NEW TOPOLOGY OF VOLTAGE INVERTER BASED ON PUSH-PULL CONVERTER WITH SPWM MODULATOR

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Abstract – This paper shows a new voltage inverter topology based on two Push-Pull. The proposed topology presents some modifications of Push-Pull converter, that allow the correct functioning of the high frequency transformer, reducing its weight, size and volume. In addition of this, its conversion is made in only one stage. It's possible to use this topology in no-breaks, audio amplifiers, etc. For this paper, it was projected a 800W inverter and switching frequency of 20kHz. It's shown a complete analysis of the operation stages, equations, simulated and experimental results.

***Ke words* - inverter, Push-Pull converter, SPWM.**

I. INTRODUCTION

This new voltage inverter topology is based on the Push-Pull converter. The input voltage is 12VDC and the output voltage is 110VAC. The switches control is made by sinusoidal pulse width modulation (SPWM). The intended power of the inverter is 800W. The Push-Pull converter, shown in Fig. 1, is the base used in the considered inverter [9].

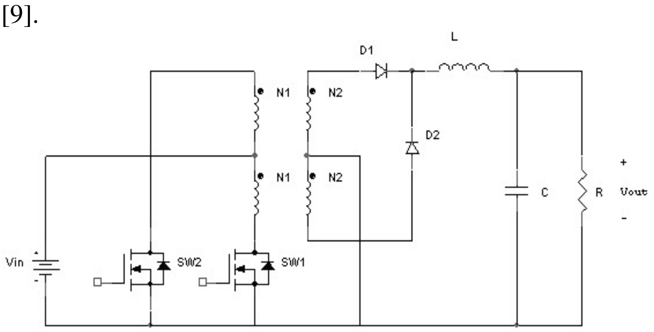

Fig. 1. Simplified circuit of Push-Pull converter.

The new topology, shown in Fig. 2, is constituted by two Push-Pull converter in parallel. The energy transference source/load and load/source is made by the Converter A in the positive semi-cycle and by the Converter B in the negative semi-cycle.

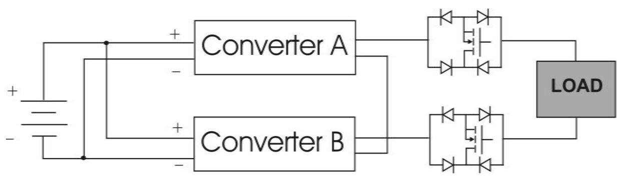

Fig. 2. New inverter topology

II. PROPOSED TOPOLOGY

The new voltage inverter topology is constituted by two Push-Pull converter as show in Fig. 3. The ideals switches on this case, due the low DC voltage, are MOSFET switches.

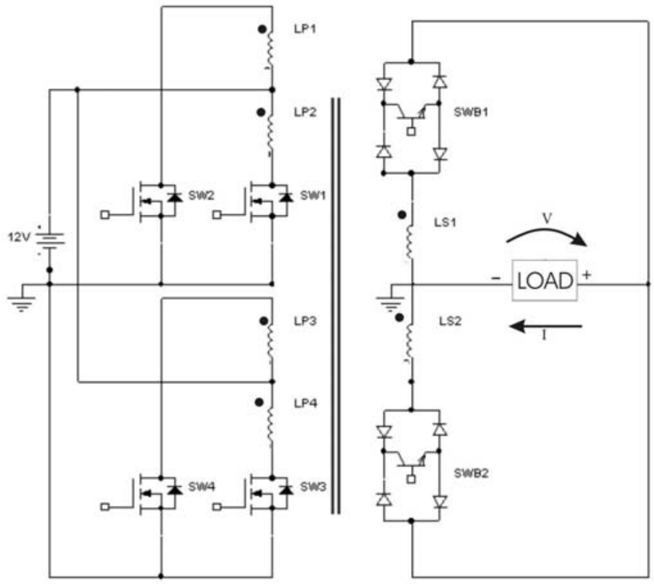

Fig. 3. Proposed Inverter

To ensure right parallel coupling of the converters, keeping the conventional voltage and current over the load, it's necessary to use bi-directionals switches, shown in Fig. 4, as it'll be analyzed in this paper.

