COMPLETE DESIGN FOR A 1.2 KVA UNINTERRUPTABLE POWER SUPPLY SYSTEM WITH A STABILIZED SINE WAVE OUTPUT AND A FREQUENCY SYNCHRONOUS CONVERTER

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***Abstract* – This paper presents a complete design for an uninterruptible power supply made with a rectifier, a Flyback converter (to keep batteries charged), two parallel Forward converter circuits (to feed the inverter in case of a blackout) and a full-bridge inverter. Resulting power is 1200W and switching frequency is 28 KHz. Operation steps are described as well as the project procedures for its proper handling. Experimental results, concerning the circuit functioning, are shown to validate the system analyses.**

***Keywords* - Voltage Inverter, AC/DC Converter, DC/DC Converter and PWM.**

I. INTRODUCTION

The voltage inverter topology is shown on figure 1. This uninterruptible power supply (UPS) circuit is divided into four blocks. HB1 is an AC/DC converter. It is composed of a rectifier circuit, a voltage selector circuit (127V/220V – a voltage doubler circuit starts electronically when operated at 127V), EMI filters and an inrush limiting circuit. The HB3 block is an AC/DC converter used to charge batteries. It uses a Fly-back converter working in discontinuous mode. It also has a 28V output and a 1A current limiter. Block HB4 is a DC/DC elevator converter. It converts batteries voltage from 24V to 260V. This converter topology mixes Forward and Push-pull converters characteristics. Block HB2 is voltage inverter circuit. It inverts both HB1 and HB2 continuous voltage output into a stabilized sine-wave output of 115Vrms/60Hz.

The four blocks together make up the uninterruptible power supply (UPS) circuit. When running on utility power, HB1 rectifies and filters the utility power wave form. After, it feeds an inverter which will regenerate a sine wave. Utility power problems like overvoltage, undervoltage, fast voltage peaks (from atmospheric discharges), transitories caused by switching operations (circuit breakers or high power fuses) and power-line noise (caused by switched power supplies via electromagnetic interference) are eliminated. At the same time, HB3 keeps batteries charged. If a blackout occurs, HB4 converts batteries voltage to 260V in order to feed the voltage inverter circuit, as long as batteries are charged.

To validate the proposed system (UPS), the experimental results in the main wave ways obtained are shown in the figures 8 to 16.

The complete circuit (annex 1 and 2) it is interesting, because brings for the community the implementation possibility. However your operation can be understood better through the diagrams of blocks according to figures 6 and 7.

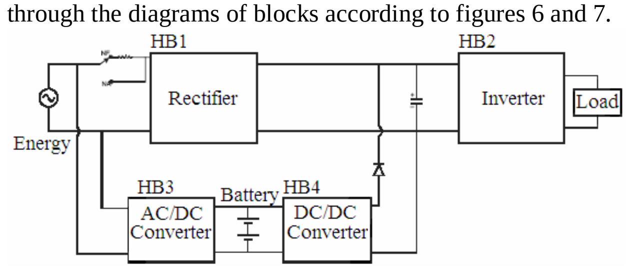

Figure 1 – Uninterruptible power supply (UPS) block diagram

II. THE RECTIFIER CIRCUIT (HB1)

The rectifier circuit is an arrangement of a diode bridge circuit, a voltage selector circuit (this circuit electronically starts a relay which will start the voltage doubler circuit), a power line filter and an inrush current limiter.

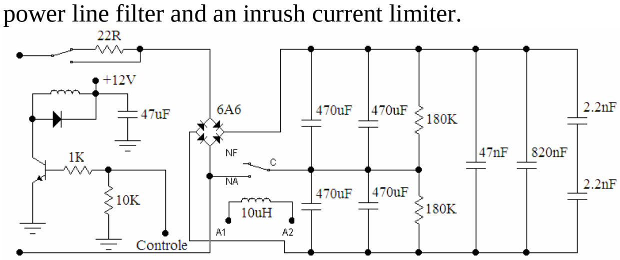

Figure 2 – Rectifier circuit with a power line filter and an auto voltage selector (127V/220V)

Completing the illustration 2, it is added in the entrance a RLC filter made of resistors, inductors and capacitors is used. Both X and Y capacitors were used because they are designed to suppress electromagnetic interference (EMI) noise, the annex 2 brings the complete circuit.

The inrush current limiting circuit on its initial condition (NF) inserts the 22Ω/5W resistor into the circuit.

