



Highly efficient flyback microinverter for grid-connected rooftop PV system



Rasedul Hasan, Saad Mekhilef*

Power Electronics and Renewable Energy Research Laboratory (PEARL), Department of Electrical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:

Received 7 December 2016

Received in revised form 26 February 2017

Accepted 7 March 2017

Keywords:

Microinverter

Flyback DC-DC converter

Active-clamp circuit

Zero voltage switching (ZVS)

Grid-connected rooftop PV

ABSTRACT

This paper proposes a high efficiency DC-DC flyback converter with a resonant full-bridge inverter to use in PV systems. The flyback converter is composed of a resonant active-clamp circuit that limits the voltage stress and provides zero voltage switching (ZVS) turn-on and turn-off of the power switches. Therefore, the switching losses of the high frequency primary switches are negligible. A resonant full-bridge inverter with ZVS of the high frequency switches is adopted to make the overall efficiency high. Moreover, using a film capacitor in the DC link for the power decoupling, the lifespan of the microinverter is increased. A 250 W prototype of the proposed microinverter has been implemented and the performance is analyzed with different loading condition. The feasibility analysis of the proposed topology for the PV modules in different weather condition confirms the superiority of the proposed microinverter for rooftop PV system compared with the existing topologies.

© 2017 Published by Elsevier Ltd.

1. Introduction

Global solar power capacities have reached approximately 256 GW by 2015 and the prices of photovoltaic (PV) panels and solar energy have fallen to one-third by past five years (“GTM Research: Global Solar PV Installations Grew 34% in 2015,”; Wagner et al., 2015). The solar photovoltaic power systems are mainly proliferating due to the grid-connected or utility-interactive PV systems. The stand-alone PV systems commonly include battery storage for an independent operation and hence require a large installation cost and periodic maintenance. Therefore, the stand-alone PV systems are only efficient in islands and remote areas (Tollefson, 2014). In grid-connected PV systems, the power is directly injected into the grid rather than storing in batteries. Thus the grid-connected systems are more cost effective and require less maintenance than standalone systems (Tareen et al., 2017). Hence, grid-connected PV systems occupy 99% of the total installed capacity compared to 1% of the standalone systems (Kouros et al., 2015). Among the grid-connected systems, small-scale rooftop PV has become a popular electricity generation system to the building owners, and widely emerged in developed countries (Rodrigues et al., 2016). The Net metering and Net feed-in tariffs policies attract the consumers to set grid-connected

rooftop PV system (Campoccia et al., 2014; Mountain and Szuster, 2015). The extraction of maximum power from the PV panel and injection of a higher quality of power in the grid is the major technical challenge for the converter used in PV system. Therefore, a maximum power point tracking (MPPT) control technique is employed for the inverter used in PV system. On the basis of the different arrangements of PV modules, the grid-connected PV inverter can be categorized into central inverters, string inverters, multi-string inverters, and AC-module inverters or microinverters (Kjaer et al., 2005). The string or central inverters are mostly used due to their ease of installation and low cost. The market share of string and central inverters is 37% and 61% respectively, whereas only 2% for microinverters (“Photovoltaics Report, Fraunhofer Institute for Solar Energy Systems (ISE), Jun 2016”). However, shading from a tree or cloud is very often on rooftop solar PV panel (Eke and Demircan, 2015; Lappalainen and Valkealahti, 2016). The worst condition arises when one or two panels of a string are shaded and reduce the output of the entire string (Bai et al., 2015). Hence, the string or central type inverters are not a feasible solution for small-scale grid-tied rooftop PV system.

The microinverter is a low power rating converter of 150–400 W in which a dedicated grid-tied inverter is used for each PV module of the system. The compact design attached to the back of each PV module with the highest MPPT provides high efficiency for the PV system under partial shading. The microinverters require an additional DC-DC stage to step up the voltage of PV modules compare to the grid level. Non-isolated boost converters

* Corresponding author.

E-mail addresses: rasel61kuet@gmail.com (R. Hasan), saad@um.edu.my (S. Mekhilef).

Nomenclature

DC-DC Converter

C_c	clamp-capacitor
C_{dc}	DC link capacitor
C_{r1}	resonant capacitance of the flyback converter
D	rectifier diode
D_c	duty cycle
D_w	dwell time duty ratio
E_{clamp}	energy stored in the clamp-capacitor
E_{Lm}	energy stored in the magnetizing inductance
i_c	clamp switch current
i_D	diode current
i_{sm}	main switch current of the flyback transformer
i_{sm-pk}	peak value of the primary switch current
i_{Lr1}	resonant inductor current
i_{Lr1-pk}	peak value of the resonant inductor current
i_{Lm}	magnetizing current
i_{Lm-pk}	peak value of the magnetizing current
I_{PV}	DC current of PV module
L_m	magnetizing inductance
L_{r1}	resonant inductance of the flyback converter
n	turn's ratio
S_c	clamp-switch
S_m	main-switch of the flyback transformer
T_1	flyback transformer
T_d	dead time
T_s	switching period
$T_{resonant}$	resonant period
$V_{ds,Sm}$	main switch drain-source voltage
$V_{ds,Sc}$	clamp switch drain-source voltage

