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Research Article

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Design of A Flyback Inverter with Interference Capability for Photovoltaic Applications and Simulation with PSIM Software

By Topalis Andreas*

Supervisor: Ganatsios Stergios, Department of Electrical and Computer Engineering, University of Western Macedonia Faculty of Engineering, 50100 Kozani, www.uowm.gr

***Corresponding author:** Topalis Andreas, Email: satan131984@hotmail.com

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Abstract
The increasing usage of green sources of energy, most of all solar energy, reinforces the need for the development of efficient and reliable power converters. Flyback converters are one of the most widespread topologies in photovoltaic applications, thanks to their simple structure, low cost and the possibility of electrical isolation they offer via a transformer. Despite their advantages, they face challenges such as high switching losses, increased output voltage ripple and limited efficiency. In this paper, the design and simulation of an interleaved flyback converter, which incorporates an RCD snubber circuit, is proposed. This circuit reduces the voltage spikes (dv/dt) on the MOSFET switches, protects the circuit from overvoltages and improves the overall system performance. The simulation results show reduced fluctuations, higher stability and increased efficiency, which makes the proposed topology particularly suitable for small-scale photovoltaic applications.

Keywords: *Flyback converter, Interleaved topology, RCD snubber circuit, Photovoltaic applications, DC–DC power conversion.*

1. Introduction

Solar energy is probably the most exploitable and the only true inexhaustible form of green renewable energy and it has an enormous part of the energy mix of the whole world [1]. According to estimates by international organizations, by the end of the 21st century, renewable sources are expected to cover 20–30% of total energy consumption [3]. However, due to its intermittent nature, solar radiation causes significant variability in the power output, requiring the use of specific electronic converters to maintain a stable supply. (Kouro et al., 2010). [2]

DC–DC converters play a crucial role in photovoltaic systems, as they provide stable output, adapt the voltage to the load requirements and ensure electrical isolation when required. In their design, the main limitations concern size, weight and the need for safe isolation between source and load, which is achieved through a transformer. [2]

Among the various topologies, flyback converters are particularly preferred in low-power applications because of their simple structure, low cost, and fast transient response (Lee & Ridley, 2011). At the same time, they have disadvantages, such as increased switching losses, limited efficiency and high MOSFET stress, which requires using specific extra snubber circuits to protect the switches (Zhang et al., 1998). In the case of interleaved flyback topologies, two or more converters operate in parallel, which leads to a reduction in RMS and peak currents, a limitation of ripple at both the input and output, other than a reduction in electromagnetic interference. Parallel current distribution also contributes to more uniform thermal management, reducing thermal stresses on the semiconductor elements and transformer. In addition, these topologies can increase the general efficiency of the system enabling the use of smaller and more economical filtering elements. The effectiveness of this approach has also been confirmed in high-power studies, where interleaved flyback configuration was applied to photovoltaic applications, achieving lower fluctuations, reduced switch stress, and increased operating stability (Kavathekar & Patil, 2020).

2. Block Diagram

The block diagram of the proposed interleaved flyback converter for photovoltaic applications that is shown in Figure 1. The input of the system consists of a photovoltaic source, which provides a DC voltage in the range of 20–30 V. This signal is fed to the interleaved flyback converter, which steps up the voltage and provides a stabilized output of 110 V DC. The output voltage gets directly stabilized by a PWM controller in current mode, which ensures fast response and reduced ripple [2]. The output then feeds a full-bridge inverter, which applies a sinusoidal PWM (SPWM) technique to convert the DC voltage into AC voltage, suitable for powering AC loads. The combined interleaved flyback–full bridge topology is capable to offer increased reliability while reducing the electromagnetic interference while also improving thermal distribution, making it particularly efficient for small and medium-scale photovoltaic applications [1].

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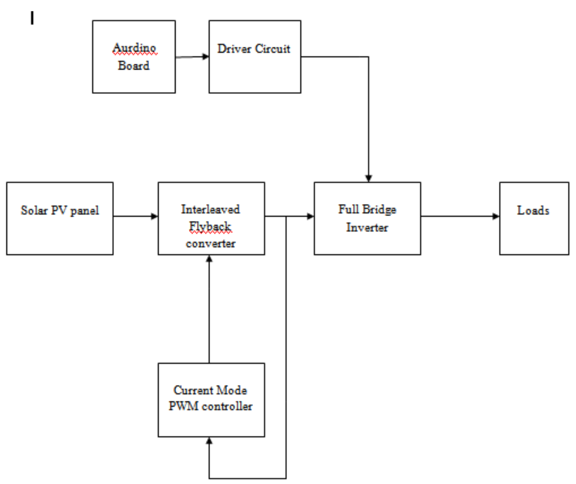

Figure 1 Block scheme of an interleaved flyback converter that has a DC–DC boost stage and a full-bridge inverter.

