Didactic Platform for Power Electronics Teaching

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Abstract – The main objective of this work is to introduce to the Power Electronics Community the results obtained with a successful experience in Power Electronics teaching at Pontifícia Universidade Católica do Rio Grande do Sul - PUCRS. To implement this platform creativity and low cost components were used. A didactic platform that studies inverters and its different modulation techniques was obtained, with an extremely low cost releasing the use of sophisticated and expensive equipments in the assembly of our laboratories.

I. INTRODUCTION

Through the ambitionless effort of main excellence centers in Power Electronics, the area had a significant growth on national ambit, in the last years. Today the teaching of this science is done in a great part of Brazilian Universities by highly qualified professors, recognized nationally and internationally for their works. However in most of cases, these professionals do not have time to develop didactic experiments, to allow their students to exercise completely the concepts demonstrated on theorical disciplines. This project was pictured to contributed with the Power Electronics teaching, in order to turn it more attractive for the students. The didactic platform was implemented based in a group of circuits that allows the implementation of a wide variety of experiments and can be used by graduation students and masters degree students.

This work wants to describe meticulously, the conception of this platform. The different modules developed in this project allow the student to have a practical experience in laboratory, as shown in table I:

Spite of the inverters being very well known structures, the practical use of these circuits has been well accepted by the students, because they can observe in laboratory the electric operation of these structures and the electronic control signals. With the use of these kits it is possible to study several types of structures, using different load types such as resistive loads, inductive loads, AC and DC machines and non linear loads such as the rectifiers.

The use of these kits allows the students to observe in practice, the operation of the several structures, visualizing the different electronic signals, such as: modulating signal, zero cross detector, modulated wave and the voltages and currents in the power stage. Today the students can use modern simulators programs that allow the electronic circuit simulation. These programs are an important tool for the study of Power Electronics, however these tools do not substitute a real laboratory experience.

In the developed platform now presented one of its main advantages, like the virtual systems, was obtained - the user's safety. In this way, the kits were elaborated seeking for students total safety, whose usually does not have the necessary ability to work with energized systems and precision instruments, for example: the digital oscilloscopes. Thus, the several circuits are supplied by isolated sources and the power stages works with low voltage levels, reducing the risks of electric hazard and short circuit by oscilloscope ground terminal. In this article it will be described step by step, the several developed modules. The development of this system was accomplished by a student as a final project of graduation, by a scientific initiation scholarship supported by CNPq (BIC) and with collaboration of several other students linked to Power Electronics Laboratory of PUCRS - *LEPUC*.

II. DESCRIPTION OF THE DEVELOPED SYSTEM

The system was concepted initially to incorporate all the necessary circuits to implement an Uninterrupted Power Supply (UPS), whose diagram blocks can be observed in figure 1.

A complete report of different blocks that constitutes the UPS system is described below.

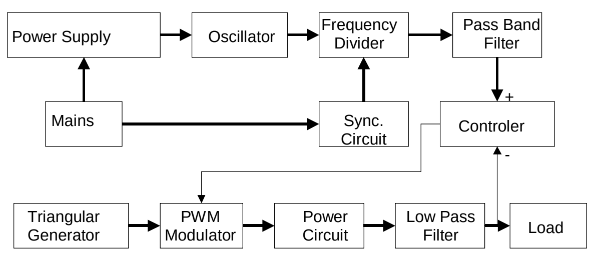

Figure 1. Diagram blocks of the UPS.

Sinusoidal Generator. The commercially available UPS system needs to attend stricted technical specifications concerning to harmonic distortion and frequency stability. The frequency stability can be obtained by crystal oscillators. In this project the time base was implemented using a 3 MHz crystal from which was obtained a 60Hz reference signal.

TABLE I - STUDY CONTENTS

Inverters:	Chopper:	PWM Modulation Techniques:	Driver Circuit
➥ Push-Pull Inverter; ➥ Half-Bridge Inverter; ➥ Full Bridge Inverter;	➥Operating in four quadrants;	➥ Two levels PWM Modulator; ➥ Three levels PWM Modulator; ➥ Sinusoidal PWM Modulator;	➥ With dead time adjustable circuit; ➥ Short circuit protection of the arms inverter;

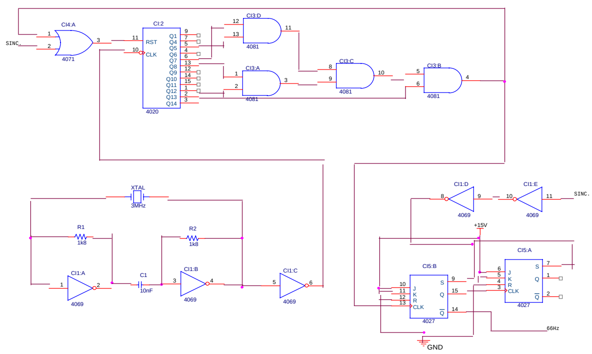

Figure 2. 60 Hz Frequency Stabilized Generator.

