# A Study of an Uninterruptible Power Supply Managed by a Microcontroller

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**Abstract – This paper presents a study of a solution for supplying uninterruptable power to a special load with the main objective of obtaining high reliability. The main focus of this paper is to explore the possibility of energy regeneration from a specific system. Two types of converters are described as solutions, as well as their designs and results. The paper will also explore the main types of stationary batteries and their different ways of charging. The use of a microcontroller for the converter charging steps management and control is also presented. A detailed analysis of battery charging methods and extensive experimental results are also presented.**

## I. INTRODUCTION

This work intends to present an uninterruptable power supply managed by a microcontroller for use in a special application. This power supply must be reliable and robust, where the microcontroller will have the function of supervision of the power supply.

The power supply will be inserted in a larger system where it will be responsible to maintain excited the magnetic bearings of a motor excited and the DC power for the electronic devices, even when the AC mains fail.

Today's applications of uninterruptible systems require great reliability with a low time response. Most of facilities that require non-interruptible supply systems, have some kind of energy generator, like diesel generators or others. The problem is that these generators have a time delay from the moment they are settled to start to generate electricity until the moment they really begin to deliver energy to the load. This time could be destructive for certain kinds of loads.

The converter here studied is used to supply energy during the short periods of time when a lapse of energy occurs until another device is settled to momentarily substitute the grid. Both converters projected for this application are described and their advantages and disadvantages are presented. A comment about the control scheme and the way it works are shown.

The next section presents a study on the charging method of the batteries of the DC-DC UPS. Some kind of batteries and characteristics of them are shown. A brief commentary over its cost is made. The implementation of the control management and the experimental results are presented at the end.

## II. THE APPLICATION

The objective of the proposed power supply system is to maintain uninterrupted power to a load of 60Vcc – 25W (magnetic bearings of a rotating motor). This load, called the main system, must be supplied without any interruption, even when the AC mains fail. This power system must be available for a short period of time (3 minutes) until a generator provides the necessary energy to continue to process. In order to offer a large reliability, a group of batteries is placed in the output of the power supply.

The energy for the batteries and for the load (this is a type of an on-line UPS) will be delivered by a DC-DC converter. The specifics topologies of converters that could be better adapted, considering the input line voltage (220Vrms), is the buck converter, and its isolated version, the forward converter. When the buck converter is used, there must be an isolation by a low frequency transformer.

In the application, both buck and forward converters were tested. In Fig. 1 it is shown the load being supplied from a buck converter.

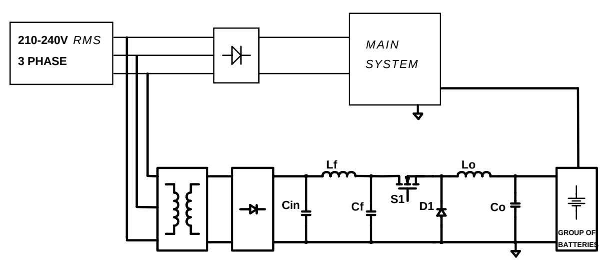


Fig. 1 - Buck DC-DC topology applied as power supply for the main system.

It can be observed in Fig. 2 the forward converter supplying energy to the load. Due to the fact that the isolation of the forward converter occurs in high frequency, the volume of this second approach minimized. However its main switch (S1) is submitted to higher voltages, making necessary the use of a semiconductor of high reverse voltage (800V).

One of the main objectives in this study is the way to control the converter in the whole system, paying attention to the output voltage regulation, output current limiting and battery charge control. The transfer function and control characteristics for both approaches (Buck and Forward) are almost the same. It is necessary to control the current of the converter, the voltage over the load, and the current through the batteries. Fig. 3 shows the simplified schematic of the control. An ‘or’ logic was implemented and it can be verified that at any time one of the feedback loops will be active [2],[4].