3. Circuit Operation

The interleaved flyback topology combines two identical converters, whose power switches (Q1, Q2) are alternated, thus providing equal current distribution and improved efficiency (Kavathekar & Patil, 2020). In the 1° phase of operation, switch Q1 is active and Q2 is inactive, resulting in energy being stored in transformer T1, while the output diodes are in appropriate bias. In the second phase, Q2 gets turned on while Q1 is turned off, storing energy in transformer T2 and delivering electricity to the load through diode D1. [4] With this alternating mode of operation, the two converters share the load, reducing current peaks switching both losses and electromagnetic interference, while improving the thermal distribution of the system [2].

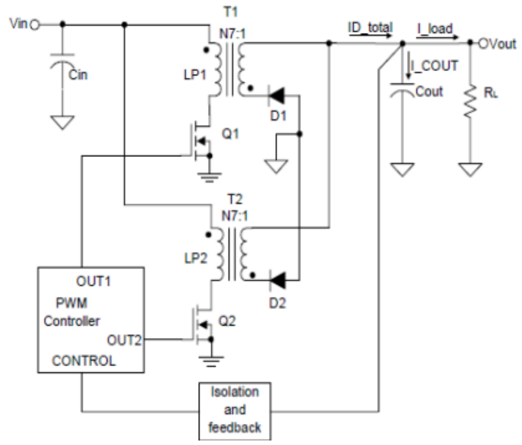

Figure 2: Circuit scheme of an interleaved flyback converter that has two operating phases.

4. Design of Interferent Flyback Converter

The switching inverter is designed for a nominal power of 45 W. The characteristics of the proposed converter are given below:

- Input voltage range: 20-30 V
- Output voltage: 110V
- Output power: 45W
- Efficiency: 75%
- Switching frequency: 100KHz
- Duty Ratio: 0.4

The input current is given as follows

$$I_{in} = \frac{P_{in}}{V_{imin}} = \frac{60}{20} = 3A$$

The peak primary current can be obtained as follows

$$I_{pp} = 2 \times \frac{I_{in}}{D} = 2 \times \frac{I_{in}}{0.4} = 15A$$

The primary inductance is

$$L_p = V_{imin} \times \frac{D}{I_{pp}} \times f_s = 20 \times \frac{0.4}{15} \times 100 \times 10^3 = 5.3uH$$

The flyback converter voltage gain equation may be derived from relation

$$\frac{V_o}{V_{in}} = \frac{n \times D}{1 - D} = 8.5$$

Below is the output current

$$I_0 = \frac{P_o}{V_0} = \frac{45}{110} = 0.41A$$

The output resistance is below

$$R_o = \frac{V_0}{I_0} = \frac{110}{0.27} = 268\Omega$$

Ripple voltage is 1% of output voltage

$$\Delta V_0 = 0.01 \times 110 = 1.1V$$

The output capacitor is correlated to the relationship

$$C = \frac{D}{\left(\frac{\Delta V_O}{V_O}\right) X\ R_O\ X\ f_s}$$

$$C = \frac{0.4}{\left(\frac{1.1}{110}\right) X\ 268\ X 100\ X\ 10^3}$$

$$C = \frac{0.4}{0.01\ X\ 268\ X\ 100000} = \frac{0.4}{26800} = 1.49X\ 10^{-5}\ F \approx 15\mu F$$

The main winding number of the transformer is figured out by the formula given below

$$N_p = \frac{V_{imin}\ x\ D}{B_{max}\ X\ A_C\ X\ f_s}$$

The number of secondary windings is given by

$$N_s = n \times N_p = \approx 8.25 \times 15 \approx 124\ spirals$$

4.1. Snubber Circuit Design

The reflected voltage of the flyback converter is given by the relationship

$$V_{ref} = \left(\frac{N_p}{N_s}\right) \times V_0 = \left(\frac{1}{8.5}\right) \times 110\ \approx 12.9V$$

The absorption voltage (Snubber) is two to three times greater than the reflected voltage. [5]

$$V_{sn}\ =\ 2\ to\ 3\ of\ the\ V_{ref}\ =\ 60V$$

The Snubber resistance is given by

$$R_{sn} = \frac{Vsn^2}{0.5 \times L_l \times Ipp^2 \times \left(\frac{V_{sn}}{V_{sn}} - n\right) \times V_0 \times f_s} = 1.3kohm$$

Snubber capacitance is related by the equation

$$C_{sn} = \frac{V_{sn}}{0.1 \times V_{sn} \times R_{sn} \times f_s} = 0.75nF$$

5. Results

In this section, an interleaved flyback converter is simulated. The PSIM software was used to simulate the circuit. Figure 3 shows the scheme of the interleaved flyback converter that is proposed.

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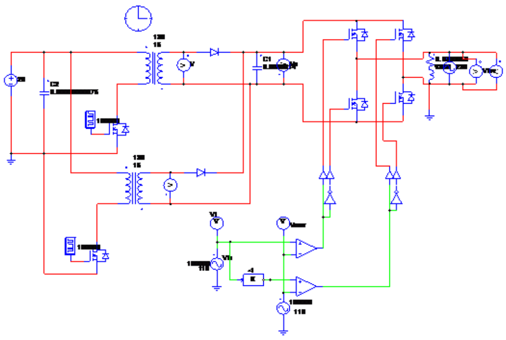

Figure 3: Simulation circuit of an interleaved flyback converter in PSIM software.