The circuit's output showed in figure 2 is a square wave. A filter is required once it is necessary a sinusoidal modulating signal for elimination of harmonic components. The chosen filter configuration is the cascade connection of two identical Sallen-Key topology. At the output of this circuit is obtained a 60 Hz sinusoidal signal. The structure of one of the Sallen-Key filters used is represented in figure 3.

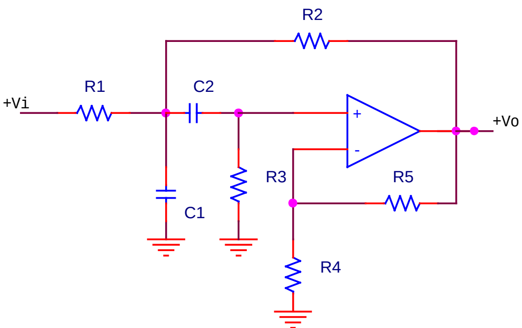

Figure 3. Sallen-Key Passband Filter.

Synchronism circuit: The objective of this circuit is to keep the generated sinusoidal wave synchronized with the commercial mains. A zero detector is used in order to obtain the synchronization with the mains. An optocoupler was connected in the mains to avoid the use of precision rectifiers which are necessary for elimination of the diodes drop voltage and to present to the students another kind of solution for this problem. The used circuit is presented in figure 4.

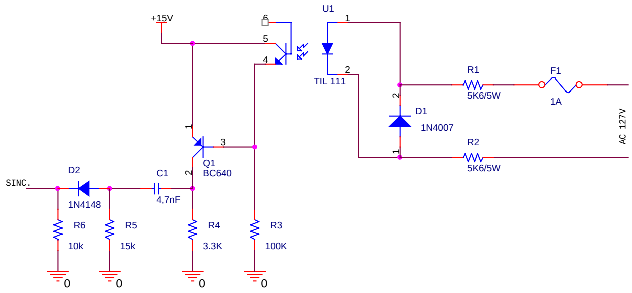

Figure 4. Zero Detector Circuit.

Modulator Circuit: The PWM modulator circuit is based on the comparison of a triangular or a Sawtooth Wave (carrier wave) with the wished modulating signal wave. It was opted for using a triangular wave generator to reduce the harmonic content of the power output in case of using a sinusoidal modulating signal. In the present project the triangular wave generator was based on IC LM566, associating to this an amplifier for level adaptation. The implemented modulator circuit is capable to implement two or three modulation levels. The circuits comparators that integrate this block were implemented using the IC LM339. The inversion of the modulating signal, necessary to implement the modulation in three levels, was obtained with the use of an AMPOP in a inverter configuration. The circuit comparator can be seen in figure 5 and the triangular wave generator in figure 6.

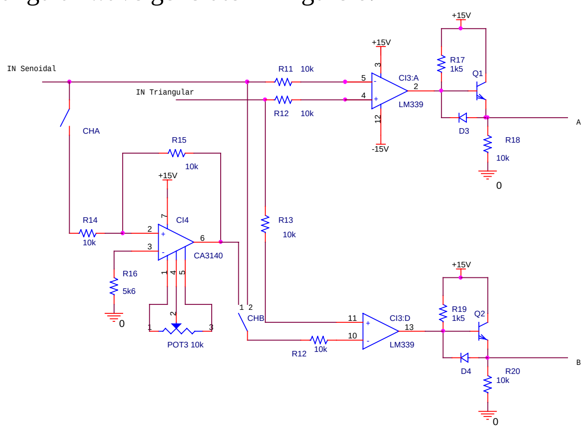

Figure 5. PWM Modulator Circuit.

Driver Circuit. The main function of this circuit is to be an interface among the power devices (MOSFETs) and the available signals in the circuit's modulator output. The power structure used in the present work is a Full Bridge topology, that presents the inconvenience of having a floating transistor. To command this floating device basically two solutions are known: to use a isolated drive using high frequency pulse transformer or using a dedicated integrated circuit. In this implementation, it was opted for the second possibility, using the IR 2110 IC. The proposed circuit also incorporates variable dead time and arm short circuit protection. The developed solution found is represented in figure 7.

