A 10kVA UPS: PROTECTION AND SUPERVISION CIRCUITS AND IT RESPONSE TO INPUT VOLTAGE DISTURBANCES

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Summary - This work presents the development of control, supervision circuits and the response of a 10kVA UPS under input voltage disturbance. The prototype is composed by a boost dc-dc converter for power factor correction at the input stage, an inverter at the output stage and a battery charger. There were developed and implemented, protection, supervision circuits for UPS and a transfer circuit, which connects the load to the grid in the case of problems with the UPS. The UPS has been tested in laboratory under input voltage and frequency disturbances for long and short duration by a 3kVA disturbance power supply to verify the output voltage stability to input variations. Experimental results are presented and discussed, for validation of the final prototype.

I. INTRODUCTION

With the rational use of the electric power in evidence, the concern with power quality and continuity is every time increasing. There are several factors, or phenomena associated with the quality of the product electric power, which constitute the power quality [1].

The expression “Power Quality” it is associated to deviation manifested in the voltage, in the current, or in the frequency that results in bad operation of the consumer equipment [1].

Electronic equipments when submitted to disturbances of energy they can work in an inadequate way [1], [2], [3]. Computers are sensitive to voltage variations, as data stored in the memory can totally be lost in conditions of undesirable voltage.

Uninterrupted Power Supply (UPS) plays an important role to minimize electric power disturbances at the sensitive load, for it supplies clean power to the load, during a grid disturbance.

This paper presents the development of control, protection and supervision circuits, and the response to input voltage disturbance of a 10kVA UPS. The prototype is composed by a boost dc-dc converter for power factor correction at the input stage, an inverter at the output stage and a battery charger. There were developed and implemented, protection, supervision circuits for UPS and a transfer circuit, which connects the load to the grid in the case of problems with the UPS. The UPS has been tested in laboratory under input voltage magnitude and frequency disturbances for long and short duration by a 3kVA disturbance power supply to verify the output voltage stability to input variations. Laboratory results are presented and discussed.

II. DESCRIPTION OF THE PROTOTYPE OF UPS

The block diagram of the UPS is shown in Fig. 1 . The input transformer promotes galvanic isolation from the grid. The rectifier provides the dc voltage. The pre-regulator boosts the rectified voltage to match the inverter input voltage. The inverter provides ac voltage in magnitude and frequency required by the load. In parallel to the rectifier output there is a battery charger and a battery bank which is a source of energy to the load when there is a disturbance at the input.

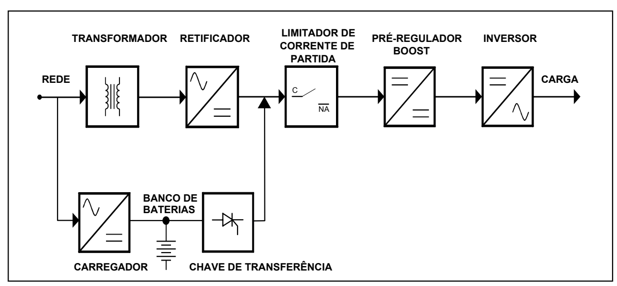

Fig. 1–Block diagram of the prototype of UPS.

III. DESCRIPTION OF THE PROTECTION AND SAMPLING CIRCUITS

To protect the input stage of the UPS against variations of the grid, over voltage and over current protection and sampling circuits were inserted at the input stage. The surge protection comes into action when happen abrupt oscillations in the input voltage and/or current. The sampling circuits inform to the supervision circuit the real values of voltages and currents [4].

To protect the UPS against voltage surge a varistor was placed in parallel to the primary of the input transformer. The varistor was chosen to go into conduction when submitted to a voltage higher than the voltage of the grid. In a situation like that the high current through the varistor trips the circuit breaker. Fig. 2 shows the implemented circuit.