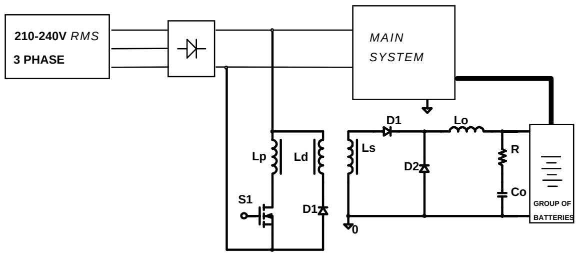


Fig. 2 - Forward DC-DC topology applied as power supply for the main system.

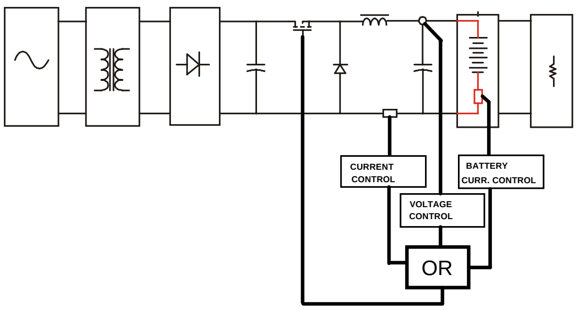


Fig. 3 - Schematic of the control model.

## III. Types Of Batteries

The specific application requires an initial study of the main types of batteries, their application and characteristics. Among a lot of battery types studied, the comparison can be focused on two types: Lead-acid batteries and nickel-cadmium batteries [6].

Lead-acid batteries have been manufactured in their present form for many decades, and they have proved to be reliable and cheap. The advantages of lead-acid technology are its wide availability and low cost. In Fig. 4 it is presented the cycle service life in relation to depth of discharge of a 12 V, 1.2 AH battery. It can be observed that the life time of a battery depends on the number of cycles of discharge that it is submitted and how deep are these cycles [7].

The main characteristic of a battery intended for applications that require high reliability is that it must be capable of being discharged completely for hundreds of times over its life.

The great advantage of the nickel-cadmium batteries is its long-life durability. Industrial nickel-cadmium batteries can present an operation life in excess of 30 years on continuous floating charge. Otherwise, the big drawback of nickel-cadmium batteries, however, is its toxicity. Cadmium is a highly toxic metal, whose use is being avoided rapidly because environmental reasons. Another problem is its greater initial cost that can be amortized in many years.

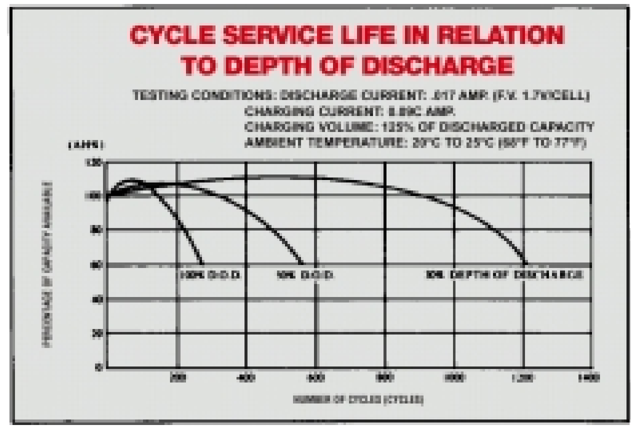


Fig. 4 - Cycle service life in relation to depth of discharge – 12V, 1.2Ah battery [16].

Fig. 5 illustrate a life comparison between a lead-acid and a nickel-cadmium battery.