III. BATTERY RECHARGER (HB3)

The 1M0380 integrated circuit (IC) [8], controls this discontinuous mode flyback converter. The TL431 [10], an adjustable precision shunt regulator, controls its voltage output. It also has a current control circuit. This is a low-power battery charger (30W, 1A limited current and 28V output). That may take a long time to recharge it and utility power must be present.

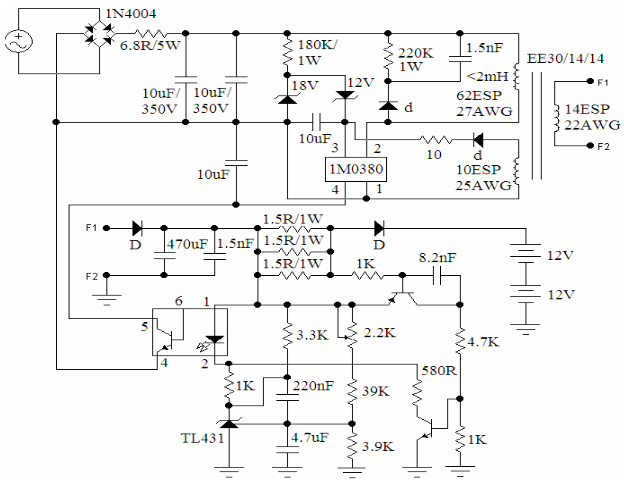

Figure 3 – Flyback complete circuit.

IV. DC/DC CONVERTER (HB4)

This Boost DC/DC converter is similar to a push-pull forward converter. It has two forward converters sharing the same inductor and capacitor from the secondary winding. They operate alternately like a push-pull output.

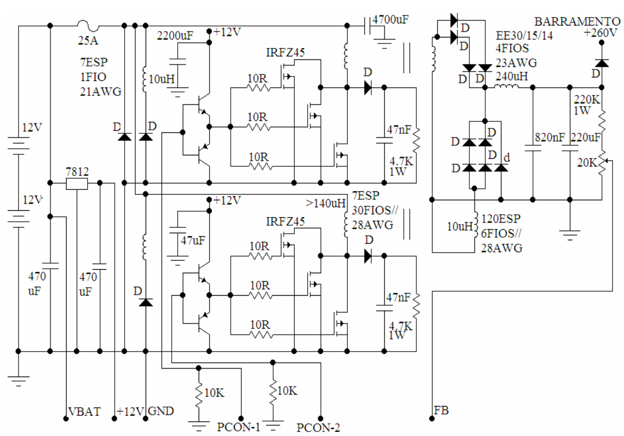

Figure 4 - DC/DC converter complete circuit.

V. INVERTER (HB2)

This inverter, which is a DC/AC converter, uses a bipolar PWM wave inverter (synchronized width pulse modulation inverter - SPWM). The bipolar PWM inverter generates pulses of variable widths to eliminate harmonics. Both sine waves and triangular waves, generated by the control circuit, are compared to generate desired PWM signals.

Low order harmonics can be eliminated by this type of modulation pulses. Due to symmetry, impair harmonics are nearly eliminated. That is why the filter's cutoff frequency must be lower than the triangular wave frequency and higher than the sine wave frequency.

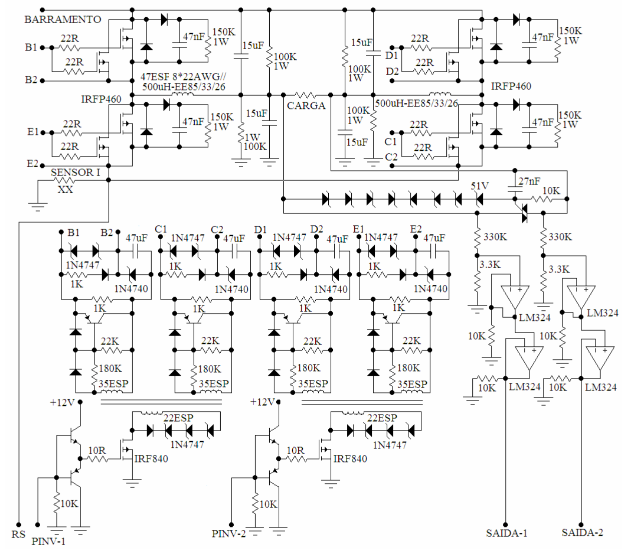

Figure 5 – DC/AC inverter complete circuit.