$V_{gs,Sm}$	main switch gate-signal
$V_{gs,Sc}$	clamp switch gate-signal
V_{PV}	PV voltage
V_{dc}	DC link voltage
V_D	voltage across the rectifier diode
V_{Cc}	voltage across the clamp capacitor
Z_i	characteristic impedance
ω_r	resonant frequency

DC-AC inverter

C_1 – C_4	small capacitors across the bridge switches
C_{ca}	auxiliary clamp-capacitor
C_f	filter capacitor
C_{r2}	resonant capacitor
i_{S1-S4}	bridge switches current
i_{sr}	resonant switch current
i_{Lr2}	resonant inductor current
L_{r2}	resonant inductor
L_f	filter inductor
$V_{ds,Sr}$	resonant switch drain-source voltage
$V_{ds,S1-S4}$	bridge switches drain-source voltage
$V_{gs,Sr}$	resonant switch gate-signal
$V_{gs,S1-S4}$	bridge switches gate-signal
V_{pulse}	short-circuit pulse
S_r	resonant switch

List of abbreviations

MPPT	maximum power point tracking
ZCS	zero current switching
ZVS	zero voltage switching

or high-frequency DC-DC converter usually provides the additional boost stage. The transformerless or non-isolated types of microinverters are superior in terms of cost, efficiency, and compactness (Chen et al., 2015; Erickson and Rogers, 2009; Meneses et al., 2013; Yu et al., 2011). However, the presence of leakage ground currents, the requirement of dual grounding, and the low voltage gain are the limitations in realizing them with PV modules. The isolated types of microinverters are a better option in solving these problems. The flyback type microinverter is typically one of the common isolated-topologies considered for a single PV application (Hasan et al., 2017; Rezaei et al., 2016; Shimizu et al., 2006; Sukesh et al., 2014). It provides simple circuit structure, minimal number of power semiconductor devices, and ease of control operation compared to other topologies. Moreover, it has better performance in low power application. Hence, it is more suitable for low power grid-connected microinverter attached with single PV panel. The lifespan of the microinverters is another important issue in terms of reliability with the lifetime of PV panel (usually 25 years). The lifespan mainly depends on the longevity of the power decoupling capacitor. An electrolytic capacitor would shorten the lifetime whereas a film capacitor can extend the overall lifetime of the microinverter (H. Hu et al., 2013). The electrolytic capacitor can be replaced with a film capacitor by allowing a high voltage DC link between the DC-DC and inverter stage or employing a power decoupling circuit on the PV side of flyback microinverter (Hu et al., 2012; H.B. Hu et al., 2013; Tan et al., 2007).

However, the switching losses associated with the hard-switched operation and the low utilization factor of flyback converters is the major drawbacks to achieve a reliable grid-tied microinverter. The hard-switched flyback converters undergo substantial switching losses in the high-frequency switches and high current and voltage stresses on power devices (Hu et al., 2012;

H.B. Hu et al., 2013; Shimizu et al., 2006). The interleaved flyback converters can reduce the voltage and current stresses by splitting them into two phases and hence increase the efficiency (Edwin et al., 2014; Gao et al., 2014; Zhang et al., 2013). However, the power density is reduced and the electrolytic capacitors shorten the lifetime of the microinverters. The line-frequency multilevel microinverter may also applied in reducing the switching losses (Carbone and Tomaselli, 2011). The zero voltage switching (ZVS) of the high frequency switches is a better option in reducing the switching losses of the microinverters. The bidirectional switches placing in the secondary (Sukesh et al., 2014), or the active clamp circuit in the primary can achieve ZVS operation of the high frequency switch (Kim et al., 2013; Lin and Hsieh, 2007; Perrin et al., 2016). The soft-switching operation of these converters increases the efficiency, but the power decoupling electrolytic capacitors decrease the lifespan. Active-clamp circuit is also applied in dc-dc forward converter of a microinverter to achieve ZVS operation in the high frequency primary switches (Cha et al., 2016, 2015). Although the forward converter has better transformer utilization factor compare to flyback converter, the extra output inductor, and freewheeling diodes increase the cost of DC-DC converter. The resonant switching operation in the flyback converter can achieve zero voltage switching (ZVS) and zero current switching (ZCS), and hence increase the efficiency of the converter (Chung et al., 2004, 1998; Keyhani and Toliyat, 2014; Perrin et al., 2016; Tarzamni et al., 2017).

In this study, a highly efficient and long lifespan flyback microinverter is proposed for grid-connected rooftop PV system. The proposed microinverter combines a resonant active-clamp flyback dc-dc converter with a resonant full bridge inverter. The resonant active-clamp circuit in the dc-dc stage composed of a resonant inductor and clamp capacitor, which achieves the ZVS

Download English Version:

<https://daneshyari.com/en/article/5451322>

Download Persian Version:

<https://daneshyari.com/article/5451322>

[Daneshyari.com](https://daneshyari.com)