PLATAFORMA: DEVELOPMENT OF AN INTEGRATED DYNAMIC TEST SYSTEM TO DETERMINE POWER ELECTRONICS SYSTEMS PERFORMANCE

María Giménez, Víctor Guzmán, José Restrepo, José Aller, Alexander Bueno, Julio Viola,
Antonio Millán, Alexis Cabello

Universidad Simón Bolívar, Grupo de Sistemas Industriales de Electrónica de Potencia,
Valle de Sartenejas, Edo. Miranda, Caracas 1080A, Venezuela.

ABSTRACT

This work presents the basic design of and later improvements to the integrated dynamic test system called Plataforma, which is a test rig developed by the Industrial Systems and Power Electronics Group (GSIEP) of the Universidad Simón Bolívar in Caracas, Venezuela. It is intended for experiments in power electronics and motor control, testing new strategies and control schemes, based on vector control theories, parametric estimation, neural networks and fuzzy logic control systems, applied to machine drives, and taking into account the effect of these control strategies over the power quality. The equipment includes driver power stages, a mechanical load emulation stage, an instrumentation stage and a signal processing and control stage. Due to its high versatility, this test system can be used in research laboratories, as well as in undergraduate and postgraduate teaching courses.

Keywords: Inverter, Active Rectifier, Vector Control, Active Filters, AC Machine Test System, Active and Reactive Power Control.

PLATAFORMA: DESARROLLO DE UN SISTEMA DINÁMICO INTEGRADO PARA LA DETERMINACIÓN DE LAS CARACTERISTICAS DE SISTEMAS ELECTRÓNICOS DE POTENCIA

RESUMEN

Este trabajo presenta las etapas de desarrollo y las mejoras posteriores del sistema de ensayo dinámico denominada «Plataforma», la cual es un equipo modular de prueba desarrollado por el Grupo de Sistemas Industriales y Electrónica de Potencia (GSIEP) de la Universidad Simón Bolívar en Caracas, Venezuela. Su finalidad es la realización de experimentos en electrónica de potencia, control de máquinas, ensayos de nuevas estrategias fundamentados en la teoría de control vectorial, estimación paramétrica, redes neuronales y lógica difusa, aplicadas al accionamiento de máquinas, considerando su impacto sobre la calidad del servicio eléctrico. El equipo incluye las etapas de potencia, de emulación de la carga mecánica, de instrumentación y una etapa de procesamiento de señales y control. Debido a su gran versatilidad, este sistema de ensayo puede ser utilizado en laboratorios de investigación, así como para la enseñanza en cursos de pregrado y postgrado.

Palabras clave: Inversor, Rectificador activo, Control vectorial, Filtros activos, Sistema de ensayo para máquinas de corriente alterna, Control de potencia activa y reactiva.

INTRODUCTION

From the point of view of the new educational demands, the continuous developments reported in Power Electronics make it one of the fastest growing areas in the Electrical Engineering field. It has been estimated that up to one third of all the electric power generated in the industrial world is manipulated by some kind of power electronic circuit, and

this fraction is growing quickly, and may reach up to 50% in the next years (Bose, 1996). As an answer to this potential market, Power Electronics is a subject included in many major Universities, at both the undergraduate and the postgraduate level.

Paradoxically, Power Electronics is a subject not particularly attractive for students, and the number of properly trained electrical or electronic engineers in this field is not increasing as fast as it is required. One of the reasons for this situation is that Power Electronics is a complex subject, were the student must grasp knowledge from a wide number of areas: solid stated power devices, converter topologies, power systems, electrical machines, control theory, digital signal processing, instrumentation, low power analog and digital electronics, microprocessors, CAD techniques and others (Karad•inov et al. 2001).

To help students to fully understand and master this subject, it is necessary to include practical laboratory work (Aller, 1996; Bauer & Kolar, 2001; Hedley & Barrie, 1998; Lentijo et al. 2003; Sierra et al. 2004). This has been incorporated in many curricula, but one of the first important facts that must be taken into account is that if every single student or group of students start from scratch, building their own power electronics system, with the instrumentation, signal processing and control systems included in this implementation, only a few very simple systems could be tested.

A similar situation occurs when serious research work has to be performed in order to test new developments, specially under dynamic conditions, such as improved vector control and DTC systems, the application of new control algorithms like fuzzy logic, neural networks, etc. (Bueno & Aller, 1996; Restrepo et al.1997; Reimondez et al. 1997). The complete development of the test system can be so time consuming that no results can be obtained in a reasonable period of time.

To overcome these problems, in 1997 the Industrial Systems and Power Electronics Group (GSIEP) of the Universidad Simón Bolívar in Caracas, Venezuela, undertook a major project to design and develop a rugged, complete and versatile power electronics test system, with all the instrumentation, signal processing and control systems included, to serve as the test rig for a wide number of research experiments and practical sessions for graduate and undergraduate students. This test system was called Plataforma.

