BCM-CPC Flyback Micro-inverter for Grid-connected Photovoltaic Application

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ABSTRACT: In the emerging era of sustainable energy, a flyback-based micro-inverter has become mainstream due to its advantages in both technical and economic aspects. The high switching loss in discontinuous conduction mode (DCM) and complex right-half plane control in continuous conduction mode (CCM), leaves the boundary conduction (BCM) as a prime candidate to achieve high efficiency in its operation. This paper proposes a single-phase flyback micro-inverter with BCM current peak control strategy. Its final voltage and current output are presented and discussed in-term of total harmonic distortion (THD) value with an efficiency of 90% at a 100W circuit configuration.

Keywords: *flyback; micro-inverter; boundary conduction mode*

1. INTRODUCTION

The sustainable energy generated from the sun via photovoltaic panel (PV) requires a system with rigid requirements such as compactness, higher in reliability and effectiveness but lower in installation and maintenance cost. Among all available inverter systems, micro-inverter satisfy all the harsh aforementioned requirements [1][2]. By definition, a micro-inverter is an integration of a single PV panel and a single-phase grid-tied inverter which generates an operational ac grid voltage by a converted low dc voltage from the PV. A flyback type, as shown in Figure 1, is one of the most interactive configurations that come with lists of advantages such as electric isolation, excellent efficiency, high power density, and high boost ratio. Despite being built on the compact structure and simple control approach, there are still more works that have to be done in several areas such as power decoupling, soft-switching, MPPT control, and control loop. Besides a BCM, a flyback micro-inverter is also operated in a CCM and DCM. However, control algorithms become complicated when it comes to CCM due to the existence of the right half-plane in the control loop and significant switching losses, huge current peaks, and high operation frequency in DCM [3].

In this paper, a BCM current peak control (BCM-CPC) approach for a 100W single-phase grid-connected micro-inverter is proposed. The proposed control strategy will be validated and confirmed by simulation results.

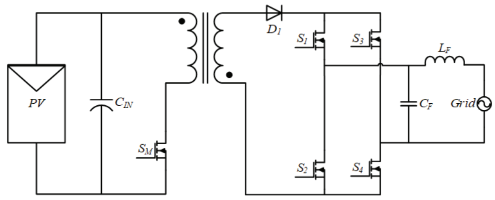


Figure 1 Flyback micro-inverter topology

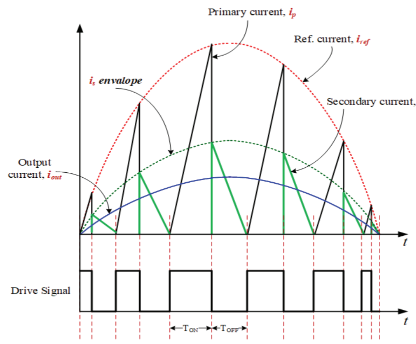


Figure 2 BCM switching characteristic

2. METHODOLOGY

Theoretically, shortcoming comes from CCM and DCM can be neutralized by the implementation of BCM current peak control. In the BCM-CPC, the peak primary current i_p is obliged to follow the reference current i_{ref}. with variable switching frequency. During each switching cycle, a master switch S_M is turned on when the secondary current i_s falls to zero. When S_M conducts, i_p rises linearly with respect to the v_{dc}. S_M turned off once i_p equal to i_{ref} and i_s decreases linearly with v_g. The switching behavior of BCM-CPC can be visualized in Figure 2. The current reference i_{ref} during the half-line period can be deducted as

$$i_{ref} = 2I_A\left(\frac{V_p}{V_{dc}}sin^2(\omega t) + \sqrt{\frac{L_s}{L_p}}sin(\omega t)\right) \quad (1)$$

Where V_p is the peak grid voltage, V_{dc} is the dc voltage, and L_p and L_s are the primary and secondary inductance of the flyback transformer, respectively. I_A is related to P_{out} which is defined as

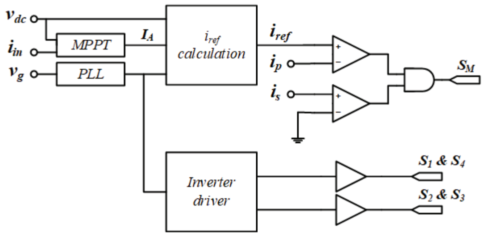


Figure 2 BCM control block

$$I_A = \frac{2P_{out}}{V_p} \quad (2)$$

Figure 3 illustrates the proposed switching strategy control block which consists of maximum power point tracking (MPPT) and phase lock loop (PLL) to detect grid frequency and phase angle. It is simulated and validated using Matlab/Simulink.

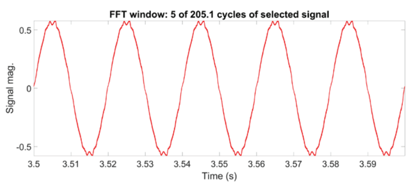
3. RESULT AND DISCUSSION

The proposed micro-inverter is modeled based on parameters listed in Table 1. Operation verification is done by simulation studies performed in Matlab/Simulink software platform and presented in Figure 4 and Figure 5.

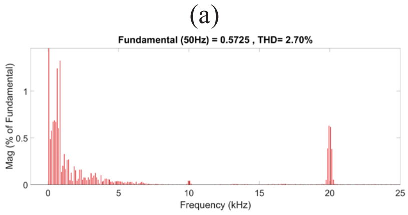
Table 1 Key parameters of the micro-inverter

Parameter	Symbol	Value	Unit
Grid Voltage	V_g	220	V_{rms}
System frequency	f_o	50	Hz
Input voltage	V_{dc}	40	V
Rated power	P_{PV}	100	W
Transformer turns	N_p:N_s	1 : 7	
Primary Inductance	L_p	55	µH
Secondary Inductance	L_s	2.69	mH
DC-Link Capacitance	C_{dc}	960	µF
Input Capacitance	C_{in}	12	mF
Switching frequency (S_1-S_4)	f_{sw}	10	kHz

The output current and its harmonics spectrum of the micro-inverter are shown in Figure 4 (a) and (b). Subsequently, Figure 5 (a) and (b) illustrate the voltage output and its respective spectrum. The total harmonic distortion (THD) is at 2.7% and 1.56% for output current and output voltage, respectively, which are in line with the standard set by international authorities i.e. IEEE519 [4]. Even without the optimized power coupling and effective snubber circuits, the simulated circuit with the proposed control strategy performed at its best with 90% efficiency.

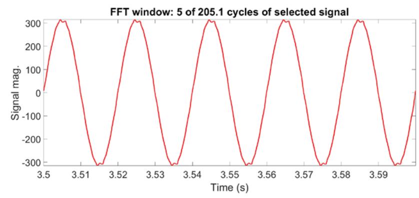


(a)

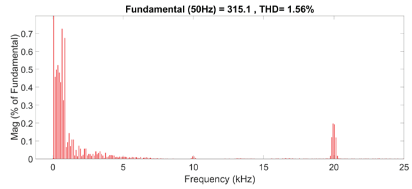


(b)

Figure 3: (a) Output Current (b) Current Harmonics



(a)



(b)

Figure 1(a) Output Voltage (b) Voltage Harmonics

4. CONCLUSION

The boundary conduction mode with current peak control for a single-phase flyback micro-inverter has been presented in this paper. The proposed topology and control method are verified in a simulation work which reveals an outstanding result in-term of THD level less than 5% and the operation efficiency reaching 90%, even if the optimized snubber and power coupling circuits are omitted.

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