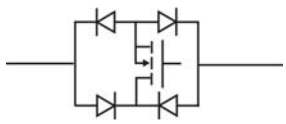

Fig. 4. Bi-directional switch

III. FUNCTIONING PRINCIPLES

The 60Hz reference sine is rectified then it's compared with a triangular wave. The pulses generated are divided between switching in the positive semi-cycle (SW1, SW2) and negative semi-cycle (SW3, SW2). Thus, the analysis can be divided in two parts: positive conduction (Converter A) and negative conduction (Converter B).

For the analysis of the circuit, the following parameters will be considered:

. Ideal transformer (ideal coupling between LP1, LP2, LP3, LP4, LS1 e LS2);

. Ideal switches;
. Stabilized input source.

1st Part: Energy transfer in the positive semi-cycle – converter A.

The switches SW1, SW2, SWB1 and SWB2 are controlled for the energy transfer.

Stage 1: The SW1 is turned-on. Voltage is induced in the secondary of the transformer. To ensure the conventional direction of voltage and current over the load, SWB1 is turned-on offering a current path. All the others switches keep turned-off.

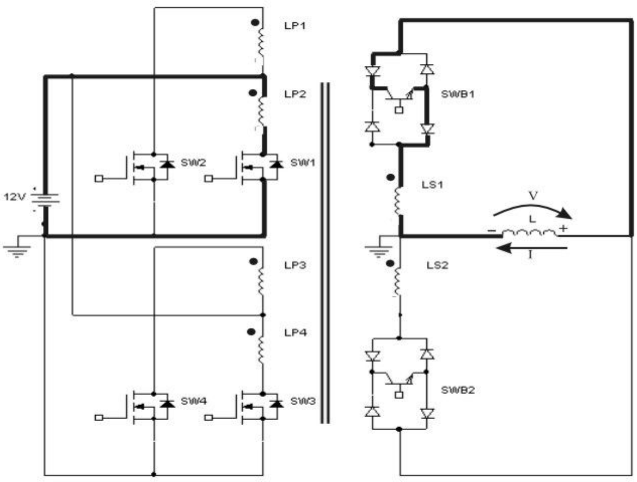

Fig. 5. Stage 1

Stage 2: It's the dead time between the conduction of SW1 and SW2. The switch SW1 is turned-off, while SWB1 keeps turned-on and SWB2 is turned-on too. The load current is in free wheeling and so the coils voltage is zero.

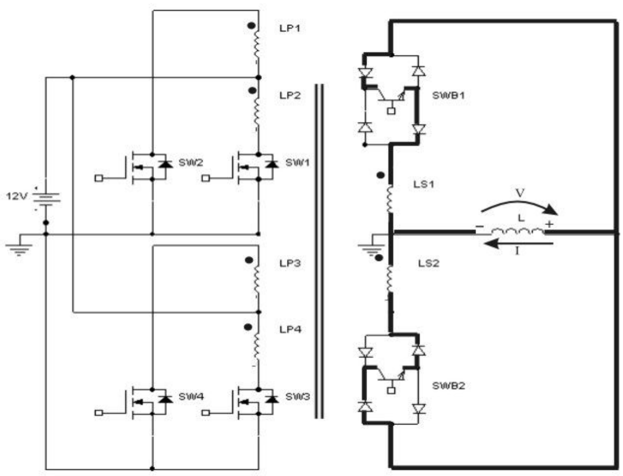

Fig. 6. Stage 2

Stage 3: The SW2 is turned-on. Voltage is induced in the secondary of the transformer with contrary polarity to the induced voltage in the stage 1, then to ensure the conventional direction of voltage and current over the load, SWB1 is turned-off, while SWB2 is turned-on offering a current path. All the others switches keep turned-off.