Plataforma was seen as a long term project, based on modular systems that could be modified and improved depending

on the actual requirements of the Group in a particular situation, considering both research an educational tasks.

Up to date, the system has evolved through three different models, named Plataforma I, Plataforma II, and Plataforma III respectively. Particular characteristics and new improvements of all three systems have been reported in the literature (Giménez et al. 1999; Restrepo et al. 1999; Giménez et al. 2000; Restrepo et al., 2002; Giménez et al. 2004) through the years. This work is a complete presentation of the developed system, its performance and numerous applications, in both teaching and research activities.

PLATAFORMA I

The first integrated dynamic test system designed by the SIEP Group was assembled in 1998 and a first report was produced in (Giménez et al. 1999). Versatility, the most important characteristic required from this test system, depends on the design modularity and the software structure. Reliability and security were also very important requirements to be taken into account in any test system to guarantee people and equipment integrity.

Hardware Description

Figure 1 presents the block diagram of the first Plataforma model, which includes the power stage, the measurement system and the control system, implemented in the PC. Heavy lines connect the blocks in the power stage, and fine lines connect the blocks in the instrumentation and control stages.
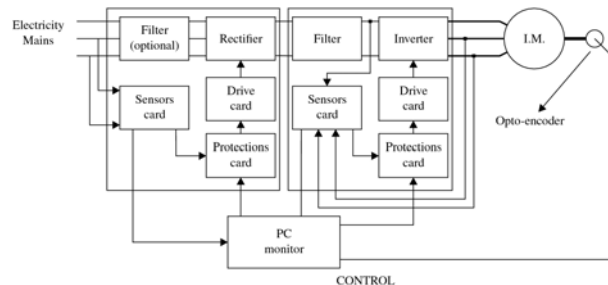

Figure 1. Test System block diagram.

- The power stage

The Plataforma power stage includes two fully-controlled power converters with their filters, one converter working as a controlled rectifier and the other as an inverter, together allowing four quadrants system operation. Both converters are identical, implemented with full controlled bridges, each one with six IGBTs, using three dual IGBTs modules, type EUPEC FF50R12KF2 (an upper-lower device array and their antiparallel diodes), rated at: Vce = 1200V, Ic = 50A; ton= 0.4

μs toff = 0.2 μseg and P = 400 W per IGBT. Each converter was constructed on an H31 heat sink, air cooled with a small fan. The thermal impedance was lower than 0.07 ºC/W. Additionally, a non-controlled rectifier with six power diodes was provided to perform simpler tests, when a controlled rectifier was not necessary. This power stage was intended for driving electrical machines under 20 HP, with plate voltages under 480 V. The modulation frequency was lower than 20 kHz.

Maximum inverter output frequency in square wave mode can reach up to 10 kHz; practical output frequency with wave form modulation will be limited to 200 Hz to avoid timing problems in the control stages.

Minimum inverter output frequency is not limited by the inverter hardware; DC component can be injected in the output if required for test purposes.

In the first version, no snubber circuits were incorporated; but it was possible to include different classical and loss-less snubber circuits to test the system performance with each configuration as required.

In each converter the drive circuits were implemented with three IHD280 integrated modules from Concept. Rated input voltage was 15 V, output drive current was 200 mA and power consumption was less than 2 W. The on and off delay times were under 60 ns. The drive circuits were mounted very close to the power circuits (less than 10 cm) to minimize noise influence. Protection circuits between each driver module and the IGBTs gate terminals were included, following the manufacturer recommendations.

- Instrumentation stage

Voltage and current measurements had to be performed to obtain data for implementing a wide range of control techniques. On the other hand, speed measurements had to be performed with the highest possible accuracy to validate sensorless speed measurement techniques that were being studied. All the required measurements were carried out in the instrumentation stage. The only used variable that can not be directly measured by Plataforma is Torque. This variable can be estimated by space vector calculation.

- Voltage and current measurements

Instrumentation cards were designed for measuring two voltages and three currents at the transformer primary and secondary terminals, three currents at the inverter output, and the DC link voltage and current. Voltage (LEM LV-25-P) and current (LEM LA-55-P/SPI) Hall effect sensors were used in these cards. Figure 2 shows the Hall effect transducers' equivalent circuit. The voltage sensors can

measure up to 500 V_{rms} at 8 kHz, with ±0.05% precision, and a delay time less than 3 μs. The current sensors can measure up to 50 A at 150 kHz. These sensors provided isolated measurements from the power stage.
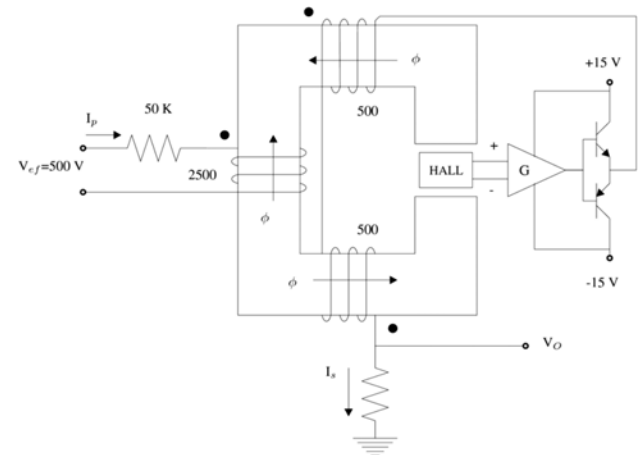

Figure 2. Hall effect transducer circuit.