VI. CONTROL CIRCUIT

Figure 6 shows the uninterruptible power supply (UPS) control block diagram. It is divided into a DC/DC control, an inverter control, a synchronism circuit for both controls, inverter drivers, limiters, protection and signaling circuits.

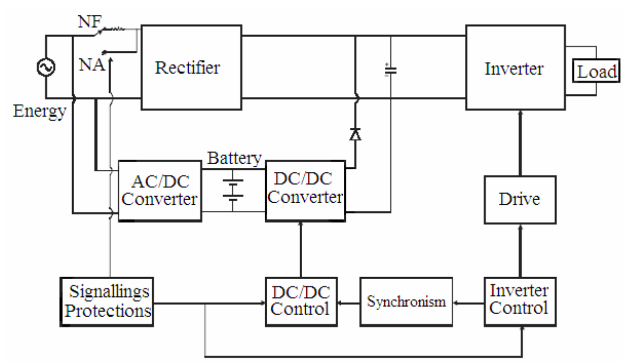

Figure 6 - Uninterruptible power supply (UPS) block diagram and its control.

VII. DC/DC CONTROL

The PWM control method was used to control the DC/DC converters by means of an integrated circuit. The 3525 IC controls said pulse widths [9]. This IC can also be used to close the loop, providing finer control over the converted output, to soft start and to synchronize these converted pulses with the DC/AC conversion.

VIII. DC/AC CONVERTER CONTROL CIRCUIT

The converter controller technique is shown on the block diagram of figure 7 and the electric schematic of the control circuit is shown in annex 1.

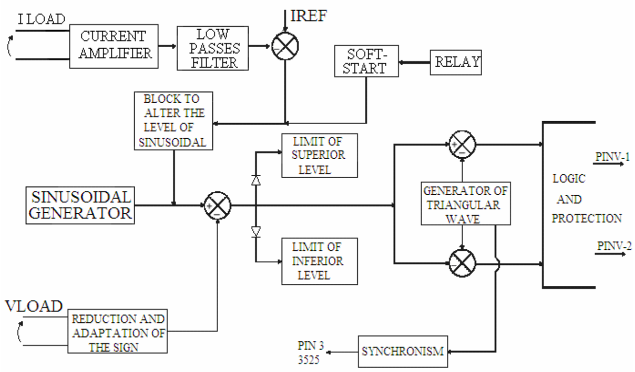

Figure 7 – A block diagram of the technique used for the inverter control.

The sine wave reference was based on Wien bridge oscillator.

A current sensor (Constantan Alloy) was connected in series with the output bus to monitor the sample current. The sensor-generated signal is amplified and filtered so that this DC voltage value is proportional to the AC voltage value on the load current. A light emitter diode (LED) will indicate when the current control circuit is operating. This circuit will alter the voltage amplitude of the sine wave reference.

For the triangular wave generator circuit we adopted the circuit suggested by the manufacturer (Harris Semiconductor), [7].

An uninterruptible power supply (UPS) output signal is sampled and its voltage level adjusted to feedback the load. This signal and the sine wave reference signal are compared to generate an error signal output. The error signal output is compared to the triangular reference in order to generate two PWM pulses, one complementing the other. Still concerning the error signal, a level limiter circuit is implemented in order to stipulate both higher and lower limiting values, so that there are always PWM pulses.

Battery voltage level is shown through four comparing circuits. An audible alarm beeps during blackout conditions. Beep duration vary according to battery charge. The lower the battery charge the faster the alarm beeps.

Over-heating protection circuit operates in two different levels. First, when temperature reaches approximately 50 degrees Celsius, the protection circuit starts a forced air cooling system. In case temperature keeps rising and reaches approximately 60 degrees Celsius, this protection circuit turns the UPS off avoiding further damages.

A soft-start circuitry controls the sine wave reference amplitude, changing amplitude very slowly. Another circuit starts a relay to limit inrush current.

The pulse blocking circuit analyzes whether the system is operating properly or not and interferes with it if it differs from the set pattern reference. This circuit analyzes the signals from the utility power and from the thermal and battery analysis commands. It blocks both the pulses generated to the inverter and the pulses generated by the 3525 IC.

IX. EXPERIMENTAL RESULTS

Below are shown the wave outputs from each project step.