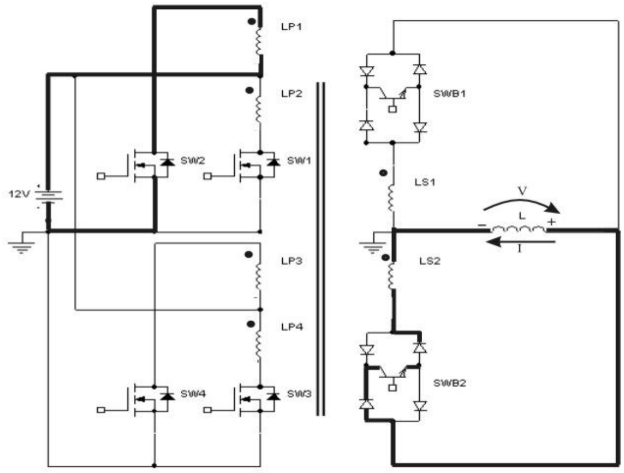

Fig. 7. Stage 3

Stage 4: It's the dead time between the conduction of SW2 and SW1. The switch SW2 is turned-off, while SWB2 keeps turned-on and SWB1 is turned-on too. The load current is in free wheeling and so the coils voltage is zero.

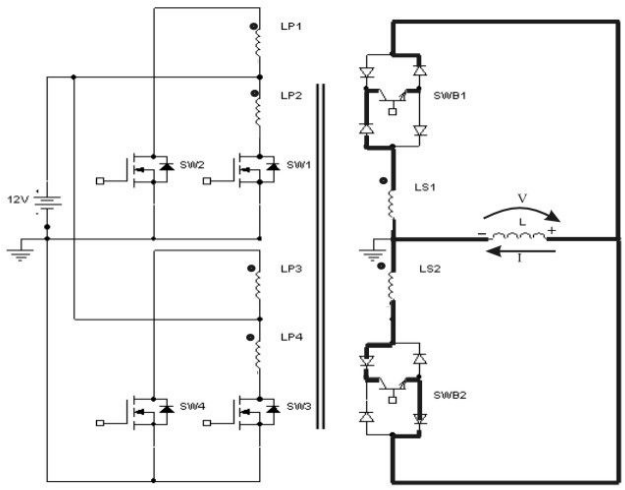

Fig. 8. Stage 4

While the current over the load is negative and SW1 and SW2 are switching, the energy flows from the load to the source. When the current over the load crosses zero, the energy will flow from the source to the load. Thus, the previous stages go over again until the current over the load turns maxim, that is, when the positive semi-cycle ends.

2nd Part: Energy transfer in the negative semi-cycle – converter B.

The switches SW3, SW4, SWB1 and SWB2 are controlled for the energy transfer.

Stage 5:

The SW3 is turned-on. Voltage is induced in the secondary of the transformer. To ensure the conventional direction of voltage and current over the load, SWB2 turned-on offering a current path. All the others switches keep turned-off.

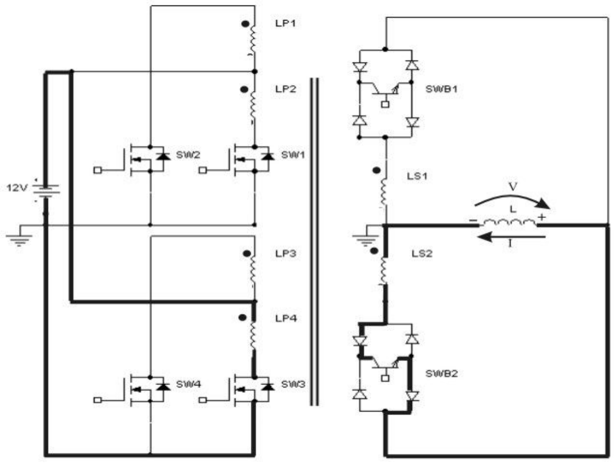

Fig. 9. Stage 5

Stage 6: It's the dead time between the conduction of SW3 and SW4. The switch SW3 is turned-off, while SWB2 keeps turned-on and SWB1 is turned-on too. The load current is in free wheeling and so the coils voltage is zero.

