero por otro lado reduce la eficiencia total e incrementa el tamaño y costo del sistema. Una alternativa para reducir el tamaño del sistema y las pérdidas de potencia es usar un transformador de alta frecuencia (TAF), el problema en este caso es que se deben usar algunas etapas de potencia adicionales. Las etapas adicionales introducen pérdidas de potencia en el proceso de conversión de la energía por lo que la eficiencia del sistema se reduce. Por lo tanto, la tendencia en la implementación de este tipo de equipos es remover el transformador para incrementar la eficiencia y reducir el costo. Sin embargo, cuando no se provee al sistema de aislamiento galvánico, surge un problema de seguridad relacionado con las corrientes parásitas de modo común. En este artículo se propone una topología de inversor para resolver el problema de las corrientes parásitas de modo común en sistemas FV sin transformador. Se proporcionan resultados de simulación con los cuales se hace un análisis relacionado con la eficiencia y el comportamiento del voltaje de modo común (VMC) para validar la topología propuesta.

Descriptores:

- *sistemas fotovoltaicos*
- *voltaje de modo común*
- *corriente de dispersión*
- *eficiencia*
- *capacitancia parásita*

Introduction

The PV renewable energy has become a very important electrical energy source within the entire energy market. The growing is mainly due to the fact that these systems have been constantly improving in terms of efficiency, power, reliability, etc. On the other hand, the policies stated by the governments in many countries have allowed the spread of the PV systems. The PV system can be designed either in island or grid connected mode being the last one the most commonly used (Kjaer *et al.*, 2005). The grid connection allows injecting the power generated into the electrical grid; in order to achieve this objective, the PV system is commonly set by using three stages: the PV array, the power inverter and the grid filter with the galvanic isolation (Kerekes *et al.*, 2009). In the conventional PV systems, the last stage includes a LFT to link the converter with the electrical grid to provide galvanic isolation as it is shown in Figure 1. However, the main problem with the LFT is that it introduces around 2% of power losses in the system yielding low efficiency. Furthermore, the LFT increases the total cost of the system and the transformer size is big due to the operating frequency that coincides with the frequency of the electrical grid which can be 50 or 60Hz (Gonzalez *et al.*, 2007).

In order to solve the problem of the transformer size, a HFT has been proposed as intermediate stage (Li & Wolrfs, 2008; Xue *et al.*, 2004), the system is shown in Figure 2. However, the efficiency in this case is significantly reduced, not only because of the losses in the transformer but also because of the additional power stages that must be added in the power conversion process. Since the efficiency is one of the most important issues in a PV system, transformerless inverters have emerged to mitigate the problems of the galvanic isolated systems. As the transformerless inverters are connected directly to the electrical grid, there is not galvanic isolation between the PV system and the electrical grid dealing in new problems to be solved.

A PV solar panel naturally presents a stray capacitance which is formed between the PV cells and the grounded frame like in Figure 3. Thus, when the PV generator is connected to the grid by means of a transformerless inverter, a leakage current can flow through the stray capacitances as it is shown in Figure 4. Then, the leakage current can generate additional power losses in the system and a high risk of electrical shock for the users in

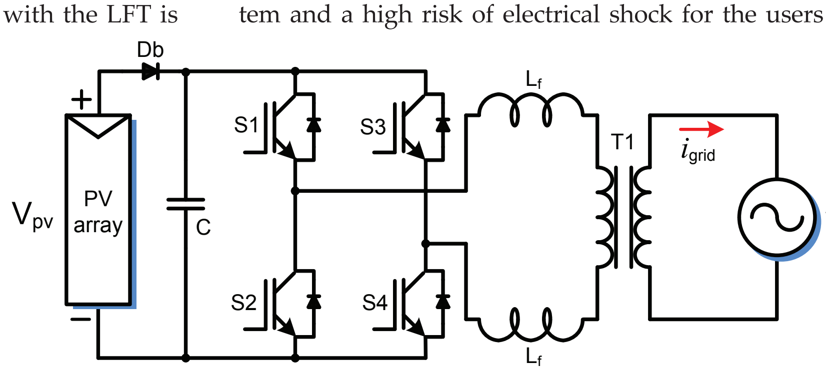

Figure 1. PV inverter with *low frequency transformer* (LFT)