APPLICATION OF THE NON-DISSIPATIVE SNUBBER IN THE AC/DC FULL-BRIDGE CONVERTER AND HIGH POWER FACTOR OPERATION.

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ABSTRACT

This work presents an AC/DC Full - Bridge converter using a non-dissipative snubber working in order to achieve an improved input power factor.

The main switches operate in a ZVS mode, and the auxiliary switches in a ZCS mode. A non-dissipative snubber associated with the Full-Bridge converter providing the soft commutation is used as the DC/DC converter.

A complete analysis, relevant equations and experimental results are presented.

I - INTRODUCTION

Quality issues are becoming ever more important in our lives. This trend has manifested itself in the electrical supply, as well as in other industry areas. The increasing non-linear electronic devices, such as switching mode power supplies, have led to deterioration in power quality.

Due to the non-linear nature of most power electronic circuits, which usually sink non-sinusoidal currents from the AC power supply, harmonics are injected into the power supply line. This harmonic pollution problem has led to the introduction of new and stringent international power harmonics standards such as IEC-1000. Efforts on reducing power harmonic have led to the development of some new "power factor correction (PFC) circuits" which sink almost pure sinusoidal current from the AC power supply in the AC/DC power conversion process.

The power supply unit is one of the main circuits for all electronic equipment or apparatus used to perform some work, whichever, professional or for entertainment, for instance - computer, equipment of the telecommunications, aviation and military, games, etc. These equipments are more sophisticated, and then they require power supply with reduced size and weight and more efficient. Generally, such equipments use AC like the main power energy, therefore, the AC line must be transformed in DC energy, because the majority systems require DC power.

The most popular method to achieve high power factor, and low line harmonics content consists of a front-end full-bridge diode rectifier followed by a boost converter. The main difficult of this technique are the switching losses, which limit the maximum efficiency and switching frequency of the converter and consequently its minimum weight and volume.

This paper proposes a variation of the Full-Bridge converter using a non-dissipative snubber, that uses the advantages the several situation mentioned up and it contributes with general research effort.

II - THE PROPOSED FULL-BRIGDE WITH NON-DISSIPATIVE SNUBER

An AC/DC Full-Bridge and resonant cell composes this converter. The resonant cell is used to form a snubber non-dissipative.

Figure 1 shows a simplified circuit of the proposed Full-Bridge converter. This converter can operate with reduced commutation and conduction losses. In this converter switches M1, M2, M3 and M4 are gated on the ZVS form due to the resonant capacitors Cr1, Cr2, Cr3 and Cr4. The Auxiliary switches Saux1 and Saux2 are turned on and off in the ZCS form due to the resonant inductor Lr.

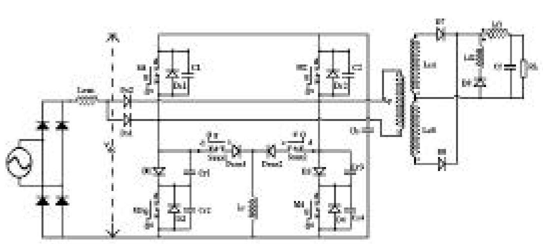
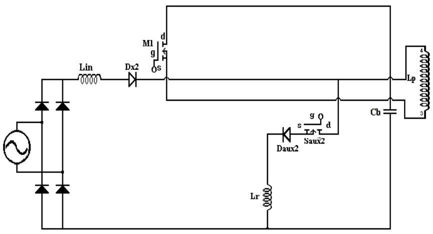


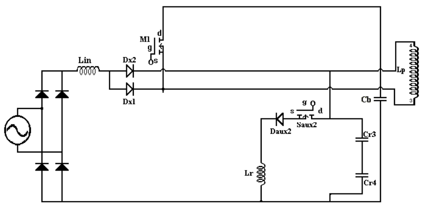
Fig.1 - The Schematic Circuit of the Full-Bridge converter.

__III - PRINCIPLE OF OPERATION__

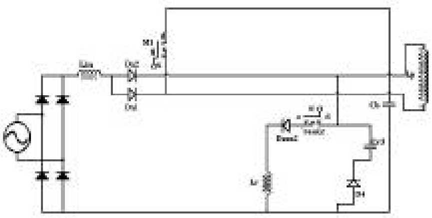
To simplify the study, a half-switching cycle of the proposed converter was divided in seven topological modes. Figure 2 shows the equivalent circuits of the proposed converter in its seven topological stages.



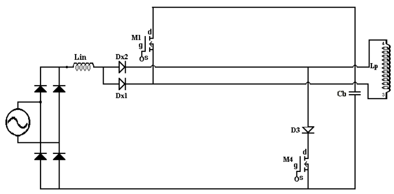
First Stage (t0,t1).



