SOFT-SWITCHED PWM HIGH-FREQUENCY WITH PFC CONVERTER USING BOOST-FLYBACK CONVERTER INTERLEAVED

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ABSTRACT - This paper proposes as a power factor correction pre regulator converter an AC-DC interleaved Boost-Flyback using a non-dissipative snubber and operating at 100kHz per cell. That is composed by switches working in ZCS and ZVS way, controlled by PWM. By using interleaved converters, can obtain an overall reduction of the Boost inductor, reduced switching losses without increasing current and voltage stresses. This topology has the advantages of interleaved Flyback that eliminates an auxiliary source and an inductor in this configuration. The complete operating principles, theoretical analysis, relevant equations and simulation results are given to show the feasibility of proposed power factor correction converter. Experimental results are presented in this work, with a power tested with the prototype rated at 2.000 Watts.

1 – INTRODUCTION

The intensive use of the electronic converters, mainly, in the equipment in industrial and domestic fields, for instance, telecommunications, control and motor drives, instruments of measures and switching power supply for computers, it is contributing to the increase of the harmonic generation in power systems. Recently, there has been great interest about the reduction of input current harmonics and high factor correction (PFC). However, at high switching frequency, switching losses and EMI emissions became significant and must be reduced. The operation turn-on and turn-off losses increase linearly with switching frequency and must be reduced in order to take advantage of the high switching frequency PWM converters. The promising solution to the switching and shot thought problems in high frequency PWM Boost converter is well known that mode soft switching that was presented, the zero voltage transition PFC (ZVT-PFC) converter and the zero current transition PFC (ZCT-PFC) converter[1,2,3]. In reference [4] was presented eight Boost topologies with the switching cells operation in discontinuous conduction mode (DCM) working at low frequency (25 kHz per cell), and in was presented a PFC with Interleaved Boost operating in continuous-inductor-current mode (CICM).

These arrangements operate with commutation and conduction losses and they require a complex circuit control, leading to higher parts and assembly cost and reduced readability and in this case to help in simulations can be used the program Mathcad to do mathematics operations, like was used in [6], but with a mores complex control system than CI 3854. Using Conventional Resonant and Quasi-resonant Converters one can provide ZCS and/or ZVS and the converter can operate with high-frequency.

The Boost PFC converter has been more used due it's dc-voltage again characteristics, lower inductor volume and weight [7,8], it is perfect as pre regulator. In [9] is used 2 switches and in this case is used only one switch to do the same thing, and this form can be switched in bigger frequency and can use a filter capacitor smaller than [10], for other side if in this case be used interleaved techniques, that can apply and can used smaller filter capacitor and inductors used in this case.

The interleaved power conversion technique is a strategy of interconnection of multiple switching cells for which the operation frequency is identical, but for which the internal switching instants are sequentially phased over equal a switching period fractions. This technique can be used with CI 3854 like [11], but in this case the with the switching cells operation is of 40 KHz, however with this frequency it needs filters capacitors bigger than working 100 KHz, because in the last situation the filter must be projected to 200 KHz, that it's smaller than 80 KHz and it's same idea to project the inductors.

The main advantage in using the interleaved techniques is because the operation lowers the net ripple amplitude and raises the effective ripple frequency of the overall converter without increasing switching losses or device stresses.

A good way to reach high-frequency and high-power operation is to use the non-dissipative snubber presented in references [7,8,12] that say about this kind of work. But this configuration is better than other presented, because in the place of two Vdc sources we have a Flyback Interleaved. Other evaluation is that we don’t need to use two inductors and two diodes to do the resonance presented in reference of a other Boost conversor, it can be done with only one inductor and one diode [13].

2 - THE PROPOSED INTERLEAVED BOOST-FLYBACK CONVERTER WITH NON-DISSIPATIVE SNUBBER

Figure 1 shows the proposed PFC AC-DC Interleaved Boost-Flyback converter with non-dissipative snubber.

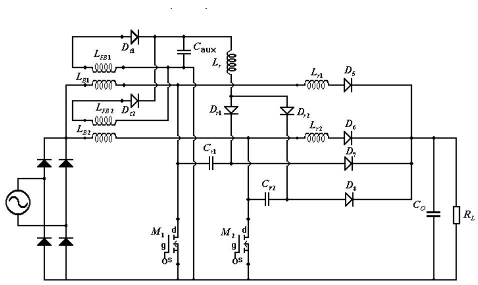


Fig.1 - The Schematic Circuit of the PFC (AC-DC Interleaved Boost-Flyback converter).

