An Active Circuit To Obtain Symmetrical Power Supply Control

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Abstract - This paper presents a controlled symmetrical power supply. While feeding unbalanced loads, the converter will operate in the switching mode, and the circuit will only process the energy necessary to balance the output voltages. Switches conduction losses depends on how unbalanced the loads are.

1. Introduction

This paper presents a power supply that is able to clamp the voltage on each load to half of the DC link voltage. If the loads are balanced, the switches do not operate. It means that the converter only operates if the loads are unbalanced and it only process the energy necessary to provide the balance of the voltage divider.

This proposed power supply is a very flexible source because in addition to operate as a symmetrical source, it allows the operator to choose the percentage of the input voltage desired on each load. For instance, one might want to have 10% V_{DC} on one load and 90% V_{DC} on the other load, in this case the loads are complements. But the main application, in this converter, is the load condition on each load have 50% V_{DC} , in this case the power supply satisfy all conditions required.

Figure 1 shows the circuit configuration of the proposed symmetrical power supply.

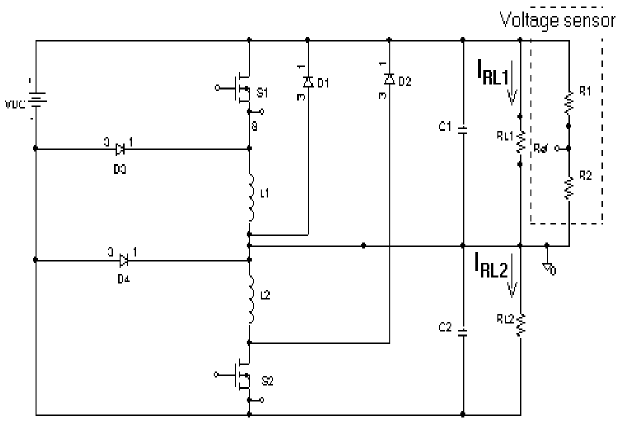


Figure 1 – Proposed converter

2. Principle of Operation

The operating principle is quite simple and it is described in two stages. These stages depend exclusively of the load conditions.

<u>For $R_{L1} = R_{L2}$ condition</u>**:** Since the converter will only process the energy necessary to balance the voltage divider, when both loads are balanced ($R_{L1} = R_{L2}$), switching is not necessary and S_1 and S_2 remain off.

For unbalanced load conditions, switching is required in order to maintain a symmetrical output voltage. In this case, the converter operation will depend on whether R_{L1} or R_{L2} is greater.

<u>For $R_{L1} > R_{L2}$ condition</u>**:** When R_{L1} is greater than R_{L2}, the operation stages are described by the state change in S_1. S_1 together with L_1, D_1 and D_3 constitute the upper current source of the converter, which will provide the exceeding current required by R_{L2}, considering that it drains more current from the power supply.

<u>For $R_{L1} < R_{L2}$ condition</u>**:** When R_{L2} is greater than R_{L1}, the lower current source consisting of S_2, L_2, D_2 and D_4 will operate and the operation stages are described by the state change in S2. Under this circumstance, R_{L1} requires a greater current share from the DC input source. Therefore, in order to maintain the symmetrical output voltage, the lower current source has to drain the remaining current, which is the difference between the current flowing in R_{L1} and R_{L2}.

The operation stages will be described for two load conditions: $R_{L1} > R_{L2}$ and $R_{L1} < R_{L2}$.

<u>First stage ($R_{L1} > R_{L2}$)</u>**:** S_1 is turned on and a current equal to $I_{RL2}–I_{RL1}$ flows through it. This stage is shown in Fig. 2.

<u>Second stage ($R_{L1} > R_{L2}$)</u>**:** Begins when S_1 is turned off. The energy stored in L_1 returns to the input power supply through diodes D_1 and D_3, as shown in Fig. 3.

<u>First stage ($R_{L1} < R_{L2}$)</u>**:** Begins when S_2 is turned on. The current through inductor L_2 is $I_{RL1}–I_{RL2}$, according to Fig. 4. When S_2 is turned off, the second stage begins.

<u>Second stage ($R_{L1} < R_{L2}$)</u>**:** During this stage, the energy stored in L_2 decreases through the input power supply and diodes D_2 and D_4, according to Fig. 5.