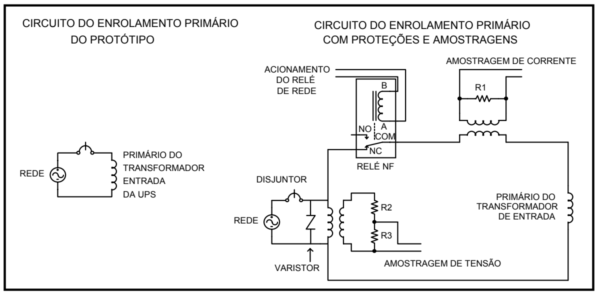

Fig. 2 - protection and sampling circuits.

IV. The on-line By-Pass Circuit

The automatic bypass circuit is a very complex circuit, because it can commutate the load at the output of the UPS directly to the mains in case the UPS is temporally out of work. This is a on-line commutation, and the load current could be in the order of 80A through UPS.

Generally a by-pass circuit have two bi-directional switches, and each switch is composed by two back to back thyristor. One switch connects the inverter to the load and the other on the grid to the load. The switches can never be on at the same time, because they connect the grid to the output of the inverter, as seen in Fig. 3. Due to the presence of thyristors any switch comes off only at the zero of the current.

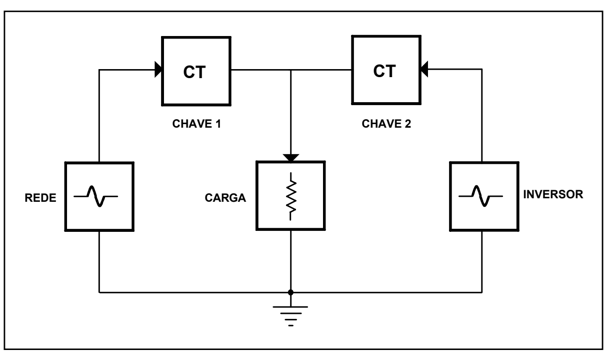

Fig. 3 – General by-pass circuit configuration.

Fig. 4 shows an alternative by-pass circuit configuration. Each switch is composed by a full bridge diode rectifier and an IGBT. When IGBT is turned on diodes D2 and D3 are forward biased during the positive semi-cycle and diodes D1 and D4 are forward biased during the negative semi-cycle, linking the load to the inverter.

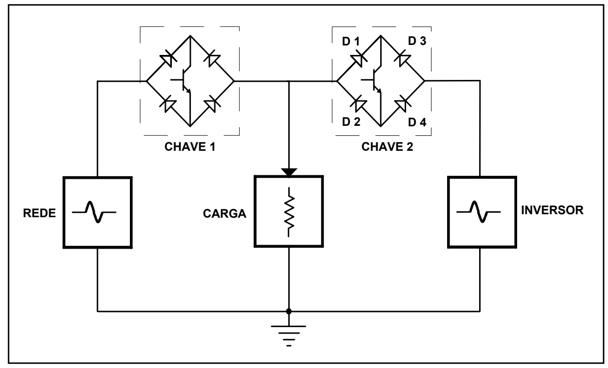

Fig. 4–Bypass composed by two bridges retificadoras and two IGBT`s.

The configuration shown in Fig.4 dos not present the delay problem presented by the previous configuration as seen in Fig.5.

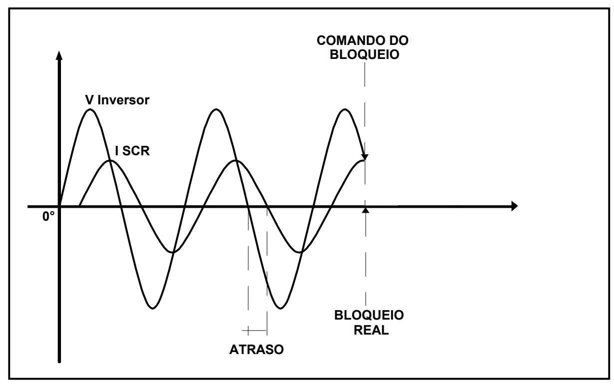

Fig. 5–Voltage and current during the IGBT operation

V. Circuit of Supervision and Drive

The supervision circuit is composed by a microcontrolador with a software, and some special function CI as clock, memory and interface for serial communication. They are also present the display, and the keyboard, for interface with the operator.