- Data acquisition system

All analog to digital conversions were performed by a data acquisition card (PC-30F/S) with 16 12-bit channels, sampling at 330 kHz. It also had three 8-bits bi-directional digital channels. This card could be programmed using high level languages (C++, Visual Basic, etc). It was possible to set each input gain independently. Data acquisition was performed using DMA interrupts. Input signals could have peak values up to ±10 V. In this Plataforma, the control algorithm was executed in a personal computer (PC) and the programming was implemented in Borland C++ V 4.5. All the inputs were sampled every 100 μs.

- Speed measurement

Speed measurements were performed by counting the pulses from an incremental optical encoder with 1,000 pulses per cycle. This encoder was mechanically coupled to the machine axis. The pulse train produced in the encoder output was processed by a dedicated conversion circuit, that included a frequency divider (LM74193), a Programmable Logic Device (PLD model LATTICE1016), a Gate Array Logic (GAL 22V10) and a 16 MHz clock. This circuit provided the speed information directly in the PC bus. Figure 3 presents the encoder and the dedicated conversion circuit board.

- The signal processing and control stage

All signal processing and control strategies were performed in a Pentium PC, 233 MHz, 32 MB RAM. The data acquisition and the speed measurement cards were inserted in the PC bus. The trigger signals for the IGBT drive circuits were sent via copper wire with the appropriate shielding to avoid EMI interference.
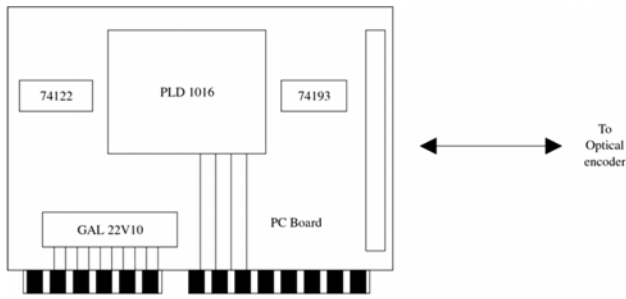
Figure 3. Encoder and the dedicated conversion circuit board.

Prototype assembly

Figure 4 shows a frontal view of the first Plataforma. This equipment was mounted in a standard industrial enclosure, which was very compact and useful in harsh environments.
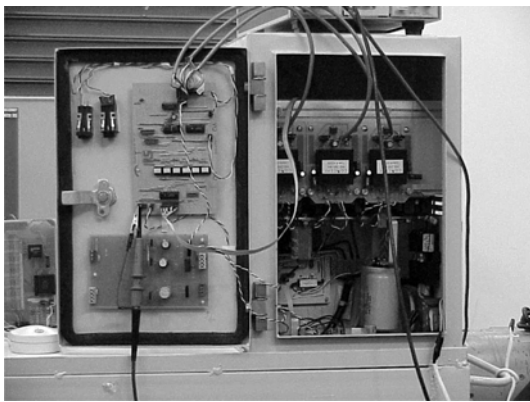

Figure 4. Frontal view of Plataforma I.

Software description

All the programs for data processing and control strategies were written in Borland C++ 4.5, employing a modular structure. As an example, figure 5 shows the program modules and their interconnections to perform a field oriented control of the induction machine. In this figure, the Main module initializes all the program parameters, while the Clock module handles the Clock interrupt, and enables the communication between the Data Acquisition Card and the PC through the Card module. The Euler module calculates the non-measurable variables (for example, inverter voltages) using the first-order Euler-forward integration method. The Control module calculates the current and torque values required in order to reach the desired operation point. The Inverter module determines the firing sequences for all the IGBTs, and the IN/OUT module generates the information displayed in the PC screen. Additionally, the SIN/COS module calculates the sine and cosine values for the angles between 0 and 2δ with three decimals precision, and the Global module contains the variable definitions required for all the modules.
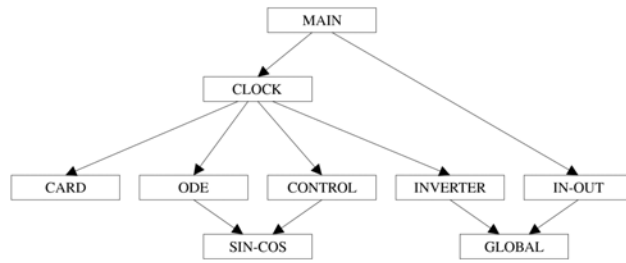

Figure 5. Program structure

PLATAFORMA II

The most critical limitation of the first Plataforma was its processing speed, limited by the PC operation speed. To overcome this limitation, the first system modification was to include an external digital signal processor (DSP) as the processing unit, leaving the PC for off-line tasks: DSP programming, system supervision and presentation tasks.