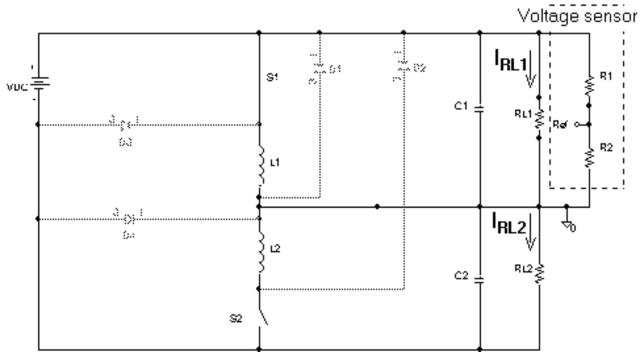


Figure 2 – Converter on first operation stage ($R_{L1} > R_{L2}$)

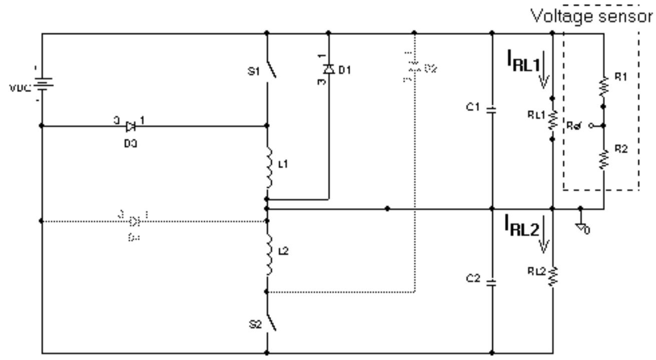


Figure 3 – Converter on second operation stage ($R_{L1} > R_{L2}$)

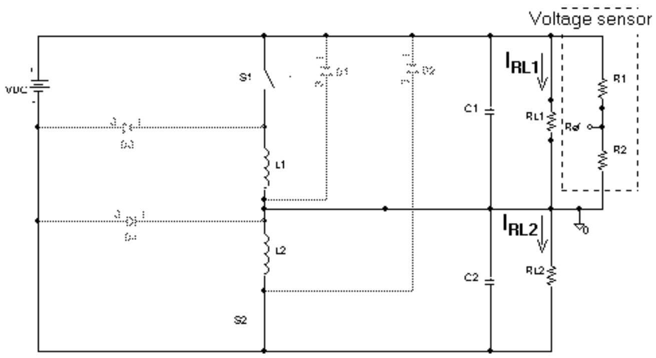


Figure 4 – Converter on first operation stage ($R_{L1} < R_{L2}$)

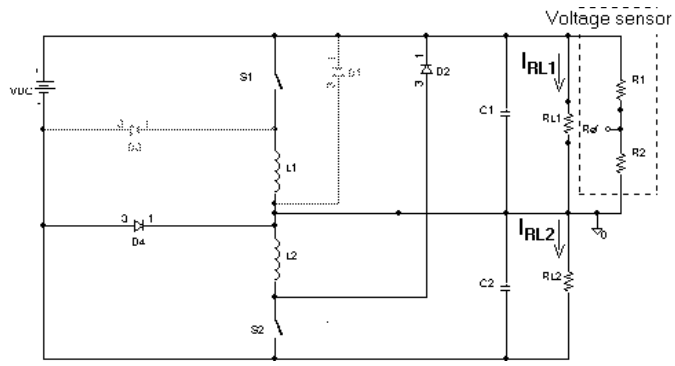


Figure 5 – Converter on second operation stage ($R_{L1} < R_{L2}$)

One can see that the upper and lower current sources described above operate as an active load, maintaining the output voltage symmetrical. This means that the DC input source ideally provides the energy to the load plus the reactive energy necessary to its operation. The reactive energy increases proportionally to the unbalance of the loads.

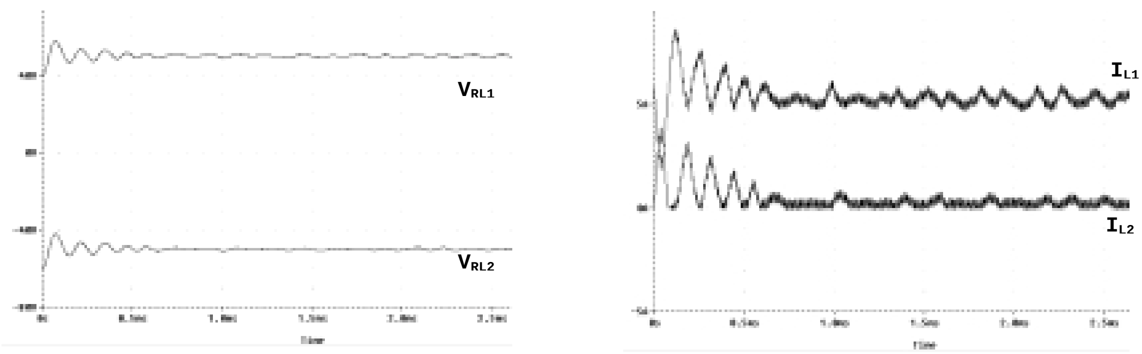
3. Simulation Results

A simulation was performed using the following parameters:

$V_{DC} = 100V$	$L_{F1} = L_{F2} = 500\mu H$
$C_1 = C_2 = 8\mu F$	$R_1 = 9k\Omega$, $R_2 = 1k\Omega$

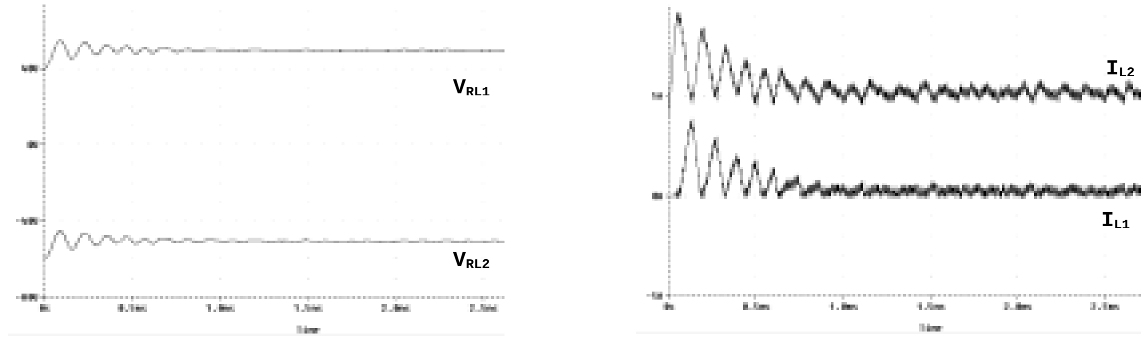
In order to illustrate the converter's behavior, several load situations were simulated.

No load condition is verified in Fig. 6 ($R_{L1}=\infty$ and $R_{L2}=10\Omega$) and Fig. 7 ($R_{L2}=\infty$ and $R_{L1}=10\Omega$). Fig. 8 shows the simulation waveforms for $R_{L1}=10\Omega$, $R_{L2}=3\Omega$ and Fig. 9 for$R_{L1}=3\Omega$, $R_{L2}=10\Omega$. Fig. 10 shows the converter operating with a balanced load ($R_{L1}=R_{L2}=10\Omega$) and Fig. 11 shows the converter operating with no load at all ($R_{L1}=R_{L2}=\infty$).



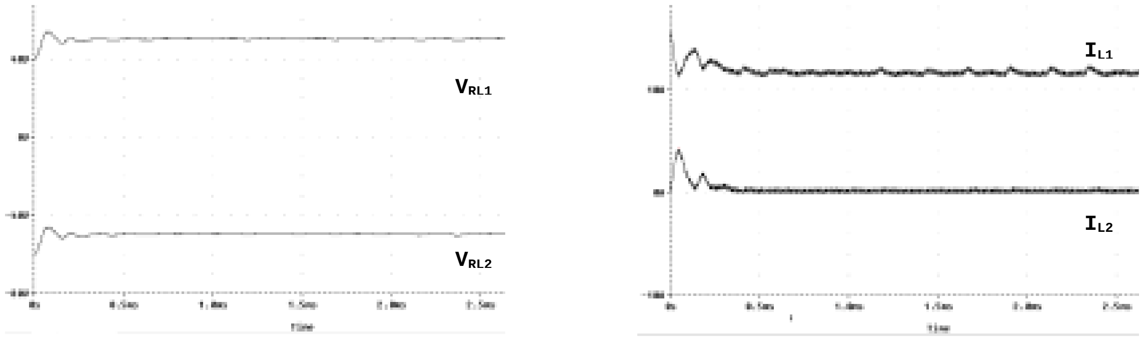
(a)V_{RL1} and V_{RL2} *(b) I_{L1} and I_{L2}*