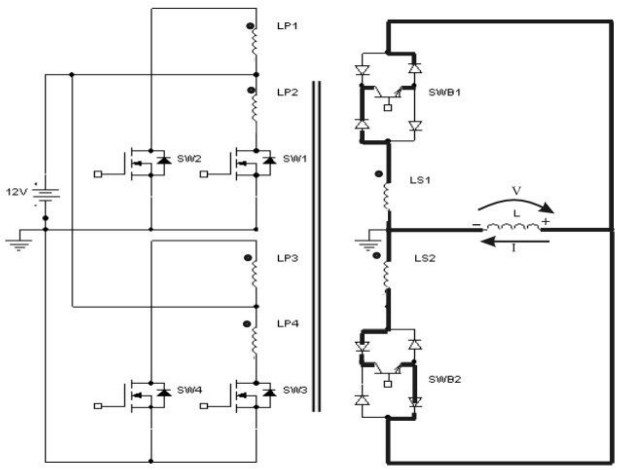

Fig. 10. Stage 6

Stage 7: The SW4 is turned-on. Voltage is induced in the secondary of the transformer with contrary polarity to the induced voltage in the stage 5, then to ensure the conventional direction of voltage and current over the load, SWB2 is turned-off, while SWB1 is turned-on offering a current path. All the others switches keep turned-off.

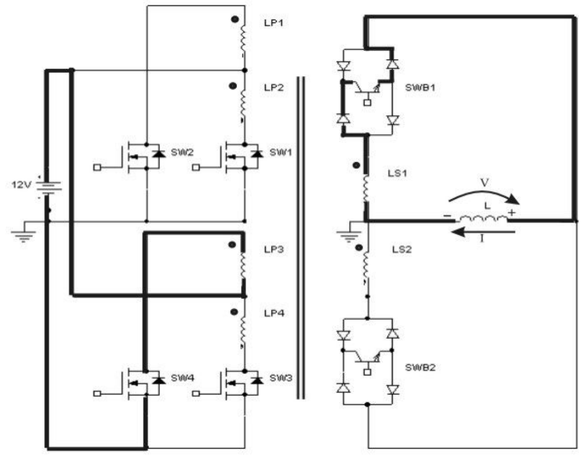

Fig. 11. Stage 7

Stage 8: It's the dead time between the conduction of SW4 and SW3. The switch SW4 is turned-off, while SWB1 keeps turned-on and SWB2 is turned-on too. The load current is in free wheeling and so the coils voltage is zero.

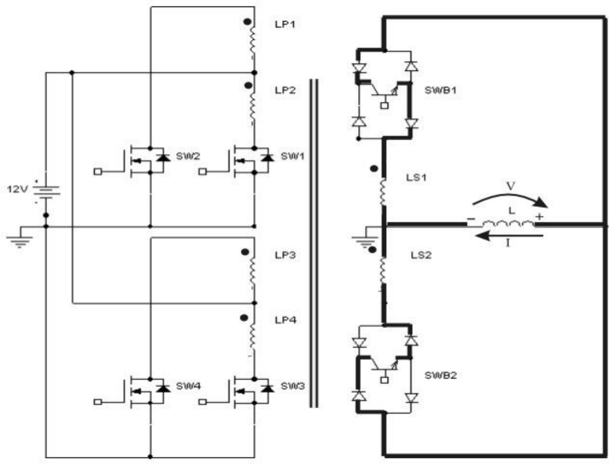

Fig. 12. Stage 8

While the current over the load is positive and SW3 and SW4 are switching, the energy flows from the load to the source. When the current over the load crosses zero, the energy will flow from the source to the load. Thus, the previous stages go over again until the current over the load turns minim, that is, when the negative semi-cycle ends.

Fig. 12 shows the switching command.

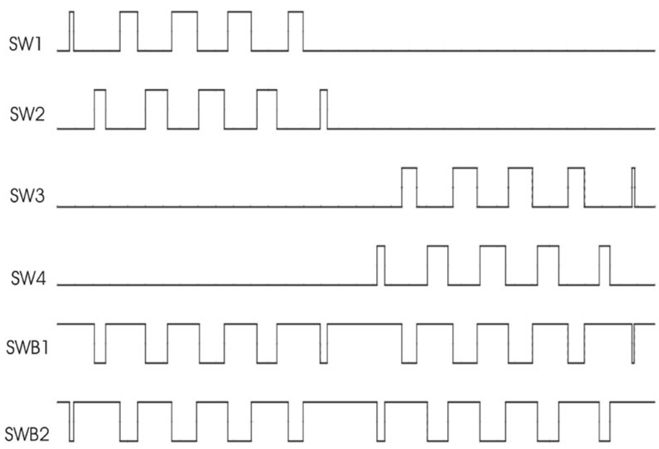

Fig. 12. Switching pulses

IV. PROJECT EXAMPLE

The output power will be of 800W. The input voltage is 12V. The output voltage will be 110VAC RMS. To ensure the 110VAC voltage, it'll established a transformation relation higher than the voltage peak (155V), than it's possible to have a margin for the modulation. The transformation relation will be 0,05 so the voltage will reach 240V in the secundary.