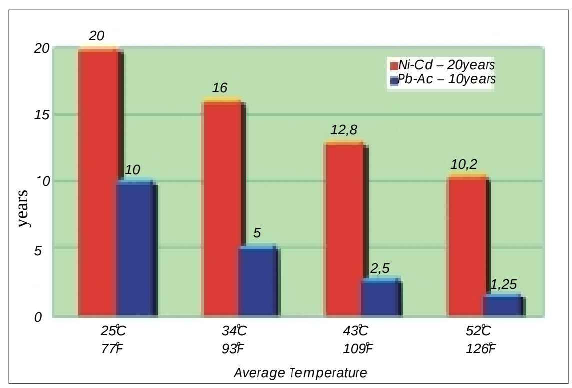


Fig. 5 - Life comparison between a lead-acid and a nickel-cadmium battery [12].

For practical reasons and for specifications of the application, it was chosen the lead-acid battery for the specific application.

The cost of a four battery group is approximately US$52.00, with and individual cost of US$13.00 for each battery.

## IV. Charging Manage

The group of batteries needs good care to improve robustness and durability. A way to improve durability of the group of batteries is to monitor its temperature, taking care to not surpass the nominal voltage and maximum currents. Several papers present methods of charging batteries, mainly of lead-acid batteries [10]. The charging method chosen for the specific application can be verified in Fig. 6.

It can be noticed that initially, when the voltage across the terminals of the group of batteries is low, the current is limited by 1/5 of its maximum current charge value. Once the minimum voltage is reached, phase one is started (bulk charging phase).

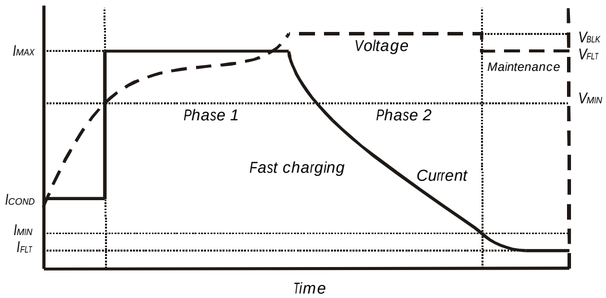

Fig. 6 - Charging phases.

When the nominal voltage is reached, it is clamped and the current trough the batteries begins to decrease. When the current is approximately zero, indicating that the battery is completely charged, the voltage imposed by the converter goes to floating value.

All these charging phases are managed by a microcontroller [3],[9]. Besides the control of the charging phases, the microcontroller (PIC16C711) controls the temperature in the group of batteries, and can inform the user through LED's each charging phase or fail in the process.

The algorithm used to build the program is also presented in Fig. 7. Each block on the figure represents a program step or decision. Each decision is based mainly on the variable inputs read by the microcontroller. The PIC16C711 was provided for three inputs [13], as follows: converters output voltage, converter output current, and temperature of the batteries group.

The signals emitted from the program to a supposed user are implemented by the microcontroller output. These signals are light signals emitted by LEDs. Each LED correspond to a state of charge (load charge or float charge), and fails during the tests.

The fails implemented on the program could be temperature fail, current fail or voltage fail. The temperature fail occurs when the input voltage from a temperature sensor is out of the specific bounds. This fact is interpreted by the program as an abnormal condition. The current fail occurs when the terminals of the battery are opened (this occurs when the terminal are excessively impregnated from the chemicals combinations on charging and discharging). Finally, the voltage fails can be signalized when the battery did not reach the minimum voltage, or the voltage over the batteries exceed a maximum value.

The cost of the microcontroller used for this research was approximately US$14.00. But this kind of microprocessor used here is one for development tools, with EPROM technology. This microprocessor can be obtained for prices from US$2.50 to US$5.00.

## V. Experimental Results

The results obtained on the implemented prototype are shown in this section.