The memory of the supervision circuit stores 4,000 events, to help the operator in future maintenance. The clock has the function of registering the moment of the events, so that a report of events is generated. Besides the interface with the operator through display and keyboard, the supervisor also communicates through RS-232 or Ethernet. UPS can be monitored and controlled from a computer that is connected to it through a RS-232 or through the internet. The block diagram in of the supervision circuit can be seen in Fig. 6.

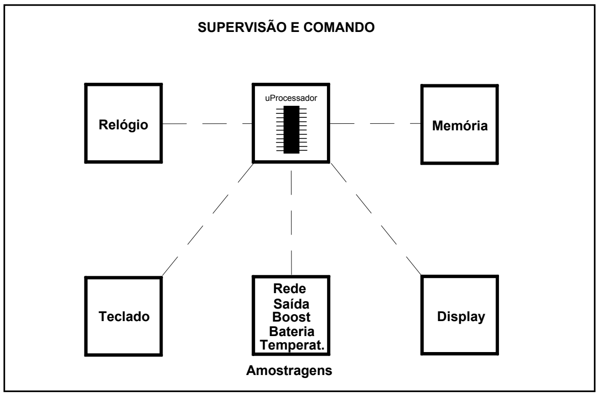

Fig. 6–diagram in blocks of the supervision circuit.

Some important characteristics of the UPS are monitored during every operation, they are: input voltage and current, tension and exit current, dc output voltage of the boost pre-regulator, tension of the battery bank voltage, temperatures and synchronization signals.

The supervision circuit communicates with all stages of the UPS, could act directly in critical points. The supervision circuit and command is interlinked to the power converters as shown in Fig.7 . The energy for the supervision circuit is originating from one of the isolated output of the auxiliary source that feeds all the control circuits of the UPS.

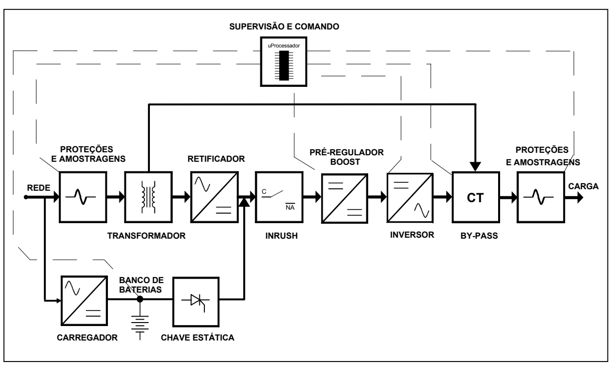

Fig. 7 - diagram of blocks of the interlinked supervision circuit UPS.

The flowchart seen in Fig.8 presents the logic operation of the UPS. When UPS is working in normal condition it supplies energy from the mains to the load through the boost converter and the inverter. In case of a UPS failure, the supervision circuit turns off the boost converter and the inverter and activates the bypass circuit. Now the load is supplied straight from the mains, and the UPS is checked for problems.

When the grid fails, the UPS is disconnected from the mains and goes to the battery mode. If the grid comes back before the battery voltage reaches the minimum value of 116V, the UPS is connected back to the mains, and UPS returns to your normal operation.

When the UPS is overload with 120% of the nominal load the supervisor informs the user (the warning can be sound), so that the extra load is removed. In case this load is not removed in 20s, the supervisor turns off the UPS. If the overload goes superior to 120% the supervisor turns the UPS off immediately.