Figure 6 – Simulation waveforms for no load ($R_{L1} = \infty$) and $R_{L2} = 10\Omega$



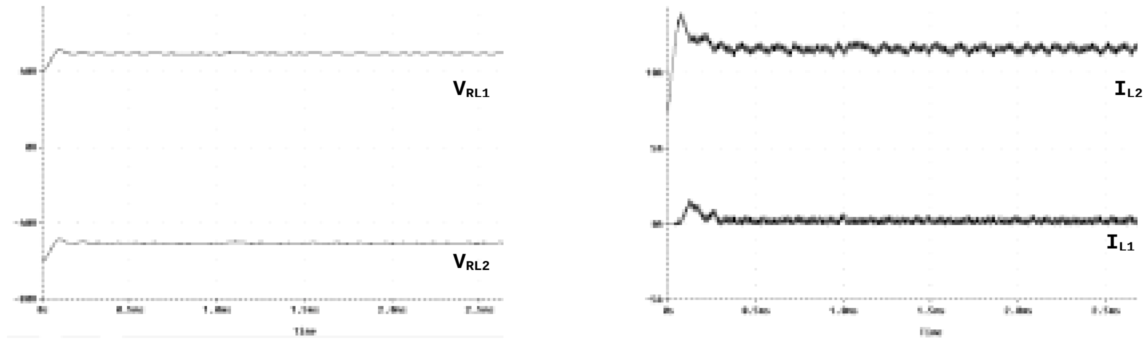
(a)V_{RL1} and V_{RL2} (b) I_{L1} and I_{L2}

Figure 7 – Simulation waveforms for no load ($R_{L2} = \infty$) and $R_{L1} = 10\Omega$



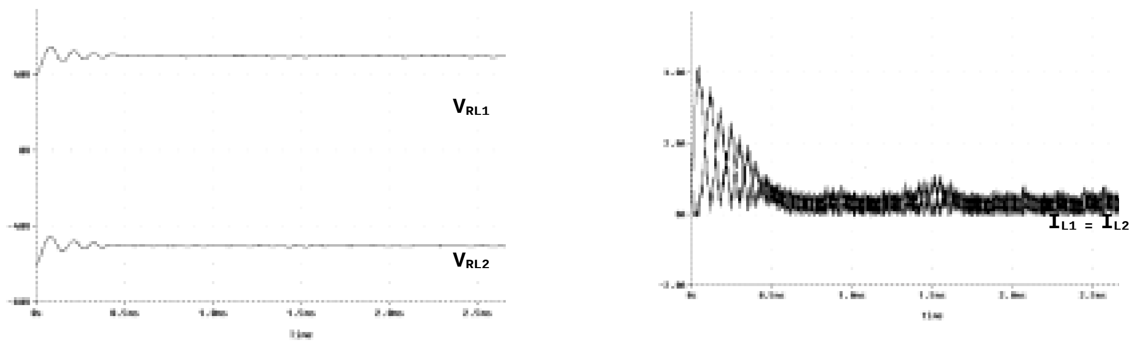
(a)V_{RL1} and V_{RL2} (b) I_{L1} and I_{L2}

Figure 8 – Simulation waveforms for $R_{L1} = 10\Omega$, $R_{L2} = 3\Omega$



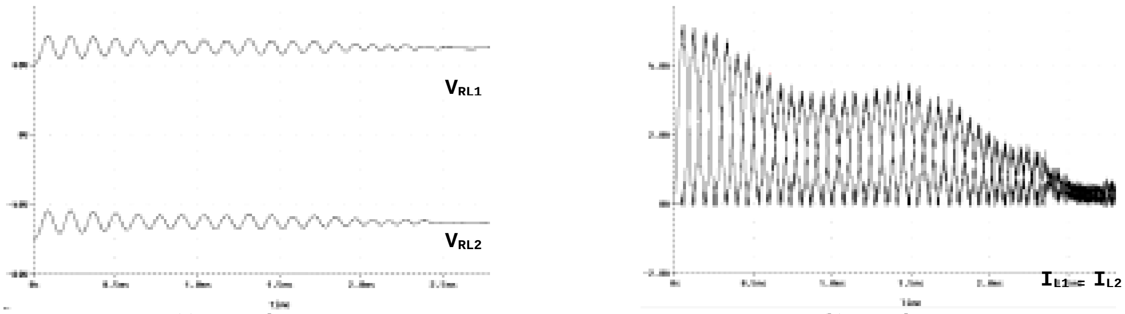
(a)V_{RL1} and V_{RL2} (b) I_{L1} and I_{L2}