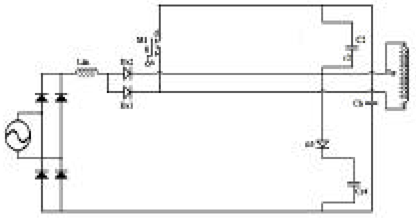
Second Stage (t1,t2).



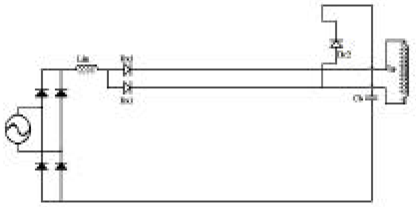
Third Stage (t2,t3).



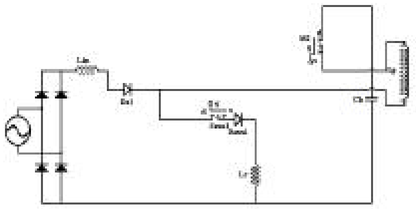
Fourth Stage (t3,t4).



Fifth Stage (t4,t5).



Sixth Stage (t5,t6).



Seventh Stage (t6,t7).

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

The converter operating stages are as follows:

<u>1st STAGE (t0,t1):</u>

This stage begins when S1 is turned on in the ZVS way and auxiliary switch Saux2 is turned on in the ZCS way. During this stage the current in the inductor Lr rises lineally, until it arrives the value ILin, when this stage finishes.

<u>2nd STAGE (t1,t2):</u>

This stage begins when current in the resonance inductor reaches ILin. At the same time there is resonance among capacitors Cr3 and Cr4 with inductor Lr. Capacitor Cr3 is charged negatively while capacitor Cr4 is totally discharged, then this stage finishes.

<u>3rd STAGE (t2,t3):</u>

During this stage begins when the voltage on capacitor Cr4 is zero (0). During this stage capacitor Cr3 resonates with the inductor Lr. This stage finishes when the current in inductor Lr reaches zero. M4 switch can be turned off in the ZCS way.

4^{th} STAGE (t3,t4):

This stage begins when M1 and M4 are on, and the voltage across the transformer primary is equal to the voltage across CB, VB. The input current rises as power is being transferred to the load. The transformer primary current (the sum of the reflected secondary current and the magnetizing current, assumed here to be negligible) rises linearly.

5^{th} STAGE (t4,t5):

This stage switch S4 is turned off and capacitors C2 and Cr4 discharge to zero and charge to VB respectively. Also during this interval, current is transferred from S1 to diode Dx1.

6^{th} STAGE (t5,t6):

The converter is in a freewheeling mode as the voltage across the transformer primary is zero. Current is flowing through the anti-parallel diode of M2. Since current is flowing through its anti-parallel diode, M2 can be turned on with zero-voltage sometime during this interval. Also during this interval, the input current falls because the voltage across the input inductor is equal to the difference between the input voltage and Vcb (which is larger than the input voltage).

7^{th} STAGE (t6,t7):

During this stage, the converter is in the same state as it was in t = t0, except that switches M3 and Saux1 are on instead of M1 and Saux2.

Starting from the sixth stages the operation is identical for the other leg of the converter, switches M2, M3 and Saux1, capacitors Cr1 and Cr2, inductor Lr. Therefore these stages will not be described.

Figure 3 shows, in a half switching cycle, the principal theoretical waveform resultante from this analysis.

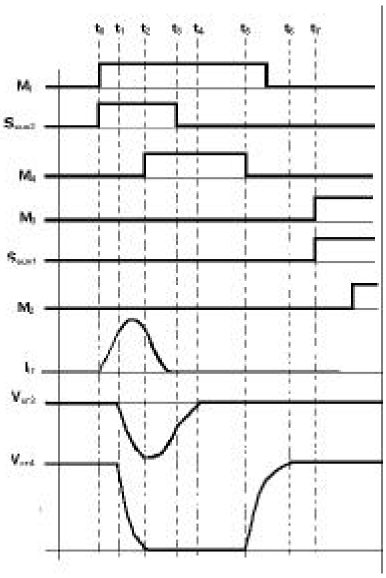


Fig.3 - Principal waveforms for figure 1 circuit.

The output voltage V_o, can be obtained by the analytical study of the operating stages and with the following assumptions:

- All components and switches are ideal;
- The input voltage V_{dc} is ripple-free;
- The magnetization inductance is very large;
- The transformer leakage inductance is negligible.