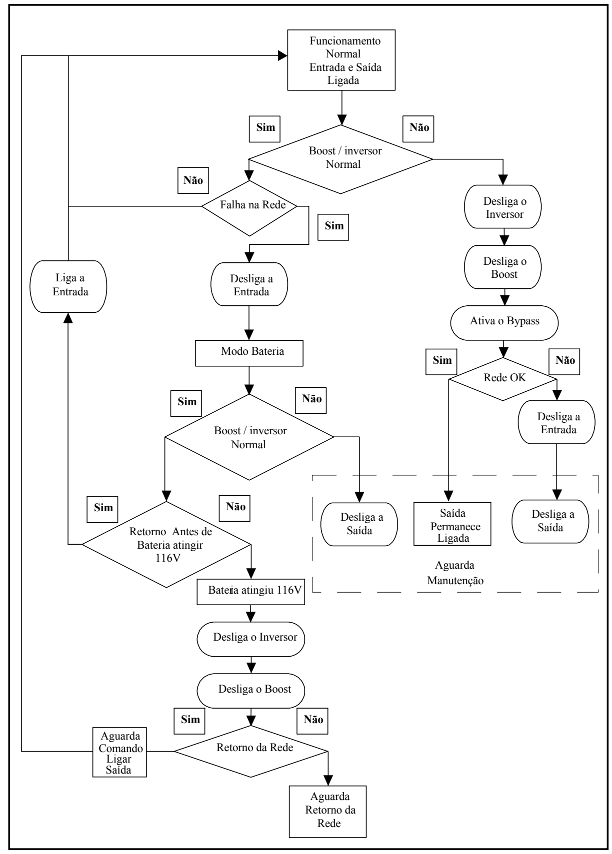

Fig. 8–Fluxograma of Operation.

VI. DISTURBANCE TESTS

To accomplish the tests a disturbance generator of 3kVA was used. The UPS was submitted to several disturbances of long and short duration. The waveforms were collected and recorded with the help of a digital scope. The laboratory setup is seen in Fig. 9.

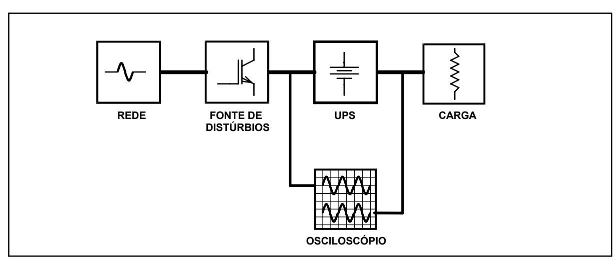

Fig. 9–Laboratory setup.

The UPS prototype was submitted to disturbance at the input voltage. In the following figures the top waveform is the input voltage. The bottom one is the output voltage of the UPS.

Initially UPS was submitted to the following disturbances: transitory and variations of short duration and finally to the frequency variations. Last figures present the response of the UPS when submitted to very unusual voltage disturbance.

Fig.10 shows a situation in which the input voltage increased to 135% of it rated value, and at the same time a frequency variation of 75% during one cycle. The output voltage of the UPS did not reflect the variation in the input voltage.

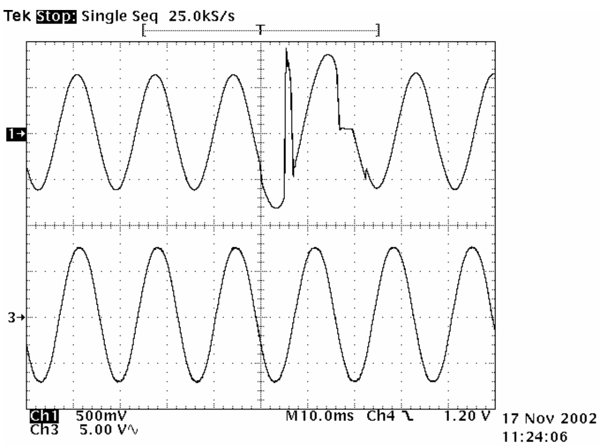

Fig. 10 - variation of the input voltage to 135% and frequency to 75% for 1 cycle.

Fig. 11 displays a voltage sag in the input voltage to 5% during 10 cycles. The output voltage of UPS stayed stable. The bank of batteries to supply energy the load through the inverter.