The output RMS current of the inverter is given by:

$$I_{0_{TOTAL}} = \frac{P_S}{V_S} = \frac{800}{110} = 7{,}27A \tag{1}$$

The RMS current in each secundary will be:

$$I_{S_{A,B}} = \frac{I_{0_{TOTAL}}}{2} = 3{,}64A \tag{2}$$

The RMS current in the Converter A primary or Converter B primary will be:

$$I_P = \frac{I_{S_{A,B}}.D'}{0{,}05} = \frac{3{,}64.\left(110/240\right)}{0{,}05} = 33{,}36A \tag{3}$$

Where:

D' - duty cycle for DC/AC current conversion.

Considering the inverter with a output LC filter and a non linear load, like a bridge rectifier, the peak current can be calculated by [4]:

$$i_{Dmáx} = I_L\left(1 + 2\pi\sqrt{\frac{V_P}{2.V_R}}\right) \tag{4}$$

Where $i_{Dmáx}$ is the diode peak current, I_L is the RMS load current, V_P is the peak voltage and V_r is the ripple voltage. [4]

$$V_R = V_P \frac{1}{2 \cdot f \cdot C \cdot R} \tag{5}$$

Where:

f - frequency.
C - capacitor.
R - a resistance (load).

For the frequency of 60Hz, peak voltage of 155V, load of 28Ω and capacitor of 660μF, it's possible to determine the ripple voltage by (5).

The filter frequency (f_c) can be calculated by:

$$f_c = \frac{1}{2\pi\sqrt{LC}} \tag{6}$$

Considering the filter frequency (f_c) of 1kHz (twenty times lesser than the switching frequency) a capacitor of 30μF it's gotten a inductor of 844μH.

For this case the filter's inductor will conduct 33,7A (peak diode current) and it might hold this energy.

V. SIMULATION RESULTS

The simulation was made using Orcad® 10.0.

Simplified blocks diagram of the control circuit that generates the switching pulses is shown in Fig. 13

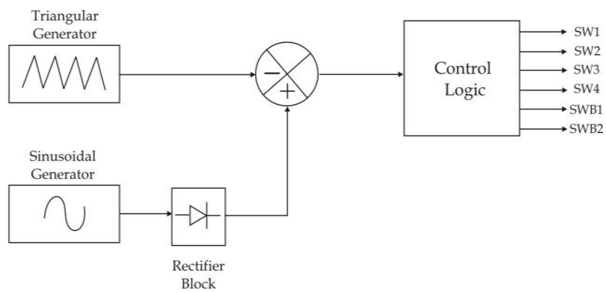

Fig. 13. Blocks diagram of control circuit

A 20kHz triangular wave is compared with a 60Hz sinusoidal reference. The resultant comparator output is a sinusoidal pulse width modulation. (SPWM). A logic control separates these pulses in individuals switches SW1, SW2, SW3, SW4, SWB1 and SWB2. The control circuit is shown in Fig. 14

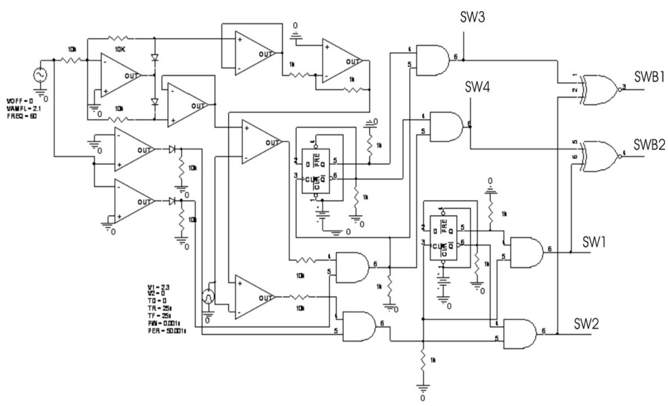

Fig. 14. SPWM control circuit

The power circuit is shown in Fig. 15.