3 - PRINCIPLE OF OPERATION

To simplify the study, a half-switching cycle of the proposed converter was divided in six topological modes. The converter operating stages are as follows:

1^0 STAGE (t0,t1): This stage begins in t0 time when switch M1 turns on in ZVS form due Lr1 that will demagnetize though Vo, D6 and DM1. During this stage the Flyback feeds the resonance between C_{r1} and Lr1 in a resonant way. This stage finishes when the capacitor Cr1 voltage reaches the output voltage (Vo) making D5 turns on.

2^0 STAGE (t1,t2): It begins when voltage on Cr1 (VCr1) is clamped in Vo, and the resonant inductor Lr1 demagnetizes linearly through D5, D7, Vo and Flyback. This stage is responsible by this converter PWM characteristics. This stage finishes when switch M1 is turned off.

3^0 STAGE (t2,t3): This stage begins when switch M1 is turned of in ZVS form, due the resonant During this stage the resonant capacitor Cr1 discharges linearly its stored energy through Lb1 (Boost inductor), Vo and D5 until to zero voltage.

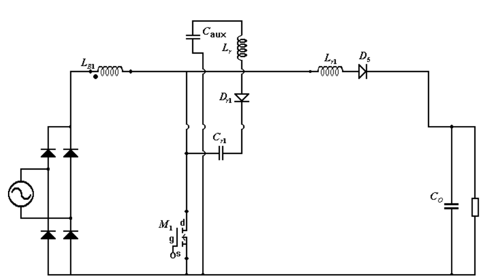
4^0 STAGE (t3,t4): In this stage inductor Lr1 oscillates with the capacitor Cr1, D5 and D7 until to reach the load current (I). At the same time there is resonance among capacitors Cr1 and Cr2 with inductor Lr1. Capacitor Cr1 changed negatively while capacitor Cr2 is totally discharged, when this stage finishes and switch M3 is turned on in the ZVS way.

5^0 STAGE (t4,t5): In this stage capacitor Cr1 oscillates with Lr1 and Lr1 through D5, Vo and Flyback voltage until L5 to reach the load current again

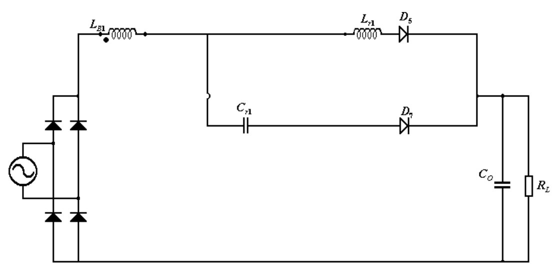
6^0 STAGE (t5,t6): During this stage the voltage on the resonant capacitor Cr1 (VCr1) is clamped in the previous stage final resonant voltage until the beginning of the next switching cycle.

The other cell (M2) analysis is the same.

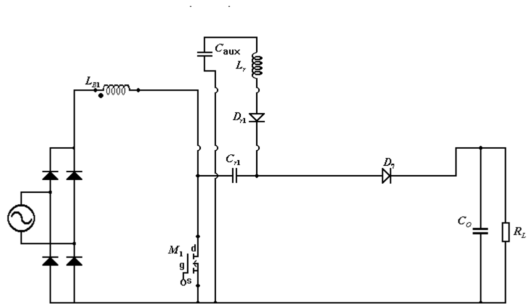
Figure 2 shows the equivalent circuits of the proposed converter in its six topological modes.



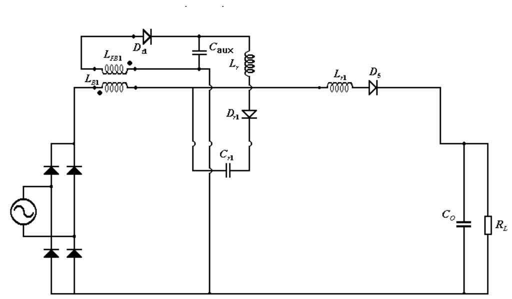
First Stage (t0,t1).



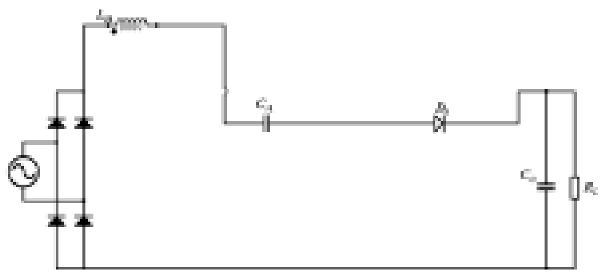
Fourth Stage (t3,t4).