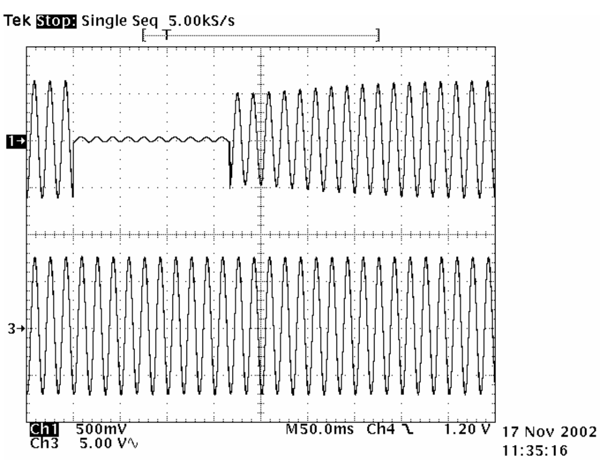

Fig. 11–Voltage sag of 5% for 10 cycles.

An instantaneous over voltage, also called swell, is characterized by having magnitude between 110 and 180% of the rated voltage and duration of half cycle up to 30 cycles. Fig. 12 displays an swell of 135% for 10 cycles. It can be observed that the output voltage of the UPS continues stable.

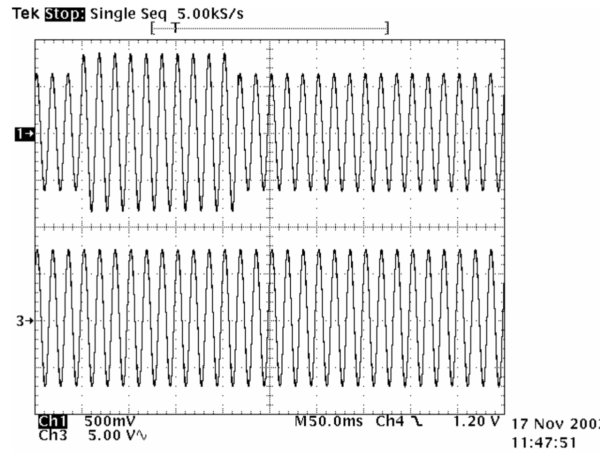

Fig. 12–Voltage swell of 135% for 10 cycles.

Fig. 13 shows an input voltage with 30% of third harmonic distortion and with 12% of fifth harmonic distortion. The output voltage presented a waveform with 2% of distortion, that is smaller than the maximum allowed by the standard.

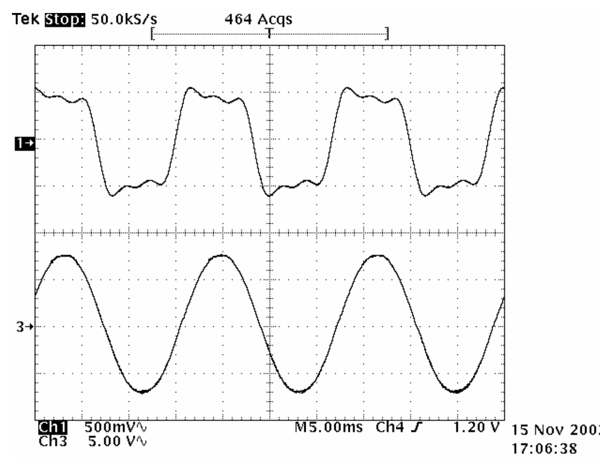

Fig. 13 - Input voltage with 3^{rd} and 5^{th} harmonic.

Fig. 14 display the input voltage with a frequency of 53Hz (-12%), however in this situation the supervisor disconnected the UPS from the mains due to low frequency. The UPS now operates in battery mode, that is: the bank of batteries supplied energy the load. The output of UPS continues stable.