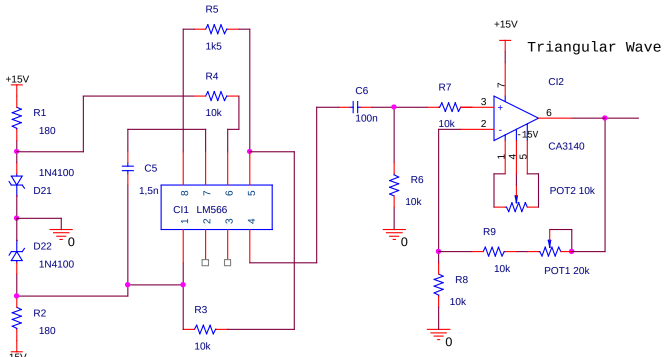

Figure 6. Triangular Wave Generator.

Inverter Circuit. From the initial conception of this project, it was adopted as a basic principle, the construction of a versatile platform at a low cost. The initial idea was to build a single module that allows the student to accomplish experiments with single-phase inverters. A circuit that incorporates these functions for the study of inverters is represented in figure 8, which topologically is nothing else than a full bridge circuit, implemented with MOSFETs (type IRFP-460).

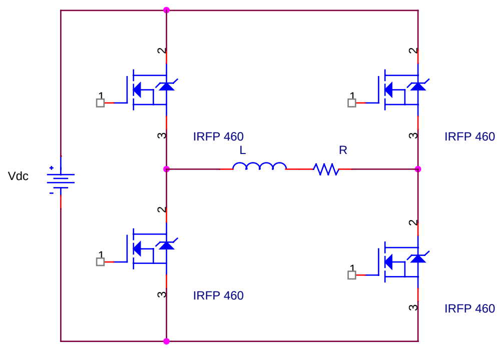

Figure 8. Full Bridge Circuit.

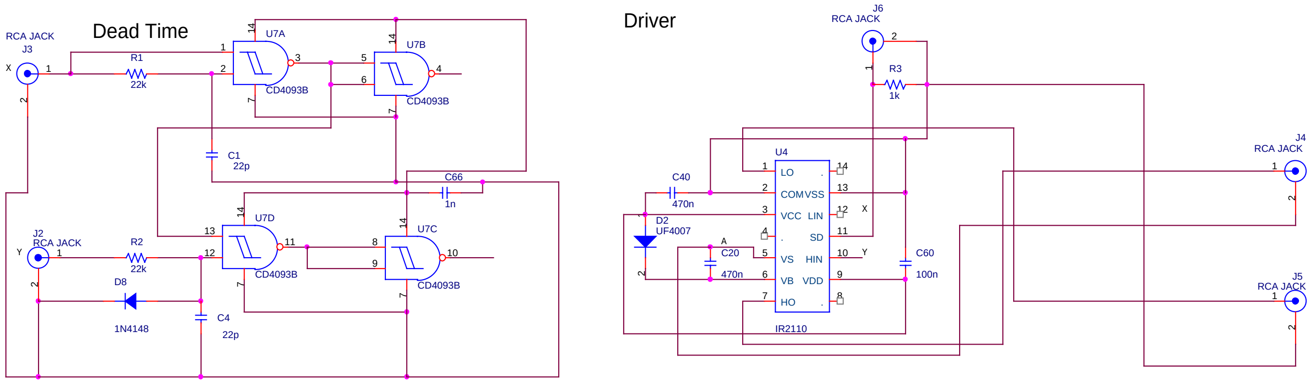

Figure 7. Driver Circuit.

Filters. The output power of the inverter should necessarily be filtered due the intrinsic characteristics of the PWM modulation. The proposed filter is a LC type and can be observed in figure 9.

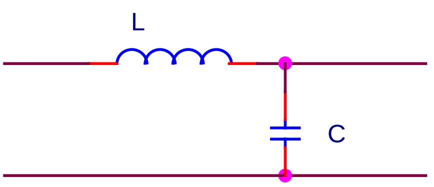

Figure 9. LC Filter.

The system was initially set up on a wood base, that gives to the equipment the necessary hardness for its use in a teaching laboratory. Due to the high level of interferences generated by the inverter power stage, an instability was presented on its operation. The solution found for this problem was obtained with the shielding of the wood base by a galvanized steel base, reducing the length of the used cables and given a new layout of the system. A general vision of the implemented system is presented in figure 10.