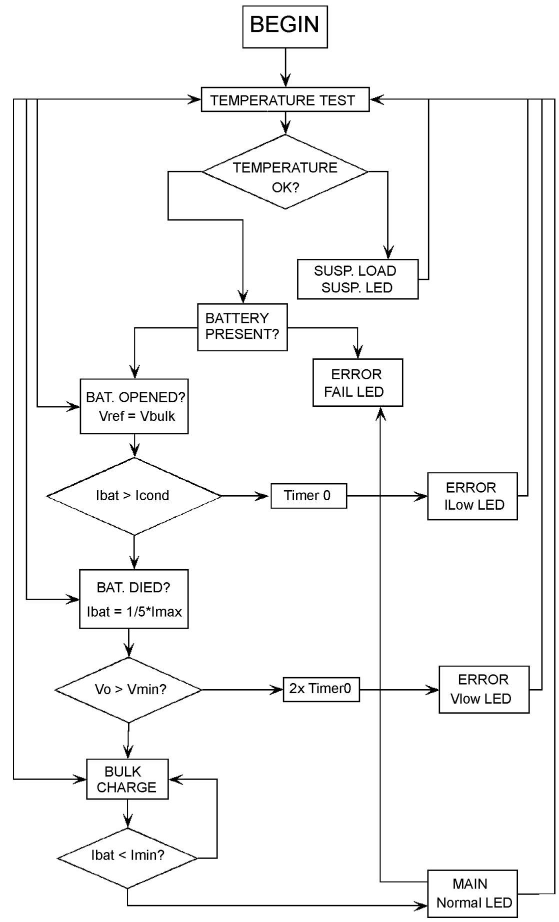

Fig. 7 - Program algorithm implemented on the PIC16C711.

Fig. 8 presents the start-up transient, when the converter is turned on. It could be seen the action of the voltage controller, avoiding the output overvoltage. This test where made with a resistive load.

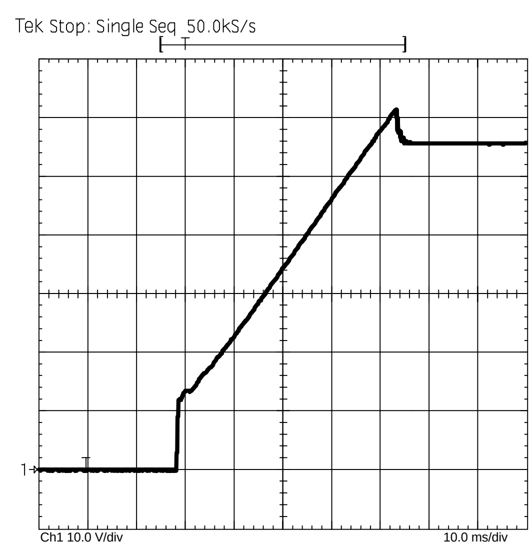

Fig. 8 - Output voltage transient on startup.

The current control action can be verified in Fig. 9. In this test (with a resistive load also) its shown the moment when a short circuit in the output terminals is applied. The voltage across the terminals falls to zero, and the current is limited to its maximum value (allowable by the settled control), after a small transient time.

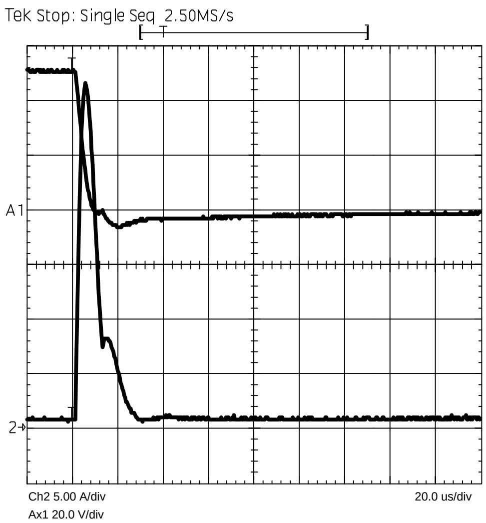


Fig. 9 - Output transient response to a short circuit on the load. Top trace – voltage. Bottom trace – current.

Fig. 10 shows the output voltage ripple. It can be noticed that exists a high frequency ripple due to the switching effects, and a lower ripple, indicating the action of the controller in suppressing the input ripple (due to grid AC voltage).