A unity turns ratio transformer is assumed.

$$\frac{V_o}{V_{dc}} = \frac{(K_{lf} - 1)}{(K_{lf} - 2D)} \left\{ \frac{(X+1)}{n\alpha} \left[\frac{1 - K_1}{\alpha X} - \frac{\alpha}{K_1} - \frac{K_1}{2\alpha X^2} \right] \frac{f}{f_0} + \frac{2}{n} D \right\} \quad (1)$$

Where:

$$\omega_0 = \frac{1}{\sqrt{L_r C_r}} \quad (2); \qquad K_1 = \frac{I_{out}}{I_{in}} \quad (3)$$

$$K_{Lf} = \frac{L_{f1}}{L_{f2}} \quad (4); \qquad \alpha = \frac{I_O}{V_{dc}} \sqrt{\frac{L_r}{C_r}} \quad (5)$$

From equation (1) it is observed that the converter static gain depends on: the ratio f / f_0; the switch duty-cycle (D); the ratio normalized load current α and period of switching frequency. See figure 4.

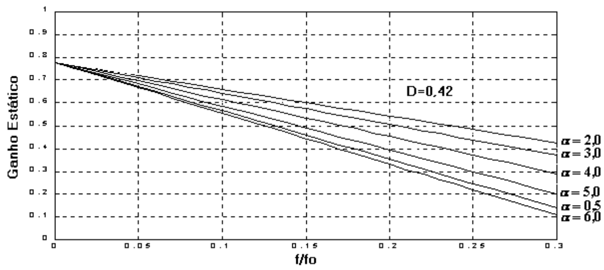


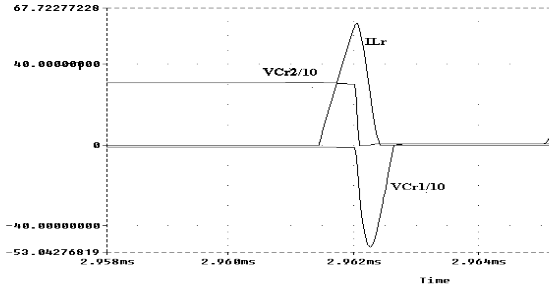
Fig. 4 - Curves of static gain vs f / f_0, when normalized load is varied.

IV – SIMULATION AND EXPERIMENTAL RESULTS

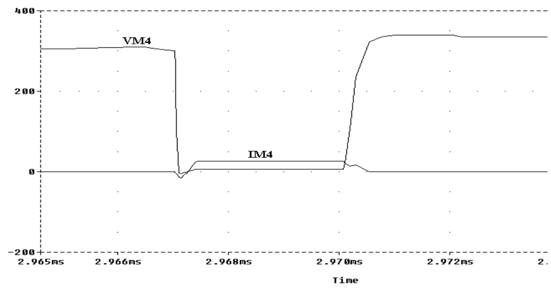
In order to illustrate the converter operation a Full-Bridge converter using a non-dissipative snubber was analyzed by simulation with the following parameter set:

Vac=150 V;	I_0 = 30 A;	f_S = 100 kHz;
Cr1 = 15.6 ηF;	Cr2 = 7.8 ηF;	ILr = 2.5 μH.

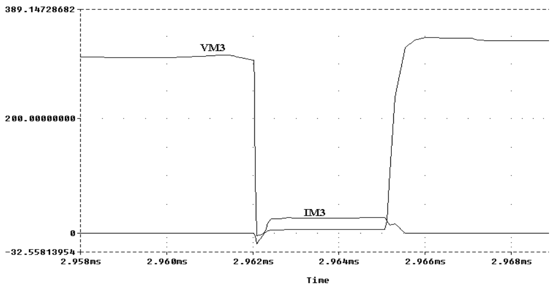
For comparison purpose, simulation results are shown in figure 4. The simulation results show the converter operating at reduced conduction and commutation losses using phase-shift with tapped inductor and soft-commutation operation and working with high power factor.



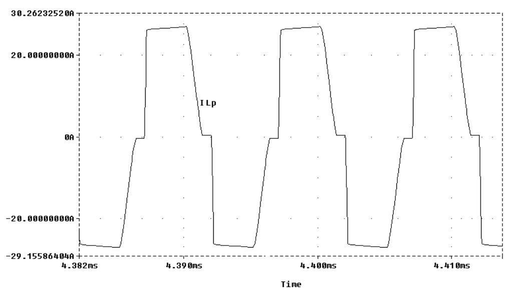
a) Voltage and Current waveforms through the resonant capacitors and inductor.



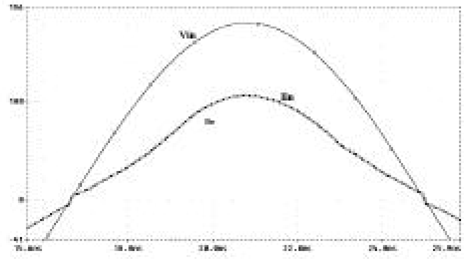
b) Drain-source voltage and current waveforms through across M4.



c) Drain-source voltages and current waveforms through across M3.



d) Primary current (Ilp).