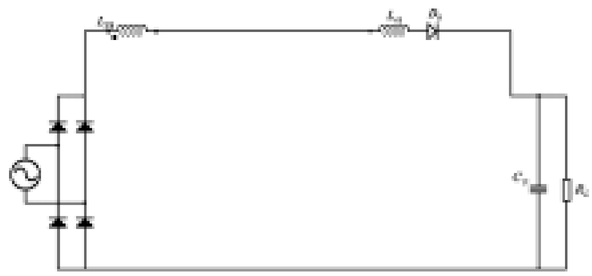
Second Stage (t1,t2).



Fifth Stage (t4,t5).



Third Stage (t2,t3).



Sixth Stage (t5,t6).

Figure 2 - Equivalent circuits for each operating stage for Fig.1 circuit.

Figure 3 shows the theoretical waveforms of one switching cycle for each cell of converter.

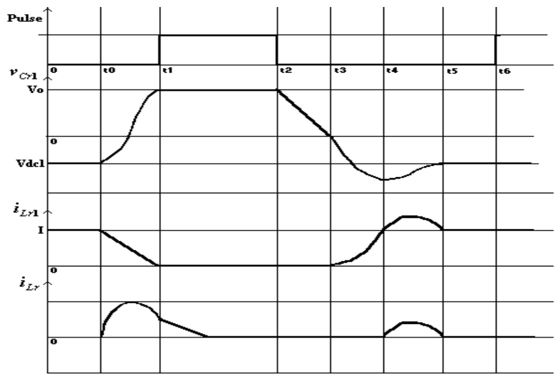


Fig.3 - Principal waveforms for figure 1 circuit.

The analysis presented in this paper is based on the following assumptions:

(1) - All switches and diodes are ideal;

(2) - Input (Vdc) and output voltage(V0) are ripple-free;

(3) - Inductors and capacitors are lossless and output current (I) is assumed continuous during the operation.

The transfer function between Vo and Vdc is given by equation 1 [1]:

$$G = 1 + \frac{DT_S}{(1-D)T_S - \left[\frac{K}{\alpha\omega_{01}} + \frac{3\pi}{2\sqrt{2}\omega_{01}} + \sqrt{\frac{3}{2}}\frac{\pi}{\omega_{01}}\right]} \quad (1)$$

$$K = \frac{V_O}{V_{C_{aux}}} \quad (2)$$

$$\alpha = \frac{I_o}{V_{C_{aux}}}\sqrt{\frac{L_r}{C_r}} \quad (3)$$

$$C_r = C_{r1} = C_{r2} \quad (4)$$

$$\omega_{01} = \frac{1}{\sqrt{C_{r1}L_{r1}}} \quad (5)$$

$$D = \frac{\Delta T}{T_s} \quad (6)$$

$$\Delta T = t_j - t_i \text{ (time interval)} \quad (7)$$

f_S = switching frequency;

T_S = switching period.

From equation (1) it is observed that the converter static gain depends on the ratio between Vo and Vdc; the switch duty-cycle (D) and α is the ratio normalized load current see figure 4.

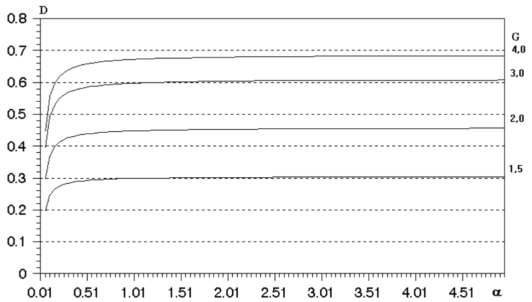
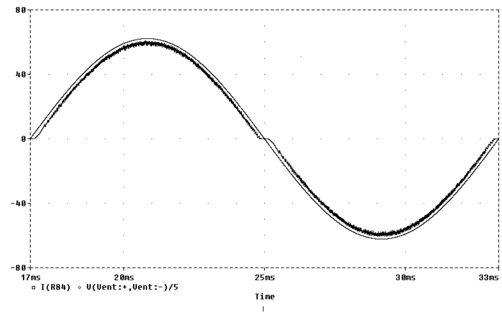
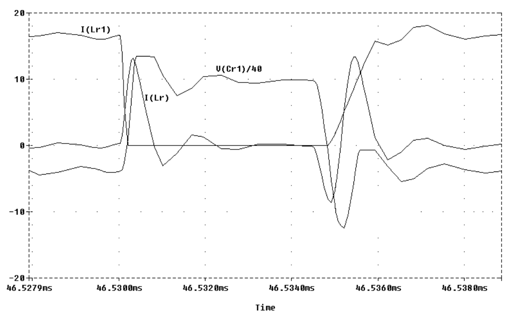


Figure 4 - Curves of duty cycle vs normalized load current, when static gain is varied.