This same system can be easily adapted to work as DC driver to DC machines working in four quadrants. In this case, it is enough to change the sinusoidal modulating signal by a variable DC voltage level. In this situation the structures shown in table II can be studied:

To use this platform to teach AC drivers, scalar control, is enough to use a proper modulating signal. The scalar control basically consists in maintain the relationship voltage/frequency constant. Therefore, the modulating signal must have this characteristic.

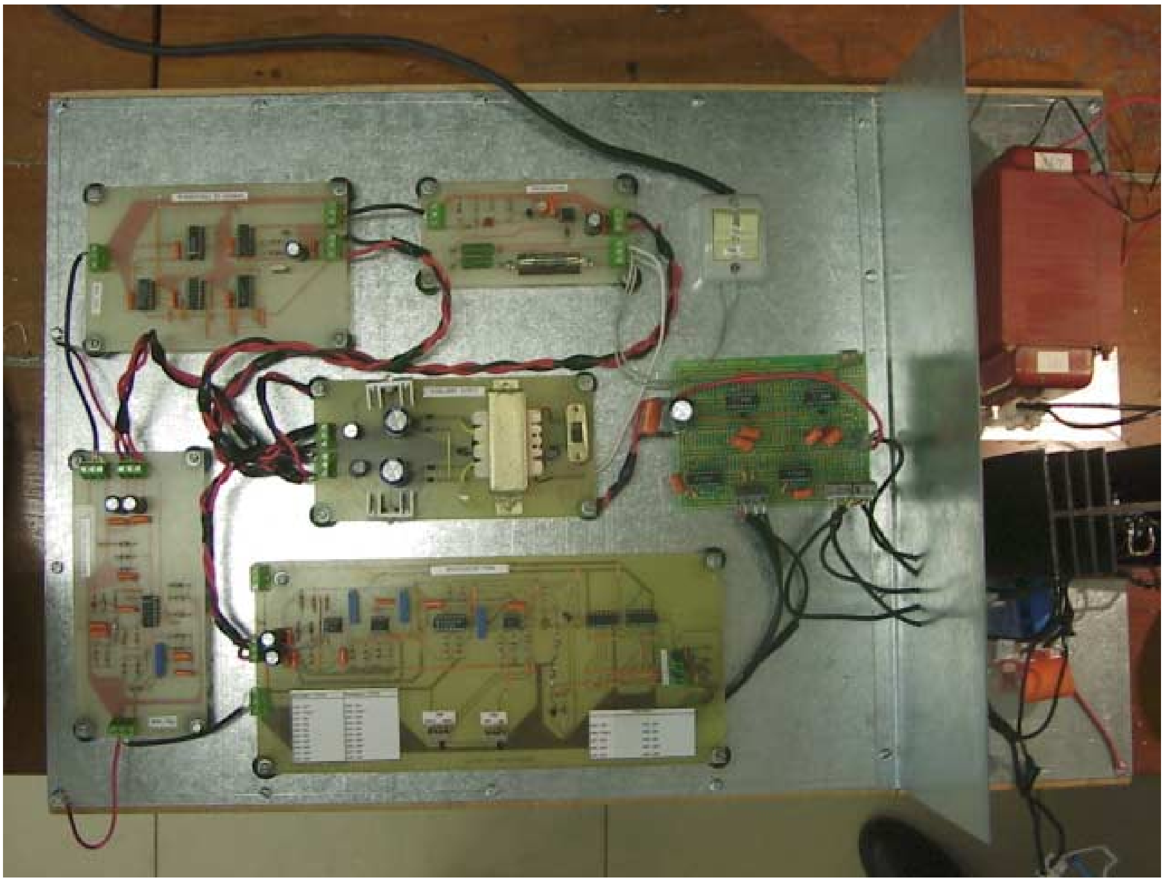

Figure 10. Implemented system.

TABLE II - STRUCTURES TO BUILD A DC DRIVER TO DC MACHINES

DC Signal Reference Generator: ➥DC adjustable Voltage levels (+/-);	Modulator Circuit: ➥Two levels PWM modulator; ➥Three levels PWM modulator;
Driver Circuit ➥With dead time adjustable circuit; ➥Arms Short circuit protection;	Inverter Circuit: ➥Full Bridge Inverter;

III. EXPERIMENTAL RESULTS

To validate the operation of this didactic platform a sinusoidal inverter using the two levels modulation technique and another sinusoidal inverter using the three levels modulation technique were implemented experimentally. For these experiments the voltage waveforms at inverter output and at load, after the filter shown in figure 9 were obtained. These signals are shown in figures 11 and 12.