Additionally, as mentioned before, the first Plataforma was mounted inside a standard industrial enclosure, which was very compact and useful in harsh environments, but access to the circuitry was very limited, making the connection of new test points a long and complex task, which is a very important limitation when performing teaching and research tasks.

Therefore, a new design was produced (Giménez *et al*. 2000), with a better modular layout and an improved signal processing and control stage. This second model, Plataforma II, was used to test the possibilities of the controlled rectifier using vector control techniques to correct the input power factor, and to analyze induction machines and permanent magnet motors behavior under Field Oriented Method and Direct Torque Control techniques, among other applications.

Hardware Description

Figure 6 presents the block diagram of Plataforma II. Heavy lines connect the blocks in the power stage, and fine lines connect the blocks in the instrumentation and control stages. The most significant difference with Plataforma I at this block diagram level is the inclusion of the new DSP-based control.

The power stage

As in Plataforma I, the power stage includes two fully-controlled power converters with one converter working as a switched rectifier and the other as an inverter and a DC-link passive filter (an AC side three-phase passive filter is optional). The converters were designed using the same power devices and H31 heat sinks with forced-air cooling in their bases. However, one important modification introduced in Plataforma II is that each heat sink is not enclosed in an
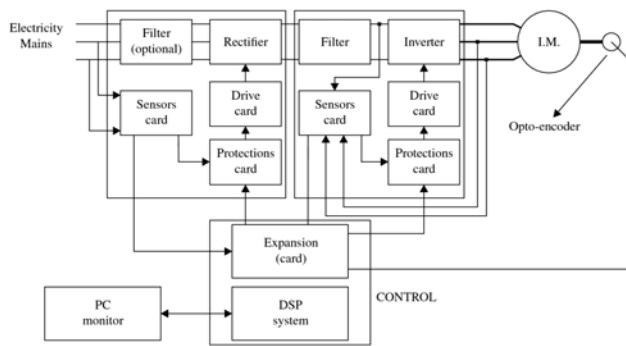
Figure 6. Plataforma II block diagram.

industrial cabinet, but is let free-standing and it is used to support three circuit cards (the Drive Circuits Card, the Sensors Card and the Protection card, described below) in the three sides that are not used by the power devices.

This free-standing circuit array, presented in figure 7, is known as a monolite. Therefore, each monolite includes all the power and auxiliary circuitry cards required by one converter, enhancing the system modularity. Additionally, some monolites are provided with a rectifier (a three phase non-controlled diode rectifier in a powerblock case), mounted alongside the IGBT modules. One of these enhanced
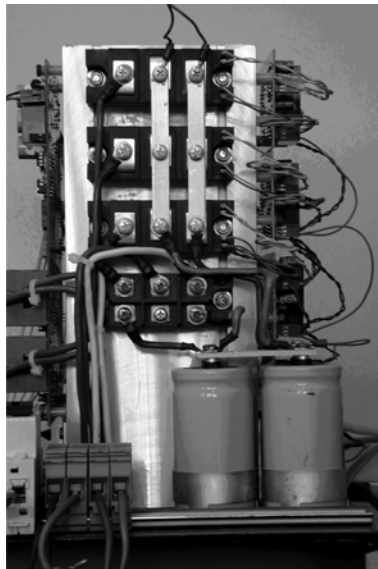

**Figure 7.** Monolite with three IGBT modules and a non-controlled rectifier.

monolites can be used in those applications that do not require a controlled rectifier. When a monolite with uncotrolled rectifier is used for driving a regenerating load, a resistive branch is connected in parallel to the DC link using an additional IGBT.