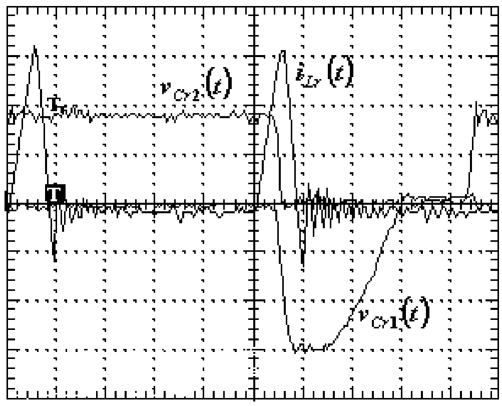
e) Voltage input and Current input

Fig. 4 –Simulated waveforms of the Full-Bridge converter using a non-dissipative snubber

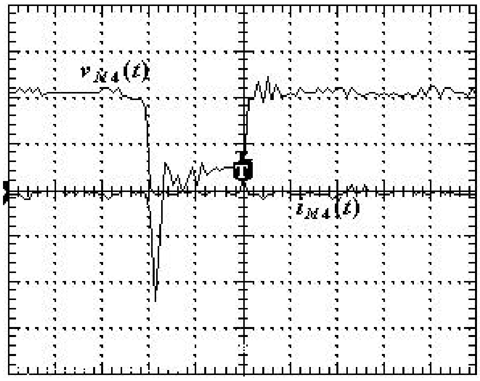
A prototype of the Full-Bridge converter using a non-dissipative snubber was built using the following set of parameters:

Vdc=50 V;	R_L = 30 Ω;
Cr1 = 15.6 ηF;	Cr2 = 7.8 ηF;
f_S = 100 kHz;	ILr = 3.3 μH. Ilin = 500uH
IRFP460 (Mosfet);	Diode MUR1560 Diode APT 30 100B

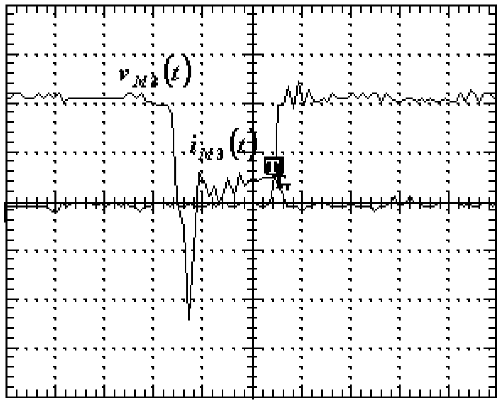
The obtained prototype waveforms are shown in figure 5.



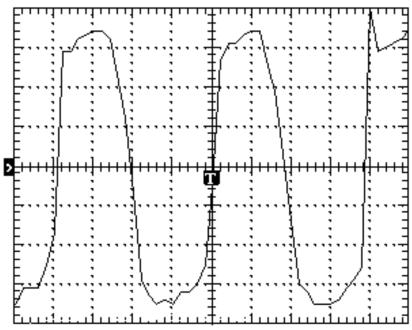
a) Voltage and Current waveforms through the resonant capacitors and inductor. Voltage: 50 V/div. Current: 4 A/div. Time: 2 ms/div.



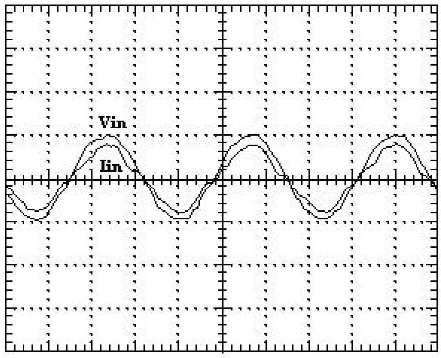
b) Drain-source voltage and current waveforms through across M4. Voltage: 50 V/div. Current: 4 A/div. Time: 2 ms/div.



c) Drain-source voltages and current waveforms through across M3. Voltage: 50 V/div. Current: 4 A/div. Time: 2 ms/div.



d) Primary current (Ilp). Current: 3 A/div. Time: 2.5 ms/div.



e) Voltage input and Current input. Voltage: 50 V/div. Current: 10 A/div. Time: 2 ms/div. Power factor: 0.985

Fig. 5 –Experimental waveforms of the Full-Bridge converter using a non-dissipative snubber

V - CONCLUSION

The Full-Bridge converter using a non-dissipative snubber presents soft-switching ZVS features for switches M1, M2, M3 and M4 and ZCS for the auxiliary switches, it operates at reduced conduction and commutation losses, it uses the resonant principle and employs a tapped inductor. It operates with high power factor without using a front-end boost converter.

The operation and performance are verified by PSPICE simulation results, this way, confirms the soft switching commutation in ZVS and ZCS way of the switches.

A comparison between experimental and simulation results shows that the use of the proposed converter prototype is perfectly possible.

VI - ACKNOWLEDGEMENT

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VII - REFERENCES

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