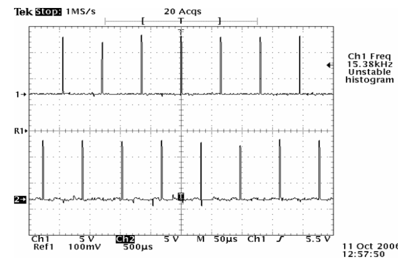

Figure 8 – Control pulses from the DC/DC conversion.

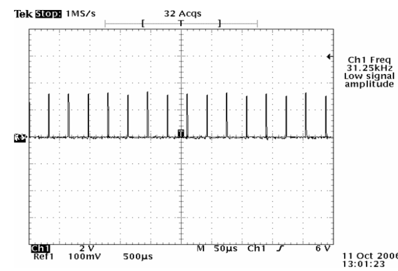

Figure 9 – Pulses for the synchronism of converters.

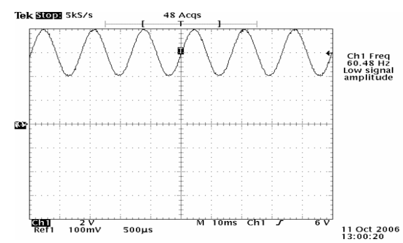

Figure 10 – Sine wave reference.

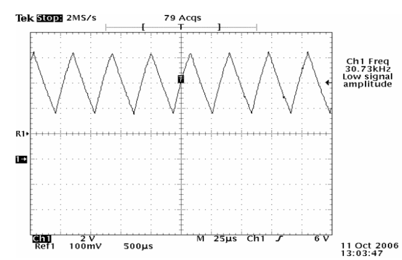

Figure 11 – High frequency triangular wave.

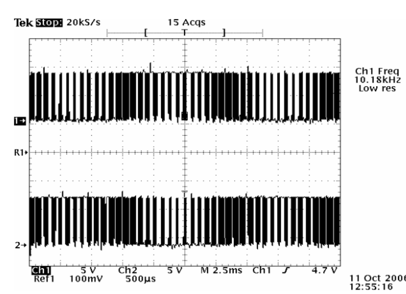

Figure 12 – PWM sine wave modulation pulses.

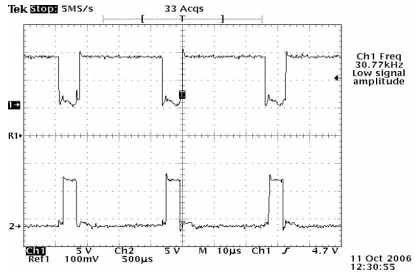

Figure 13 – Inverter control pulses.

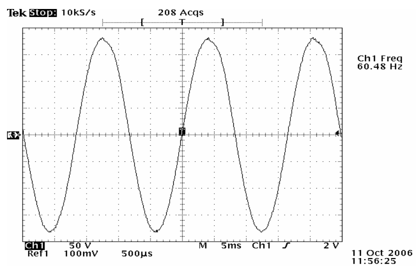

Figure 14 – Load wave form.

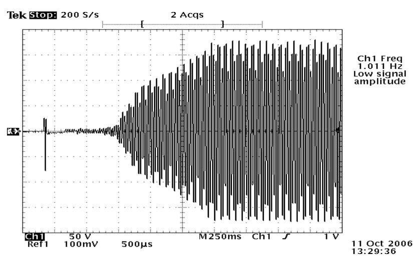

Figure 15 – Load soft-start wave form.

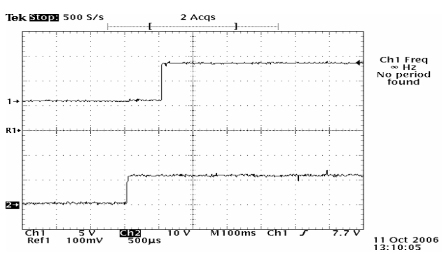

Figure 16 – Relay response to system powering.

X. CONCLUSION

Each control wave type and its generated wave types were shown with UPS parts altogether and turned on.

We can better understand the system operation analyzing the wave type of each functional block, and based on its interactions generate the specific pulse for each converter control.

Concerning the DC/AC conversion, the sine wave pulse width modulation sent a precise signal to the inverter output. The UPS output had a very little distorted sine wave signal. In brief, this output can be used with any device that demands a stabilized sine wave input for proper operation.