As in Plataforma I, the drive circuits in each converter were implemented with three IHD280 integrate modules from CONCEPT. These modules and the required auxiliary circuits
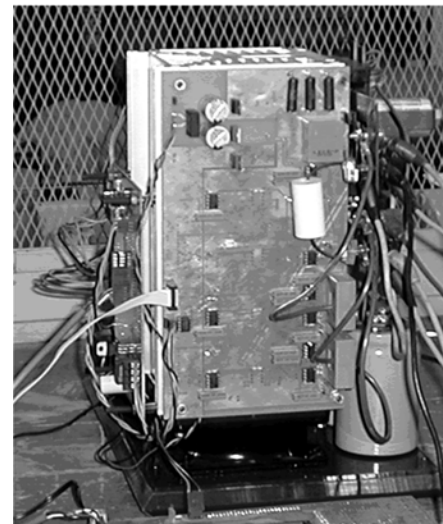
were mounted in the Drive Circuits Card, which is attached on face 2 of the heat sink, as shown in figure 8(a).
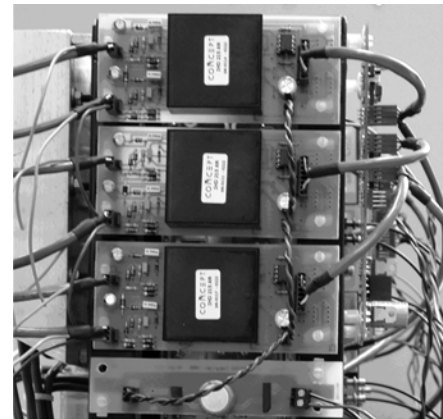
a). Drive circuits card in the monolite.
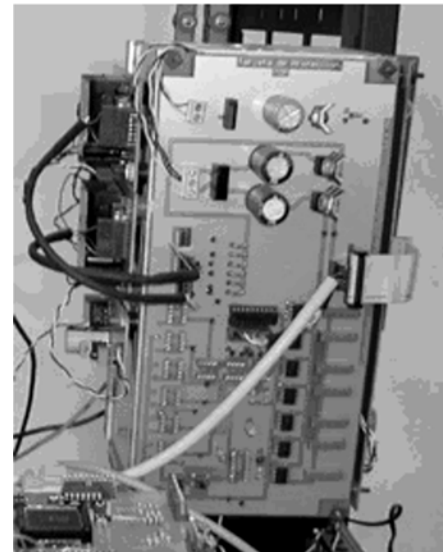
b). Protection card in the monolite.

c). Sensor card in the monolite.

Figure 8. Monolite card

95

- The Instrumentation stage

The Protection Card receive the control system firing orders and combine them with the alarm signals produced in the Sensors Card (described below), in order to apply the fire signals to the IGBT when appropriate. This card is mounted over face 3 of the heat sink, as shown in figure 8(b).

For Plataforma II, a Sensor Card was designed with two Hall effect current sensors, one Hall effect voltage sensor connected directly over the DC bus, and the circuitry for another Hall effect voltage sensor, to be connected when required. All the Hall effect sensors are similar to those employed in Plataforma I. This card is mounted over face 4 of the heat sink, as shown in figure 8(c).

- The Control stage

The DSP processing unit used in this work was the EZ-KIT evaluation unit for the SHARC DSP processor (ADSP-21061). This card was connected to the PC through the serial port. The connection between this card and the inverter system was performed through a specially designed Expansion Card (Restrepo *et al*. 1999) described below. A library of functions was developed for communicating the personal computer with the DSP board.

The Expansion Card, whose block diagram is shown in figure 9, was designed to complement the DSP card in the motor control tasks, and it was connected piggy-back on the EZ-KIT card. In the Expansion Card, a motion coprocessor, ADMC-201, performs most of the power related tasks (Analog Devices, 1995), and it is used to reduce the number of components in the card.
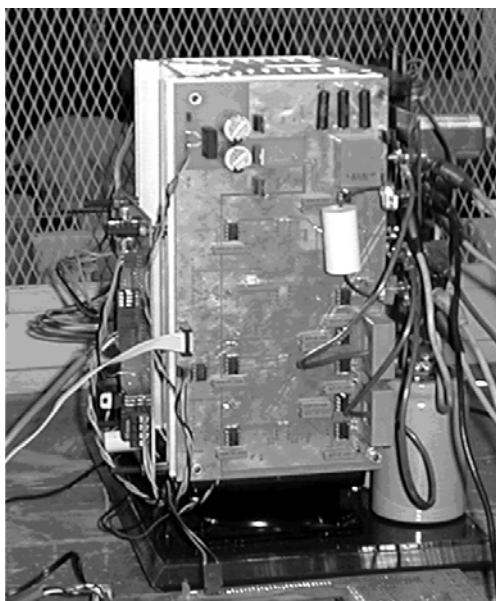

Figure 9. Expansion card block diagram.

The motion coprocessor is composed of several blocks. A vector transformation block performs the forward and reverse Clark and Park transformations, and the PWM timer block performs several of the tasks involved in the generation of pulses for the voltage source inverter. The analogue to digital block consists of an 11-bits A/D converter, fed from four simultaneously sampled inputs, and four-multiplexed channels extension. This coprocessor also includes a six bits fully programmable I/O port.

A FPGA (ISP-1016) was used for mapping in memory space the different devices in the Expansion Card and for implementing a digital counter, included for use in those applications that require direct machine speed measurements.

The PC was used to develop the software to be run in the DSP, and to supervise the Plataforma system during normal operation. The DSP board contains a communications kernel for transferring and receiving information from the PC.

