Modulation Techniques to Reduce Leakage Current in Three-Phase Transformerless H7 Photovoltaic Inverter

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***Abstract*—Recently, reduced common-mode voltage (CMV) pulsewidth modulation (RCMV-PWM) methods have been proposed to reduce the leakage current in three-phase transformerless photovoltaic (PV) systems. However, most of these studies only focus on leakage current elimination and neglect the overall performance of the PV systems on issues such as cost, voltage linearity, dc-link current ripples, and harmonic distortion. In this paper, a three-phase transformerless inverter, adapted from the single-phase H5 topology, is investigated. Since the H5 topology has been conventionally developed for a single-phase system, its adaptation to the three-phase system requires the development of corresponding three-phase modulation techniques. Hence, modulation techniques are proposed based on conventional PWM. The performances of the proposed PWM, in terms of CMV, leakage current, voltage linearity, output current ripples, dc-link current ripples, and harmonic distortion are studied and discussed via simulation and experiment. It is proven that the proposed topology is able reduce the leakage current without sacrificing the overall performance of the system.**

***Index Terms*—Common-mode voltage (CMV), leakage current, photovoltaic (PV) system, transformerless.**

I. Introduction

THE rapid increase in human population and the fast growth of industries have shifted the attention of the research community toward photovoltaic (PV) energy. PV energy is free, green, and inexhaustible. Recently, PV power systems have become widespread due to the government incentives, reduction in PV arrays prices, and the advancement of power electronics and semiconductor technology [1]–[6].

Generally, there are two types of grid-connected power systems, i.e., with a transformer and without a transformer. The transformer used can be a high-frequency transformer on the dc side or a low-frequency transformer on the ac side [7]–[10]. In addition to stepping up the input voltage, it plays an important role in safety by providing galvanic isolation, which eliminates the leakage current and avoids dc injection into the grid. Nevertheless, the transformers are bulky, heavy, and expensive. Hence, transformerless PV systems are introduced to overcome these issues. They are smaller, lighter, lower in cost, and highly efficient [9]–[12].

However, safety is the main concern for the transformerless PV systems due to high leakage current. Without galvanic isolation, a direct path can be formed for the leakage current to flow from the PV to the grid. When the PV is grounded, stray capacitance is created. The fluctuating potential charges and discharges the stray capacitance, which generates high leakage current [13]–[15], [26]. In addition to the safety issue, the high leakage current will degrade the performance of the PV system by increasing the grid current ripples, losses, and electromagnetic interference.

Conventional pulsewidth modulation (PWM), either space-vector PWM (SVPWM) or discontinuous PWM (DPWM), are not suitable for three-phase transformerless PV applications due to high leakage current. In order to reduce the leakage current to meet the requirement of the standard, several conversion structures and modulation techniques have been proposed recently. In [5], the connection between the neutral

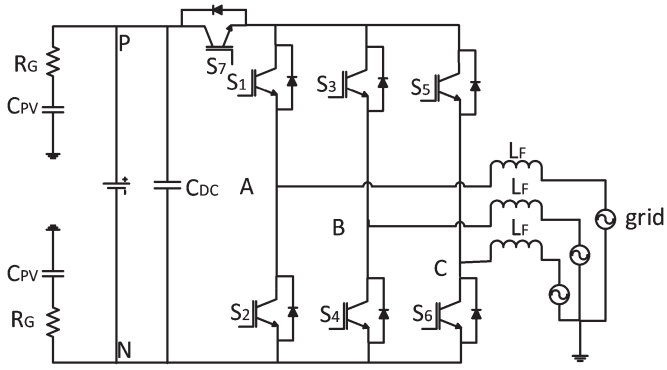

Fig. 1. H7 topology for three-phase transformerless PV systems.

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