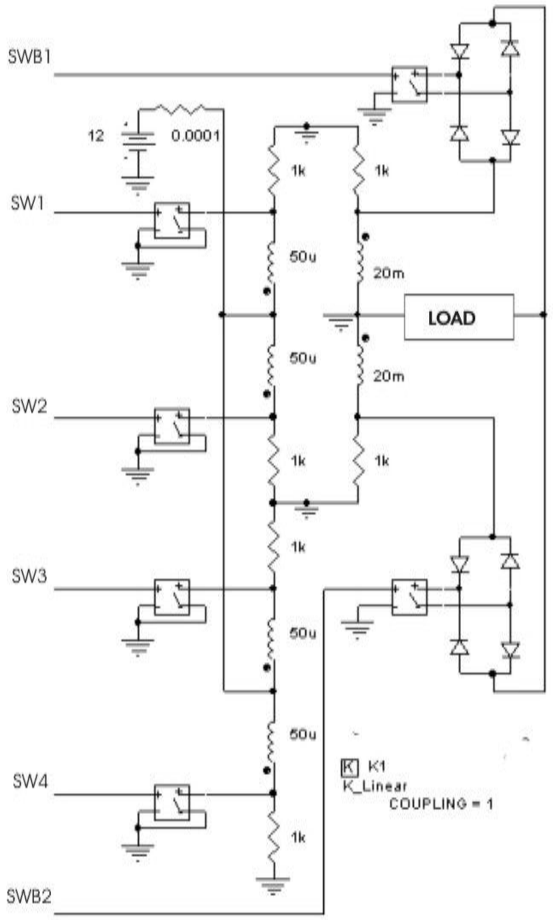

Fig 15. Power circuit simulated

Considering a pure inductive load of 100mH, the current through the inductor is shown in Fig. 16.

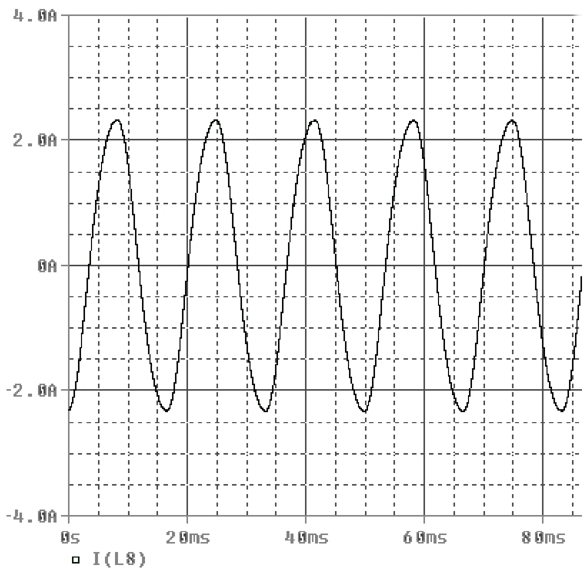

Fig. 16. Current through the inductive load

Considering a pure resistive load of 28Ω, the voltage over the resistance is shown in Fig. 17.

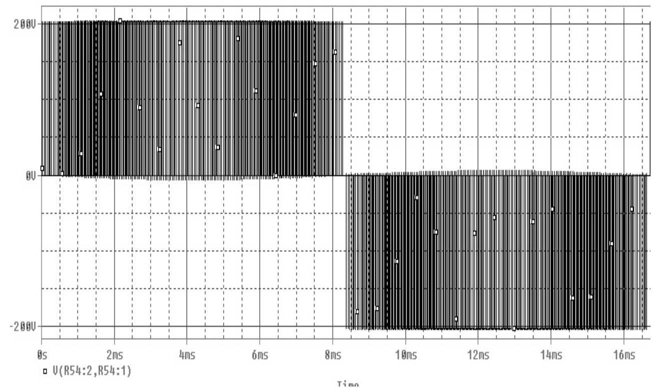

Fig. 17. Voltage over the resistive load

Considering the voltage inverter with a output LC filter, where L=844μH, C=30μF and the load a resistence R of 28Ω, the voltage over the load is shown in Fig. 18.