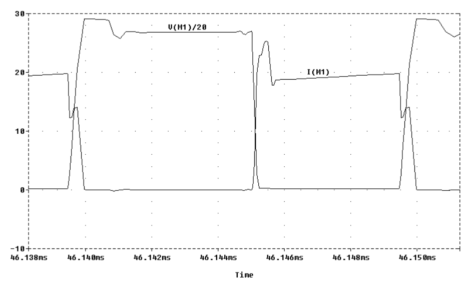
The simulation results are shown in figure 5.



a)Voltage input and Current input



b) Voltage and Current waveforms through the resonant capacitors and inductors



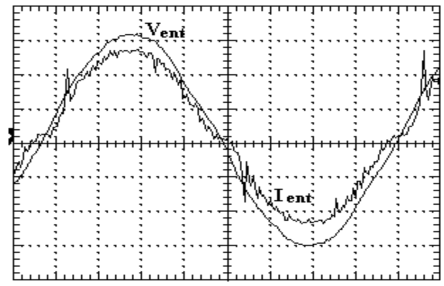
c) Drain-source voltage and current waveforms through across M1.

4 - SIMULATION RESULTS

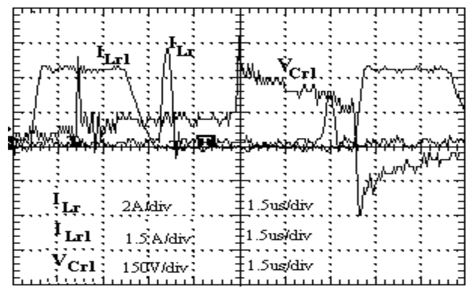
In order to illustrate the converter operation on AC-DC Interleaved Boost-Flyback converter using a non-dissipative snubber was analyzed experimentally and by simulation with the following parameter set:

Vdc=311 V;	I0 = 5.0 A;	f_S = 100 kHz;
Cr1 = 8.2 ηF;	Cr2 =8.2 ηF;	Lr = 5 μH.

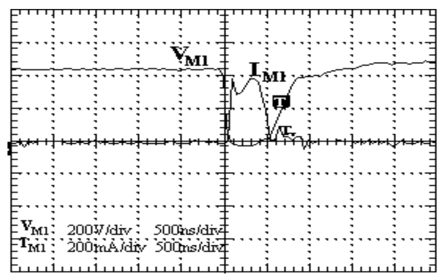
The experimental results are shown in figure 6.



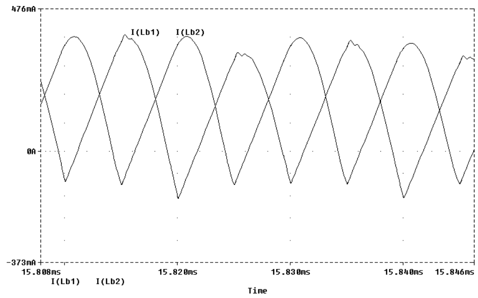
a)Voltage input and Current input



b) Voltage and Current waveforms through the resonant capacitors and inductors

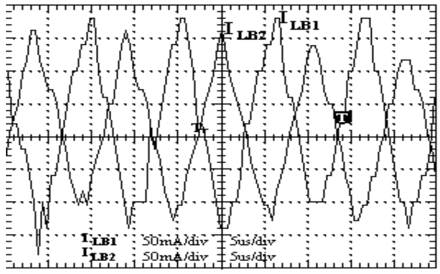


c) Drain-source voltage and current waveforms through across M1.



d) Current waveforms through across Boost inductors.

Figure 5 - Simulated waveforms of the PFC Interleaved Boost- Flyback converter using a non-dissipative snubber.



d) Current waveforms through across Boost inductors.

Figure 6 - Prototype waveforms of the PFC Interleaved Boost- Flyback converter using a non-dissipative snubber.

5 - CONCLUSION

This paper reports the analytical ,simulation and experimental developments of a PFC INTERLEAVED BOOST-FLYBACK using the interleaved converter. It has been demonstrated that the use of interleaved permits high efficient power factor correction preregulator without commutation losses with the same number of switches that hard interleaved Boost. The proposed approach allows a good performance in high frequency of operation. The use of soft-switching technique in the interleaved Boost converter relief its performances for high voltage, high power and high switching frequency due to the lower conduction and switching losses.

The operation and performance are verified by ORCAD simulation results, this way, confirms the soft switching commutation in ZVS and ZCS way of the switches. Theoretical results have been verified. A laboratory prototype this converter was implemented and the experimental results were presented, where was showed the waveforms of current and voltage, with this power of 2.000W .

6 - ACKNOWLEDGEMENT

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