The protection circuit made this UPS trustworthy for its regular usage. Alterations or unwanted conditions do not affect the system. In dangerous situations, the UPS stops operating in order to avoid its future malfunctioning and to avoid damages to the load connected to it. Signaling systems worked out perfectly, informing the UPS user whether it malfunctions or not (operation status).

The UPS output continuity during a blackout condition was satisfactory, not interfering with the load connected to it, as long as its battery is enough charged to keep it operating.

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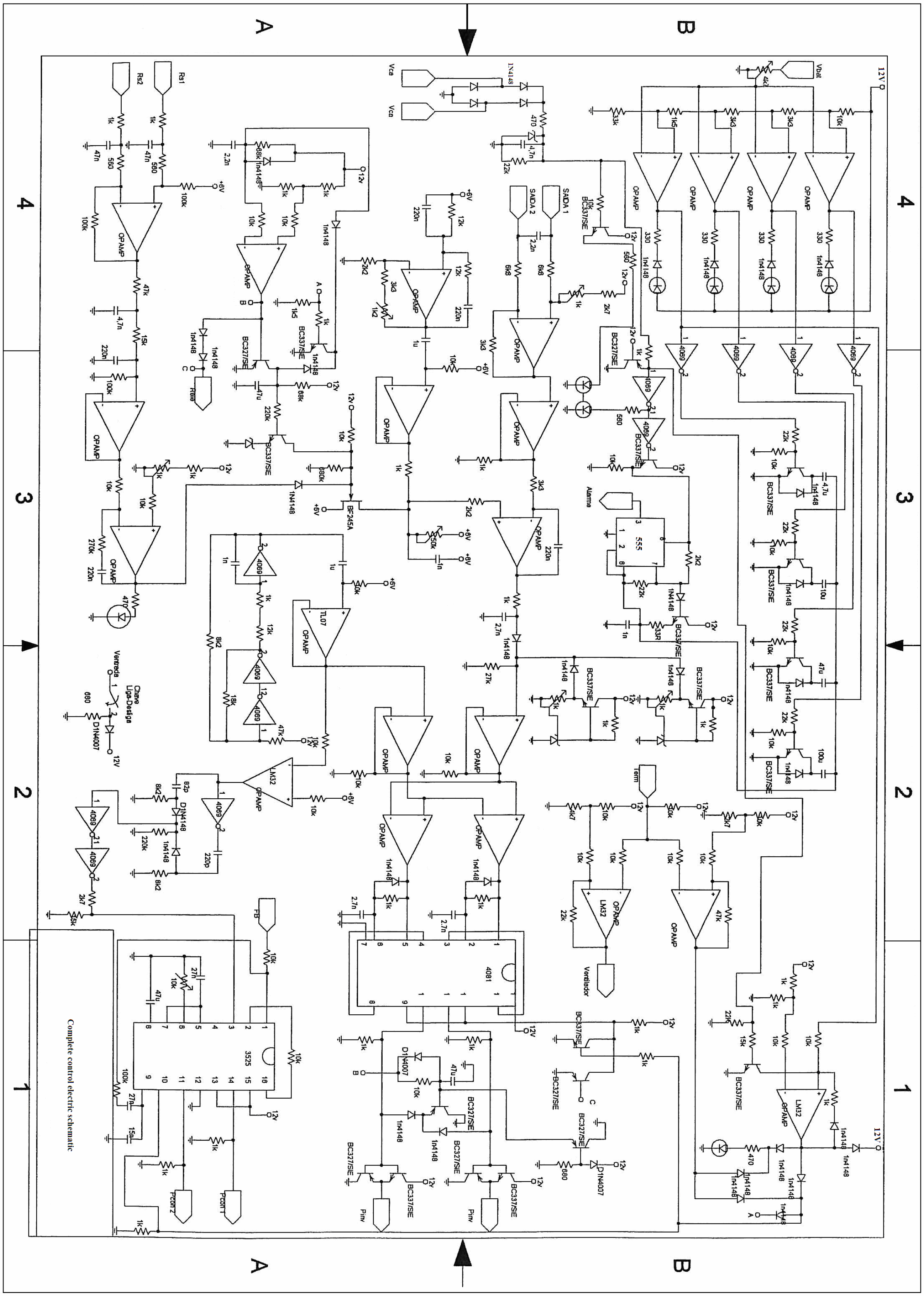
ANNEX 1 – Complete control electric schematic.



ANNEX 2 – Complete power electric schematic.