Figure 9 – Simulation waveforms for $R_{L1} = 3\Omega$, $R_{L2} = 10\Omega$



(a)V_{RL1} and V_{RL2} (b) I_{L1} and I_{L2}

Figure 10 – Simulation waveforms for $R_{L1} = R_{L2} = 10\Omega$



(a)V_{RL1} and V_{RL2} (b) I_{L1} and I_{L2}

Figure 11 – Simulation waveforms for $R_{L1} = R_{L2} = \infty$ (no load**)**

From the waveforms shown above, it can be observed that, in all load situations, the output voltage remained symmetrical and stabilized in 50V.

As it was explained previously, for the load condition $R_{L1} > R_{L2}$, the current on inductor L_1 is given by $I_{L1}=I_{RL2}-I_{RL1}$ and $I_{L2}=0$. As an example, for $R_{L1}=10\Omega$ and $R_{L2}=3\Omega$, the load currents are $I_{RL1}=5A$ and $I_{RL2}=16,7A$ and therefore $I_{L1}=11,7A$. This example can be verified in Fig. 8(b), where $I_{L1}=11,7A$ and $I_{L2}=0$.

For a balanced load condition (Fig. 10), the simulation results show that the inductor currents are approximately zero. In experimental results, $I_{L1}=I_{L2}=0$ are expected.

In Fig. 11(a) it can be noticed that the voltage on R_{L2} presents some oscillations. This is due to the control strategy used in simulation.

4. CONTROL STRATEGY

The control strategy employed for simulation is extremely simple, consisting of a comparator as illustrated in Fig. 12.

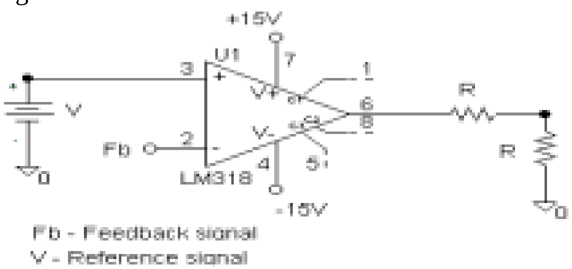


Fig. 12 – Control circuit.

The principle of operation is very simple, it is constituted for two stages of operation. The comparator emit two types of pulses, positive and negative. According the control strategy the positive pulse activate S2 and the negative pulse activate S1.

The control circuit take a feedback signal from the output voltage, which be introduced in the negative input of comparator, this signal is compared with a reference signal in the other input. This reference signal determine the output voltage division. Thus this converter can operate with symmetrical voltage output or with this voltages unbalanced, and can there is a control this asymmetry.

This control objecting to keep a determined division is realized em two stages describes below:

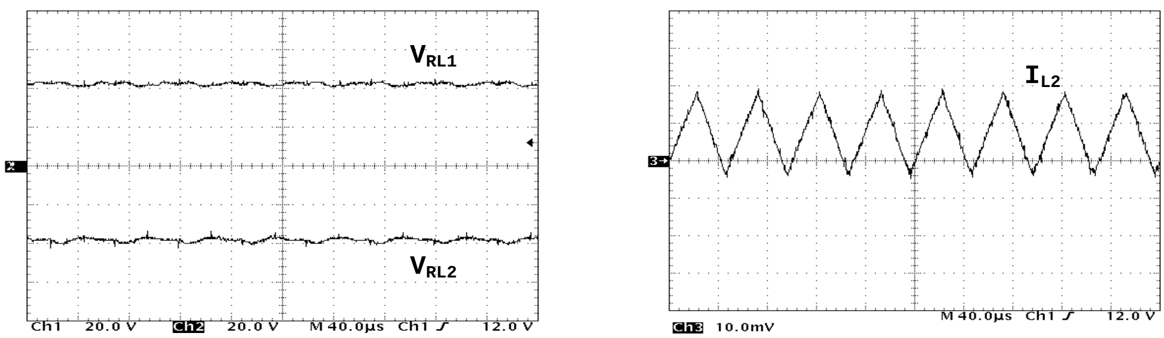
<u>For Fb > V(fig.12) condition:</u> the comparator will emit a negative pulse, activating S1, thus this switch begin to conduct.

<u>For Fb < V(fig.12) condition:</u> the comparator will emit a positive pulse, and in opposition to the anterior condition, activate S2, soon this switch begin to conduct.