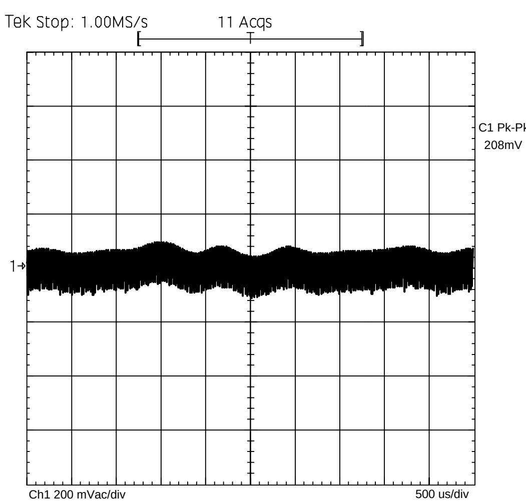


Fig. 10 - Output voltage ripple.

All the results shown here are from the forward converter, but there are not significant differences in the results obtained in the buck converter. These results were suppressed here only for brevity.

The results presenting the action of the microcontroller management are demonstrated in Fig. 11. In this figure, it can be observed the voltage across the battery terminals and the current through the group of batteries. Initially, the voltage across the terminals of the converter is the rated voltage (approximately 55V) and the current through the terminals of the batteries is negative (Fig. 11 - ①), indicating that the current flows through the group of batteries (battery charging). In this figure it is also shown a failure of the AC mains (Fig. 11 -②). In this situation the energy of the battery is drained out and the voltage across its terminals goes down and the current is now positive (battery supplying energy to the bearings).

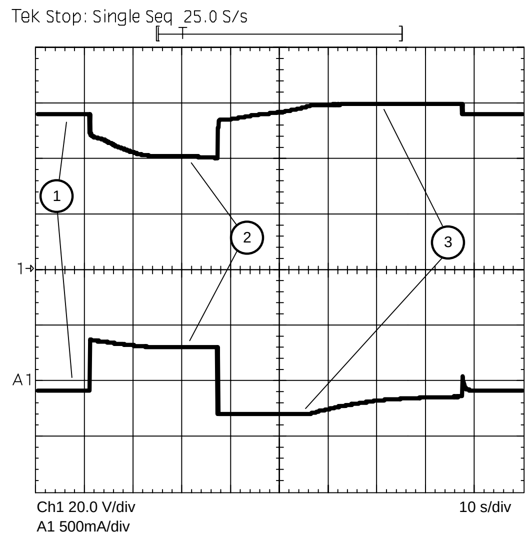


Fig. 11 - Steps of charge – practical results.

When the power from the grid returns (Fig. 11 - ③), the current becomes negative and it is clamped in its maximum value until the voltage reaches the bulk voltage (or overcharging voltage). Once in the overcharging value, the voltage stays clamped until the current drops to its minimum value. At this point, the voltage returns to the floating charge voltage.

## VI. Conclusion

This work presented a design of a system that can supply uninterrupted power for a specific load, and can at the same time, charge a group of batteries by the best way, preserving the battery capacity. The system is completely managed by a PIC microcontroller, taking care of every charging decision of the batteries.

It can be concluded that the buck converter presents a robustness structure for specific application due mainly for the use of a less reverse voltage on the main switch. It presents also a vantage of being completely independent from the main system. But it is greater on volume (it needs three low frequency transformer for adapting the voltage) and presents a high cost due to the magnetic low frequency cores.

The forward converter presents a high reverse voltage in the main switch (at least 650V) and depends on the rectifier bridge present in the main system. But its highly recommended because it permits the regeneration from the system, what gives to it a great advantage over the buck converter.

The use of the microcontroller was implemented also with great success, even in the action of changing the references of current and voltage. This encourages the use of microcontroller in applications where it is not only necessary to manage the steps of charging and control, but effectively control and actuate on the switching commands.

## VII. References


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