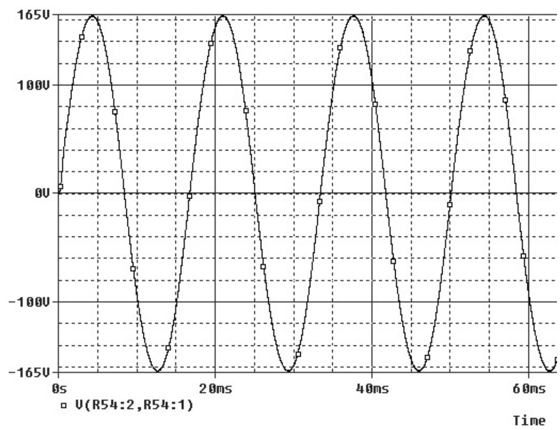

Fig. 18. Voltage over resistive load (inverter with a output LC filter)

Considering the voltage inverter with a output LC filter, where L=844μH, C=30μF and the load a bridge rectifier with a capacitive filter, where R=28Ω e C =660μF, the voltage over R and the current through R are shown in Fig. 19.

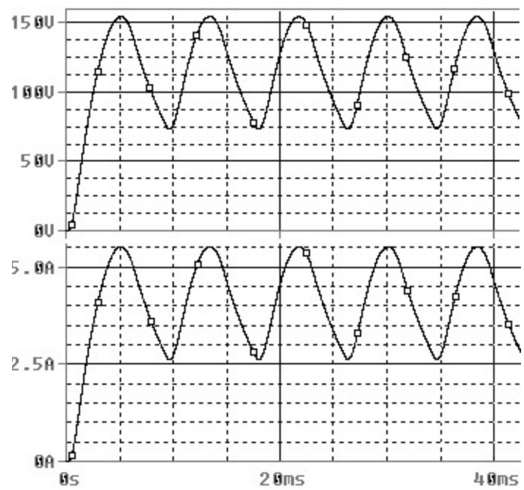

Fig. 19. Voltage (above) over the load R and the current (below) through the load R

VI. EXPERIMENTAL RESULTS

The voltage over the load R (inverter with the LC output filter) is shown in Fig. 20.

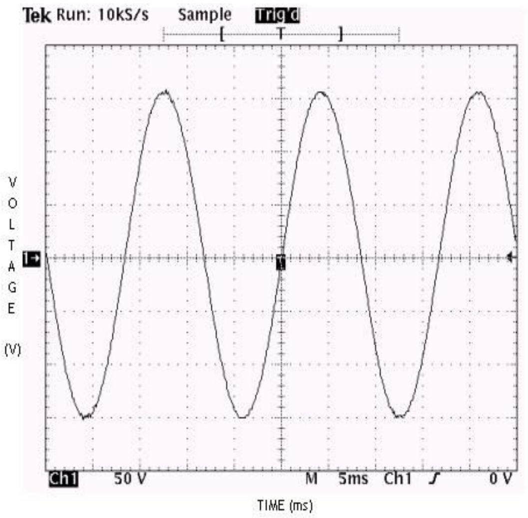

Fig. 20. Voltage over resistive load (inverter with a LC output filter)

The prototype photo is shown in Fig. 21

Fig. 20. Prototype developed of the inverter

VII. CONCLUSION

This paper describes a new voltage inverter topology using only one high frequency transformer with SPWM.

The circuit simulation gives excellent results.

It was inserted bi-directionals switches in the secundary that apparently affect the efficiency, but the inverter is very advantageous because it has just one stage of convertion. This advantage turns this topology extremely versatile for diverse applications as: no-breaks, audio amplifiers, motor control and others loads that it's necessary frequency and voltage control.

The experimental results show a good output wave form that has a little peak voltage distortion. It wasn't possible to get yet the voltage over inductive load, so it suggested for future papers.

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