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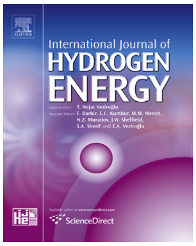

Soft switching maximum power point tracker with resonant switch in PV system[☆]

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ARTICLE INFO

Article history:
Received 11 November 2015
Received in revised form
13 January 2016
Accepted 14 January 2016
Available online 14 February 2016

Keywords:
Boost converter
MPPT
Resonant switch
Zero voltage switching
Frequency control

ABSTRACT

Conventional boost converters are used in many applications such as power factor correction, electronic ballasts, battery chargers, photovoltaic (PV) applications. PV systems need maximum power point tracker (MPPT) to have efficient power conversion. Maximum power point trackers are usually implemented by pulse width modulation (PWM) controlled converters. In PWM control, the switching losses and the voltage–current stresses of the device increase. In the present paper, an MPPT with soft switching boost converter is designed, simulated and experimentally tested. The topology adds a resonant network to the conventional boost converter and controls the PV power by changing the switching frequency. In the proposed converter, Perturb & Observe method is used as power tracking algorithm that is implemented with dsPIC30F2020 and zero voltage switching (ZVS) is achieved in wide range. The variable frequency controlled MPPT is tested for different radiation levels and loads and switching characteristic is compared with PWM controlled boost converter. The proposed single switch resonant converter is simulated in PSIM and experimental validation is also given for a 40 W PV generation system.

Introduction

Over the last years, for improving the efficiency and the power density of renewable energy sources like photovoltaic (PV) energy conversion systems, the interest in power electronics applications has increased. The output power of the PV panel is related to the intensity of solar radiation, the temperature, and the load [1–5]. PV systems work in different environmental and electrical conditions. For this reason, PV generators are connected to loads by dc–dc converters called MPPT. The MPPT changes the operation point of the PV system to find the maximum possible power in any case [6]. Generally PWM type boost converters are used for transferring the maximum output power of the panel. The advantages of the boost converters in such applications are the low input current ripple, and the easy control [1,7]. Furthermore, in the continuous current mode, the boost converter has better characteristics than the buck converter [8–11].

For increasing the power density of the converter, it is necessary to increase the switching frequency, and in this way the size and weight of the converter decrease too. However, operating at high switching frequency can produce several problems, such as increased switching losses and

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[☆] This work was supported in part by the Karabuk University BAP, KBÜ-BAP-13/1-YL-034.

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http://dx.doi.org/10.1016/j.ijhydene.2016.01.088
0360-3199/

stress [12]. For preventing such problems, a snubber circuit or a soft switching cell in the PWM converter [13,14] can be used. For decreasing the switching losses in PV applications, some researchers tried to use soft switching PWM converters [15–18]. But PWM converters with an auxiliary soft switching circuit are more complex and expensive since they need an additional power switch, a complex control algorithm, and a floating gate driver [14,17–22]. By using a resonant switch, the mentioned drawbacks of the PWM converters may be avoided [23–28].

In this study, for tracking the MPP a quasi-resonant boost converter is designed and experimentally tested; soft switching is achieved by help of a resonant switch. The ZVS of the power device is achieved by using an *LC* resonant circuit. Parasitic inductances and capacitances can be incorporated into this resonant circuit. No snubber circuit is used. In addition, neither auxiliary switch nor floating gate drive is required. Perturb and observe MPPT algorithm is applied with dsPIC30F2020 and implemented on the single switch resonant converter. MPP of the 40 W PV panel is tracked by changing both switching frequency and the duty cycle. Zero voltage switching operation is maintained while tracking the MPP. Soft switching MPPT is compared with PWM controlled MPPT at 35 kHz switching frequency. The proposed system has good start-up characteristics with low switching losses and, it tracks the maximum power value in different conditions by variable frequency operation.

ZVS boost converter for PV systems

The soft switching boost converter with a resonant switch is shown in Fig. 1(a). The converter consists of a PV Panel, a power switch (*M*) with its anti-parallel diode (D_1), a choke inductor and filter capacitors (L_i and C_i, C_o), a resonant circuit (*L* and *C*), a rectifier diode (D_2), and a load (R_o). In steady state, the input inductor and the input voltage source of the converter can be represented by a current source and output circuit can be replaced by a voltage sink [25,27]. Fig. 1(b) shows the equivalent circuit of the resonant boost converter.

The resonant circuit shapes the voltage of the switch from a square wave to a sinusoidal wave. Fig. 2 shows the switching waveforms of the quasi-resonant boost converter [25]. A short description of the functioning of the proposed MPPT is as follows.

Assuming the input current and output voltage are constant and the converter is in steady state, the converter has four operation modes [25].

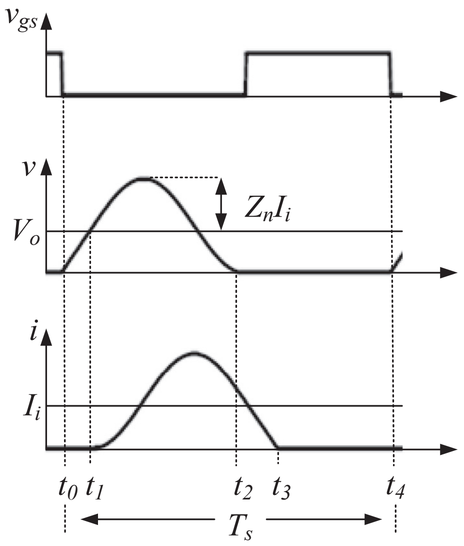


Fig. 2 – Theoretical waveforms of ZVS boost converter.

Mode I ($t_0 \le t < t_1$): When the switch is turned off, the input current flows through the resonant capacitor.

Fig. 3 shows the equivalent circuit for Mode I.

This mode continues until the capacitor voltage reaches V_o. During this stage, D_2 is open circuit and the resonant capacitor is charged from zero to V_o. The capacitor voltage rises linearly, so its voltage can be derived as:

$$v(t) = \frac{I_i}{C}t \tag{1}$$

Mode II ($t_1 \le t < t_2$): When the capacitor voltage reaches V_o, the diode D_2 is forward biased and the resonance occurs (Fig. 4).

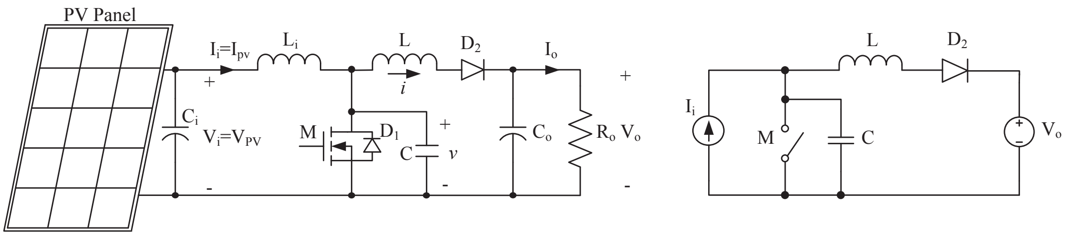
The capacitor voltage and the inductor current are expressed by:

$$v(t) = V_o + Z_nI_i \sin\omega_r t \tag{2}$$

$$i(t) = I_i\,(1 - \cos\omega_r t) \tag{3}$$

where Z_n is the characteristic impedance and ω_r is the resonant angular frequency.

$$\omega_r = \frac{1}{\sqrt{LC}} \tag{4}$$



(a) (b)

Fig. 1 – (a) The proposed MPPT with quasi resonant boost converter, (b) the simplified circuit.