5.EPERIMENTAL RESULTS

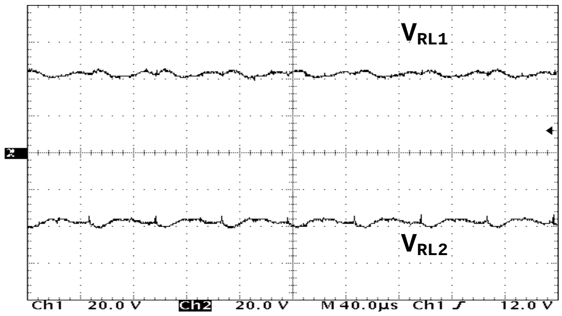
The experimental results is shown below were obtained from a prototype of fig. 1. This results obtained using the following parameters:

$V_{DC} = 80V$	$L_{F1} = L_{F2} = 1mH$
$C_1 = C_2 = 8\mu F$	$R_1 = 9k\Omega$, $R_2 = 1k\Omega$

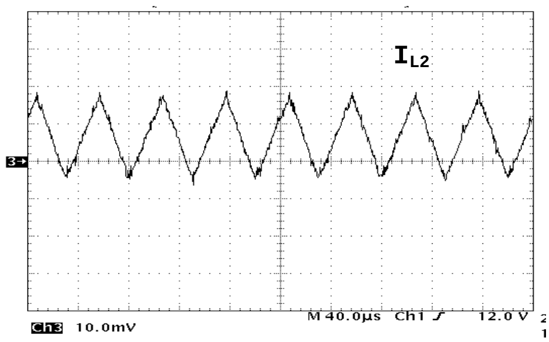


(a)V_{RL1} and V_{RL2} (b) I_{L2} – 0.5A / Div

Figure 10 – Experimental waveforms for $R_{L1} = 35\Omega$, $R_{L2} = 7.5\Omega$.

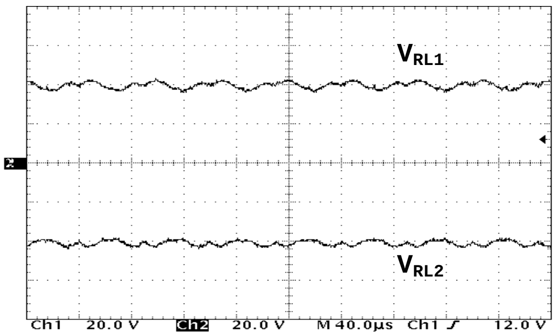


(a)V_{RL1} and V_{RL2}

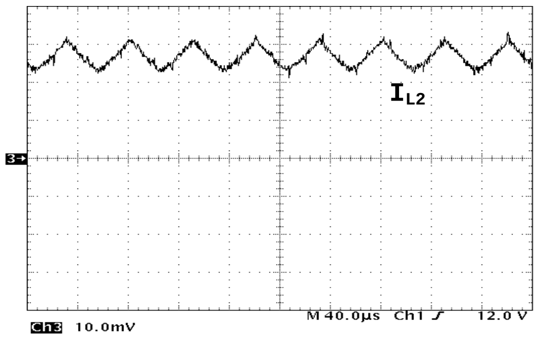


(b) I_{L2} – 0.5A / Div

Figure 11 – Experimental waveforms for ($R_{L1} = \infty$) and R_{L2} = 7.5Ω.



(a)V_{RL1} and V_{RL2}



(b) I_{L2} – 2A / Div

Figure 12 – Experimental waveforms for ($R_{L2} = \infty$) and R_{L1} = 7.5Ω.

5. Conclusion

A simple symmetrical power source is proposed. The operating principles and control strategy were presented. Balanced and unbalanced loads were simulated and the converter operated as expected, clamping the output voltage to half of the input voltage in every load situation.

It is important to notice that the overall efficiency of the converter will depend on how unbalanced the loads are. The efficiency will be better when there is no unbalance in the load. In this case, the active circuit is not operating.

Experimental results will be presented in the final version of this paper.

6. References

[1] – Mohan, N.; Underland, T.M.; Robins, W.P.; “Power Electronics: Converters, Applications and Design” , John Wiley & Sons, Singapore, 1989.
[2] – Presmman, A. I.; “Switching Power Supply Design”, McGraw Hill International Editions, Engineering Series, Singapore, 1992.
[3] – Symmetrical Power Supply – patent pending.