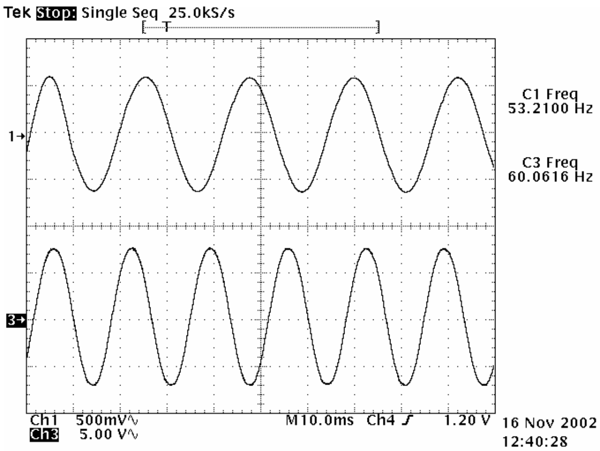

Fig. 14–Input voltage with a frequency of 53Hz.

Fig.15 present a very unusual situation in which the input voltage has a waveform with 12 pulses. That situation could be found in places where many rectifiers were installed. That wave form can cause many problems in sensitive loads. Once again the UPS output voltage was stable.

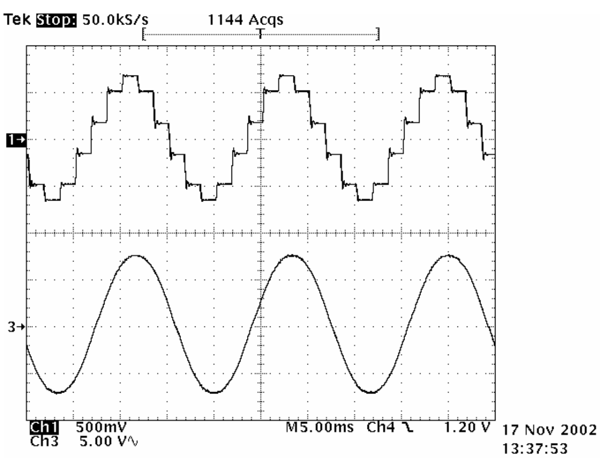

Fig. 15–Voltage waveform with 12 pulses.

It is finally the worst case presented in this work is shown in Fig. 16, that is an asymmetric input voltage waveform. It can be observed that in spite of the strange waveform the output voltage was still stable.

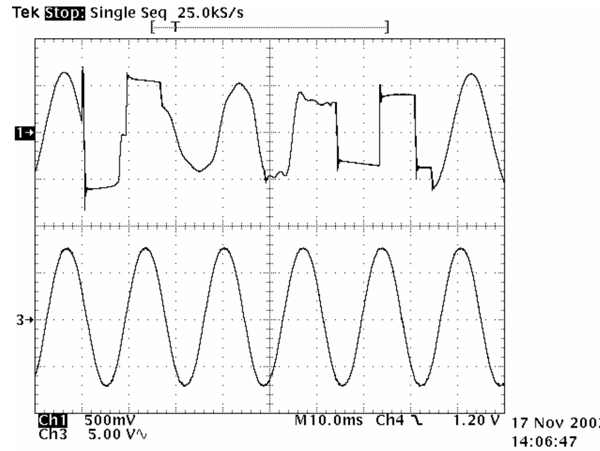

Fig. 16–Asymmetric voltage waveform.

VII. CONCLUSIONS

UPS are used to guarantee the supply of energy to the loads for variation in the grid. Several types of configurations of UPS already exist. The choice of the type depends on the power and load characteristic. It was presented in this work, protection and supervision circuits of an UPS double conversion on-line that is recommended for sensitive loads.

The microcontroller-based supervision circuit collects data from several points of UPS, it processes those data to makes the decisions. The events are stored in a memory for subsequent collection and analysis of possible problems. The supervisor is very important in UPS, because he guarantees operation limits for the equipment. In that way it protects the load and the equipment.

It can be concluded that UPS is robust and insensitive to most of the problems that can happen in the electric grid. It was verified that the configuration double conversion is quite efficient, for the UPS output in insensitive to most variations at the input voltage. The robustness demonstrated by UPS guarantees that the load is always fed by a voltage without distortion and without abrupt variations.

VIII. AKNOWLEDGEMENTS

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