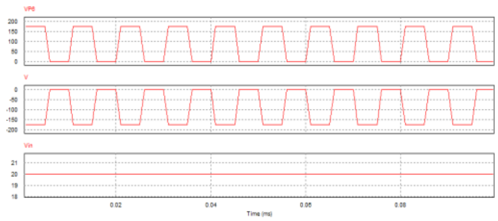

Figure 4: Input voltage (V_{in}) and output voltages of the two interleaved flyback inverters.

Figure 4 shows the output voltage waveforms of the two interleaved flyback converters. When the input is set to 20 volts, each converter generates an output close to 110 volts.

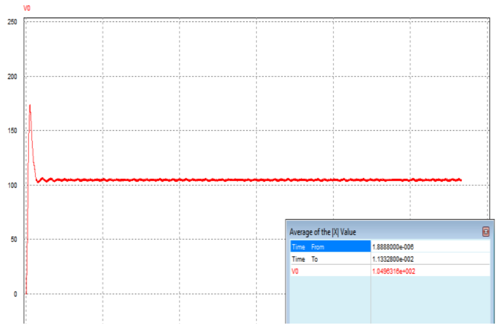

Figure 5: Overvoltage in the interleaved flyback converter during switching (PSIM).

The above waveforms show the output voltage of the flyback converter with interpolation. The output voltage is 170 V for an input voltage of 20 V.

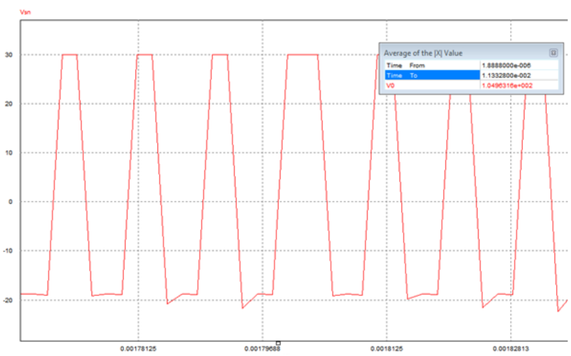

Figure 6: Voltage across the switches of the interleaved flyback converter.

The waveform in the image above illustrates the output voltage of switch 1 of the interleaved flyback.

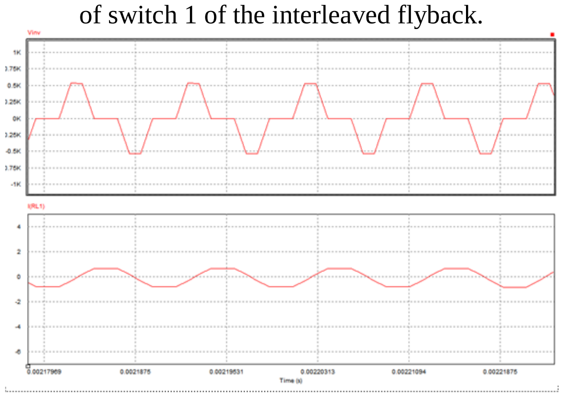

Figure 7: Inverter output and output current.

The waveforms are indicative of both the output voltage and the output current of the flyback interleaved converter.

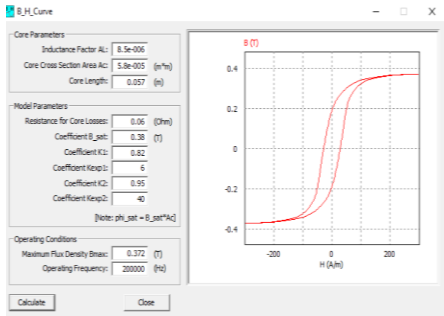

Figure 8: B-H curve and core, transformer parameters (PSIM).

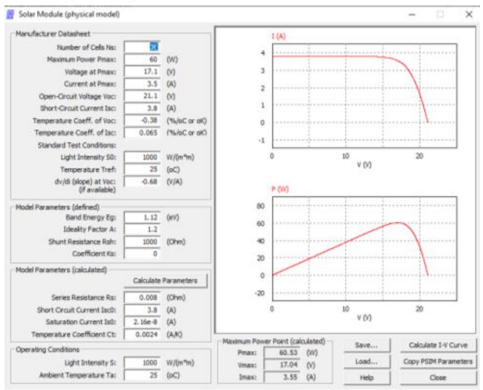

Figure 9: Solar panel model and its characteristic curves (PSIM).

6. Conclusion

This article presents the design and simulation process of an interleaved flyback converter for photovoltaic applications. An RCD snubber circuit was also designed to protect the circuit breakers from high voltages and fast dv/dt changes. The proposed converter ensures low output ripple and reduces the need for large filter capacitors. The converter can provide a constant voltage of 110 V for an input of 20–30 V and operates at a frequency of 100 kHz. The output filter is designed to minimize voltage and current ripple.

In the context of the work, the simulation results from the PSIM software were presented, including the B–H curve of the transformer (Figure 8) and the photovoltaic panel model (Figure 9). Based on the above, it is demonstrated that the proposed topology is efficient and can form the basis for future implementation in real photovoltaic devices, aiming to further improve the performance and control of the system.

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