Prototype assembly

Figure 10 shows a test system which includes a monolite module used as a Rectifier Bridge, and the control stage composed by the DSP in the EZ-KIT card with the Extension Card over it, surrounded by the oscilloscope and the current probes connected to it.
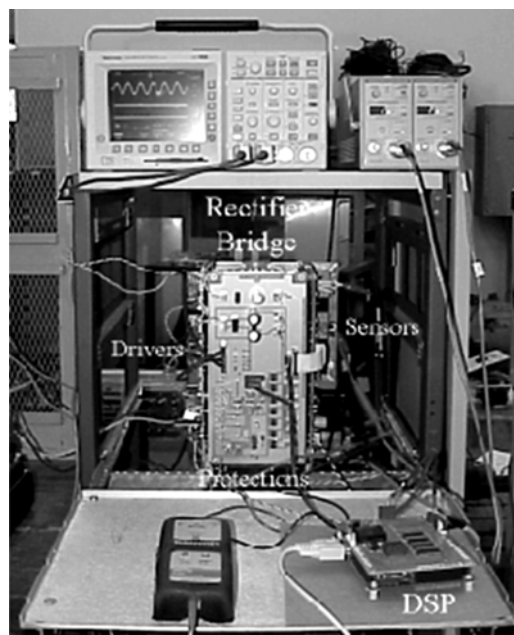

Figure 10. Plataforma II assembly

Software description

A virtual instrument implemented using the Lab-Windows CVI programming environment allows the user to visualize

in real time the system operation and to change the value of the different control variables. A graphic interface shows the user the control algorithm being executed by the DSP. It also allows the storage in disk of different variables. The main tasks of the supervisory system were:

a) Man machine interface.
b) Downloading the control algorithms to the DSP board.
c) Start and stop the AC machine.
d) Gathering and control of the machine speed.
e) Visualize and saving to disk different control variables.

Figures 11 and 12 show two examples of the program interface in use in scalar and space vector controllers respectively.
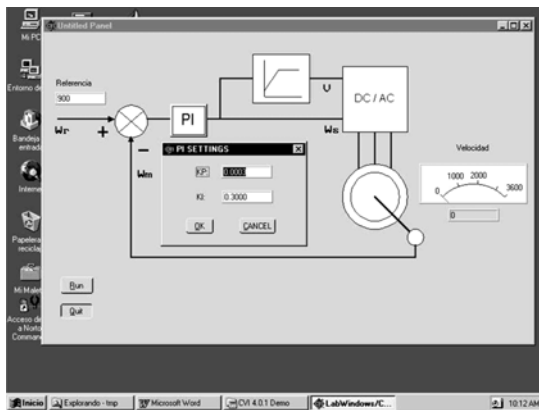

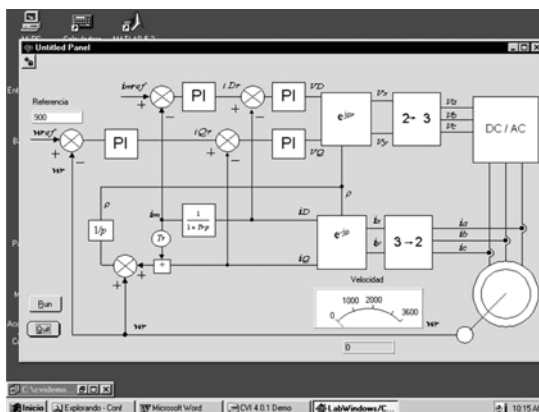**Figure 11.** Scalar controller windows interface.

Figure 12. Space vector controller windows interface.

Experimental tests

Plataforma performs all the voltage, current and speed measurements required to characterize and control the electric machine or the electric power system. Nevertheless, in order to validate the results provided by the test rig, all the relevant measurement were also made using up to date laboratory equipment such us high frequency Tektronix digital scopes, Fluke power quality analyzers, differential high voltage probes, digital frequency counters and Hall Effect current probes.

Some typical control algorithms, ranging from standard scalar control to the more complex vector control were employed for testing the Plataforma II.

For example, figure 13 is the phase current waveform of an AC motor controlled using the Direct Torque Control strategy (DTC), without mechanical speed sensors, when the load motor is reduced using a mechanical brake, while figure 14 shows the current and voltage waveforms in one of the phases of a controlled rectifier bridge employed as an active filter with vector control.

