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Integrated ZVT Cell Applied to Decentralized Multi-String PV System

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Abstract. This paper exploits the advantages of using a cascaded connection of dc-dc step-up stages for a series string of photovoltaic (PV) panels in a single-phase residential/commercial grid connected installation. It is demonstrated that when multi-string PV systems are adopted in order to minimize shadowing problems, it is required to employ some approach to reduce the switching losses (turn-on losses of MOSFETs and mainly diode reverse-recovery losses) of the dc-dc step-up stages. As a multi-string PV system is normally comprised by several dc-dc step-up stages, integrated soft-switching topologies are attractive due to their compactness, reliability and low cost. Thus, this work proposes to use an integrated zero-voltage transition (ZVT) cell, which assists all dc-dc step-up stages and employs a very compact circuit, enabling to minimize the switching losses, improving the system efficiency. The proposed cell makes use of a magnetically-coupled auxiliary voltage source implemented by adding a secondary winding on the input inductors. In order to validate the proposed topology, experimental results are presented.

Key words

Multi-string photovoltaic (PV) system, dc-dc step-up converter, zero-voltage switching (ZVS), zero-voltage-transition (ZVT).

1. Introduction

Nowadays, there has been a significant growth of the photovoltaic (PV) market mostly due to the proliferation of grid connected PV systems [1]. Likewise other intermittent renewable sources, to optimize the PV array area and make the implantation of grid connected PV systems economically viable, it is essential to drain the maximum power produced by the PV panels, which is accomplished by means of a maximum power point (MPP) track algorithm [2]-[3] commonly applied to the front-end dc-dc stage.

Due to dissimilarities of panel production, different temperatures and irradiations – due to panel orientation, aging or partial shading [4] – PV modules cannot produce identical energy in an array. Hence, in a long string PV array, this situation may result in the lost of the MPP, which reduces the overall efficiency of the entire array and, in some cases, can cause degeneration of the panels due to the hot spot phenomenon. To ensure the maximum production of electricity even when shading or other dissimilarities are present, decentralized PV systems have been proposed in the literature. Some works demonstrate that a gain of up to 16% of generated energy could be achieved with decentralized PV systems [5].

In general, decentralized PV systems split the maximum power point tracker (MPPT) stage, which can be dedicated exclusively to a single or a small group of PV panels. Decentralized systems can be grouped in three different approaches, namely module integrated systems [6], string and multi-string systems [7].

As a multi-string PV system is comprised by several dc-dc step-up stages, to reduce the turn-on losses of MOSFETs and diode reverse-recovery losses of all dc-dc stage is a quite complex task since the auxiliary circuitry may increase significantly the converter size, weight and cost. Additionally, a large semiconductor count could reduce the reliability of the PV system.

This way, this paper exploits the advantages of using a cascaded connection of dc-dc step-up stages for a series string of PV panels in a single-phase residential/commercial grid connected installation with an integrated soft-switching topology [8]. It is proposed the use of a very compact integrated zero-voltage-transition (ZVT) circuit, which assists all the dc-dc step-up stages, enabling to minimize both the turn-on losses of MOSFETs and diode reverse-recovery losses.

2. Performance of Multi-String MPPT Stages

Multi-string PV systems combine the use of individual MPPT algorithm with the lower costs of a central inverter PV system [9], reducing the possibility of shadowing mismatches.

Fig. 1 (a) shows the efficiency comparison of multi-string PV systems with one through four input dc-dc step-up stages. The analyzed system makes use of the Hypothetical Standard Module (HSM) specified in Table I. The step-up stage parameters and components are defined in Table II.

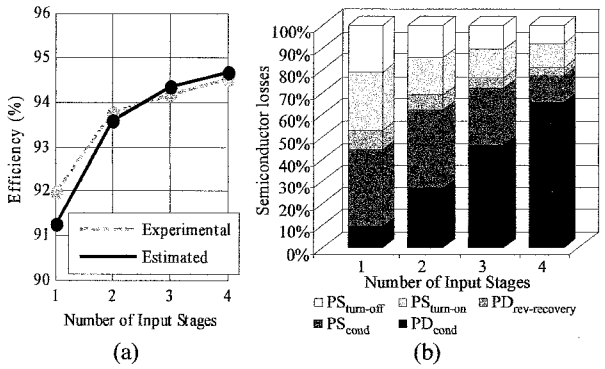

Fig. 1. Decentralized multi-string dc-dc step-up stage performance. (a) Efficiency of hard switched system. (b) Semiconductor power loss balance.