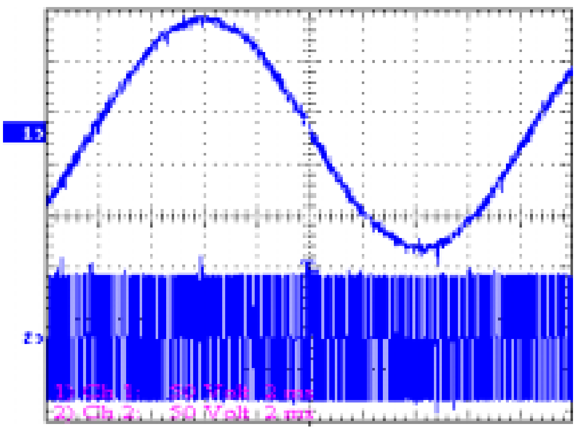

Figure 11. Output inverter voltage after and before LC filter (2 levels).

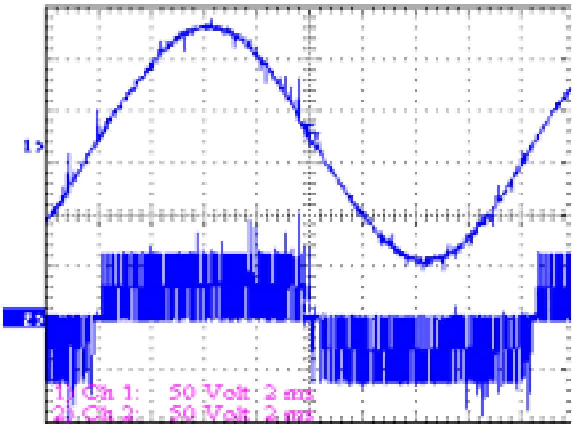

Figure 12. Output inverter voltage after and before LC filter (3 levels).

The waveforms show that the experimental results obtained are very close to the theoretical results described in the bibliography, as for example, in Barbi [1], Rashid [2], Kassakian [3]. It happen through the choice of large size semiconductor devices. This choice also brought as benefit the increase of the platform useful life described in this work.

The output voltage shown in figure 12 presents a very low (1,8 %) THD. The harmonic spectrum is shown in figure 13. This voltage was obtained using 60 W incandescent lamp load. The great results obtained with this platform stimulates the researches to implement a conventional UPS system in collaboration with local industries.

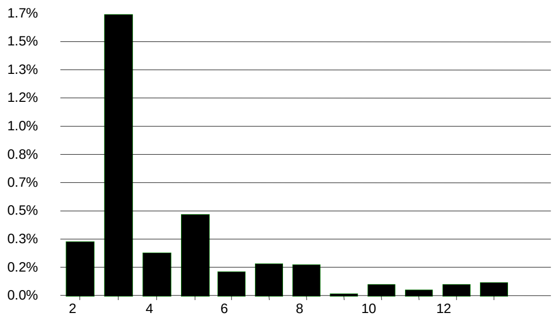

Figure 13. Harmonic magnitude of the output voltage as a percentual of the fundamental amplitude (3 levels).

IV Acknowledgment

The authors thanks CNPq support to this work by a scientific initiation scholarship (PIBIC program) and PUCRS for the economic contribution, that made possible this initiative.

V. Conclusion

In this article a didactic platform to teach Power Electronics was described. This work is inserted in the context of a solid pedagogic proposal for the Power Electronics teaching, based on the theoretical practical experience mainly in the field of the inverters and DC drivers.

The system now presented is inserted in a wider proposal, started with a didactic kit family, elaborated for the study of rectifiers circuits presented in [5]. After the implementation of these kits an expressive improvement of the learning process was observed, obtaining high approval indexes different from what happened when the discipline was presented in the traditional way.

At PUCRS the teaching of power electronics is realized in two disciplines. The first one, theoretical, is called Power Electronics with duration of 60 hours. In this discipline the textbook is the Power Electronics by Prof. Ivo Barbi [4]. The second discipline offered is denominated Laboratory of Power Electronics which purpose is to develop experimentally the theoretical contents approached in the Power Electronics discipline, with duration of 30 hours.

We would like to remark the importance of the popularization of this kind of work, that approaches pedagogic aspects and is concerned with the formation of a new methodology of teaching the Power Electronics disciplines.

Is important to observe that the work here presented constitutes the second stage of a more ambitious project in which the main objective is to develop didactic kits that assists the Power Electronics teaching.

The versatility of the platform and the great economy obtained in relation to the available educational kits found on the market are additional advantages of the proposed system.

VI References

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