Other applications of Plataforma II are reported in (Pagá *et al*. 2000) and (Restrepo *et al*. 2000). These results show that Plataforma II was a flexible system easily adapted to new control algorithms, being useful in training undergraduate and graduate electrical engineering students, as well as in research activities.
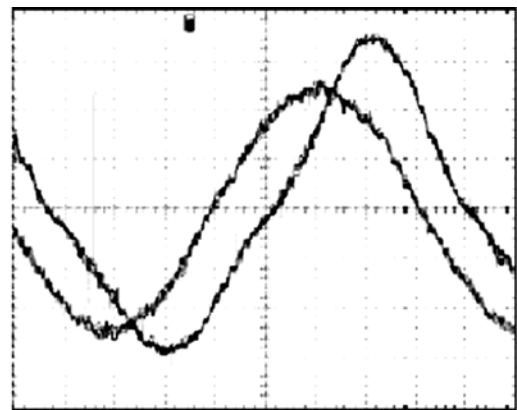

Figure 13. AC motor current during load reduction. Horizontal axis=50ms/div; Vertical axis= 5A/div.
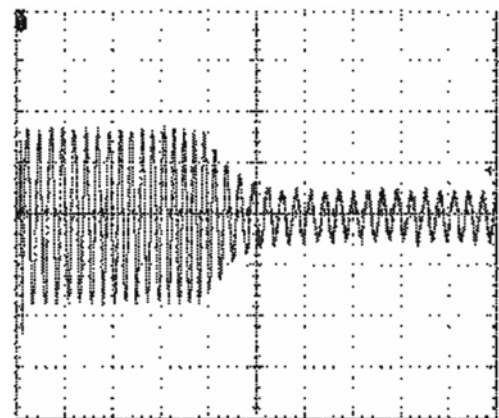

Figure 14. Current and voltage waveforms in one of the phases of a controlled rectifier bridge employed as an active filter with vector control capacitive response. Horizontal axis = 2ms/div. Voltage vertical axis = 50 v/div. Current vertical axis = 5 A/div.

PLATAFORMA III

Several tests with Plataforma II showed that it was necessary to improve this system in the following aspects: First, to get a better acquisition system with lower noise. Second, to develop new tools for controlling the complete system. Third, to incorporate a dynamic load emulator. The next sections present a detailed description of the designed improvements, which gave birth to Plataforma III.

Hardware Description

Figure 15 shows the Plataforma III block diagram. Heavy lines connect the blocks in the power stage, and fine lines connect the blocks in the instrumentation and control stages. The most significant difference with Plataforma II at this block diagram level is the inclusion of the DC motor with the chopper control in order to produce the dynamic load emulator.
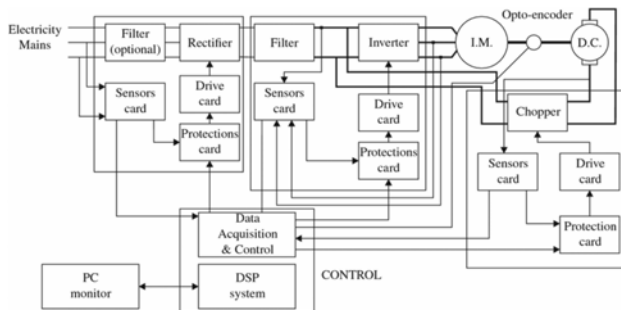

Figure 15. Plataforma III block diagram.

The Power Stage

In Plataforma III this stage includes three main active blocks: The controlled rectifier, the inverter for driving the AC motor and the chopper for driving the DC motor used as the dynamic load. The two passive blocks are the DC-link filter (always present) and the AC-line input filter (optional).

To ensure modularity, the same monolite is used in the three active power blocks, mainly implemented with the same components used in Plataforma II. The IGBT modules have been changed to the (PONER EL NUEVO NUMERO) which is the current version in the market.

In the chopper block, a single-phase full-bridge configuration is used, which is actually a standard Rectifier/Inverter block (Monolite) with one dual IGBT module and its drive circuit omitted. Up to this version, no snubber circuits have been incorporated, but it is possible to include different classical and loss-less snubber circuits to test the system performance with each configuration.

For lower power applications, where the IGBTs are going to work well below their rated current, a simpler monolite has

been designed, which is mounted in a lighter metal structure with the same physical dimensions that the H31 heatsink. Therefore, the users can choose between two structures, depending on the type of experiments the have to carry on.

The Instrumentation Stage

In order to reduce the noise in all measurements, it was decided to perform the analog to digital conversion of the measured signals in the Sensors Card, and to pass the digital signals from one card to another though plastic fiber. Therefore, a new Sensors Card was designed, including the two Hall effect current sensors (LEM LA-55-P/SPI), the Hall effect voltage sensor (LEM LV-25-P), and the circuitry for the DC bus voltage sensor (which is physically installed over the DC bus).

Additionally, a A/D conversion circuit for each sensor was implemented in the new Sensors Card. Each conversion circuit includes an amplification stage, two comparators to define the protection limits, and the analog to digital converter, whose output goes to the corresponding plastic fiber transmitter. The signal, once converted to digital form, is transmitted serially to the Data Acquisition and Control card, via plastic fiber. For proper operation, the analog to digital converters require two signals, the clock and the conversion initialization, which come from the Data Acquisition and Control card through two plastic fibers, whose receivers are located in the upper part of the sensors card. The modified Sensors Card block diagram is presented in Figure 16(a). Figure 16(b) shows a photograph of the new Sensors card. The two current sensors can be seen at the card's upper right hand corner, the voltage sensor is at the upper left hand corner. The plastic fiber receivers and emitters can be seen in the lower card's edge.

- **The Control Stage**

The Expansion Card designed for Plataforma II was replaced by the new Data Acquisition and Control Card. This card incorporates the plastic fiber transmitters and receivers required for connection with the new Sensors cards. To ensure backward compatibility, it also keeps the option based on the motion coprocessor (ADMC201), which makes it able to receive the already converted voltage and current signals, and pass them to the DSP, if the new Data Acquisition and Control Card is used with the old Sensors cards. The motion coprocessor is connected to a PWM generator, a seven input channel connector and a six bits I/O port for the IGBT control signals. The Data Acquisition and Control Card also holds two FPGA circuits. FPGA 1 is dedicated to speed measurements and it operates only when a encoder-type speed sensor is used, while FPGA 2 processes the serial incoming signals from the A/D converters in the sensors cards, converting them from serial to parallel, in order to pass them to the DSP, and also controls the clock and the
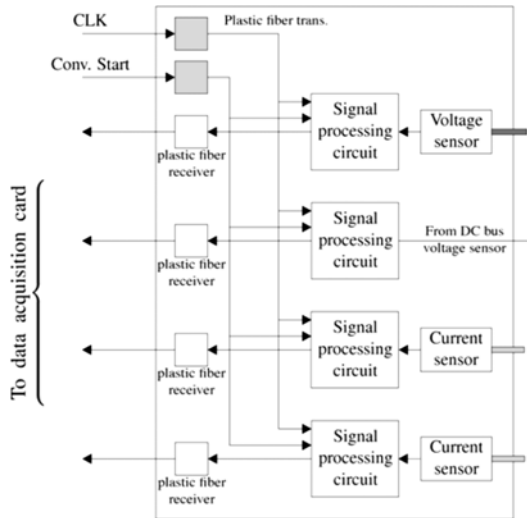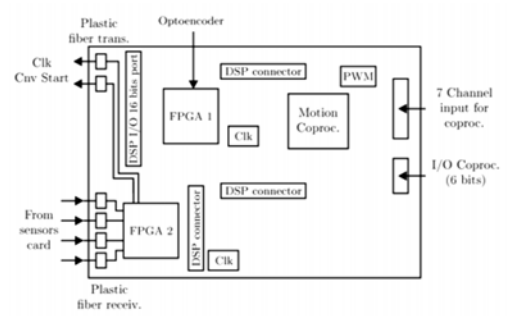
a) Block diagram
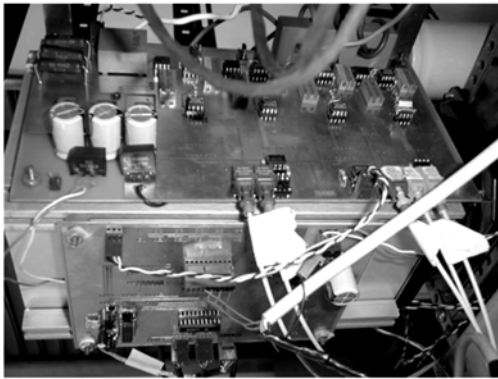
b) Picture

Figure 16. New sensors card.

a) Block diagram.

b) Picture.

Figure 17. Data acquisition and control card.

a) Front view.

b) Rear view.

Figure 18. Plataforma III assembly.

initialization signal that must be sent to the sensors cards, for the analog to digital converters. Three connectors located in the card's lower surface link this card with the DSP card.
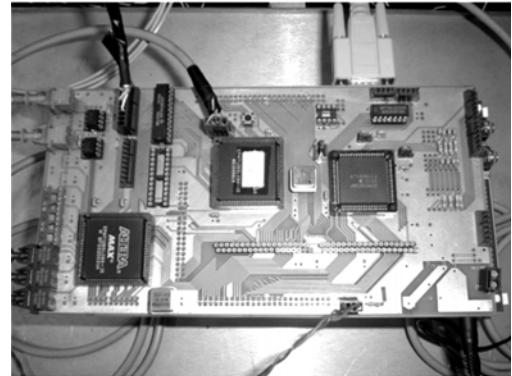
Figure 17(a) shows the new Data Acquisition and Control card block diagram, while Figure 17(b) presents a picture of this card. The plastic fiber receivers and emitters can be seen in the left card's edge.

Prototype assembly

Figure 18(a) presents Plataforma III in frontal view, in an high power application (Monolites assembled over the H31 heatsinks) where two monolites are being used, showing the Protection Card on the left hand monolite and the Sensors Card on the right hand one. The Control system, with the Data Acquisition and Control Card over the DSP card, is shown on the front. Figure 18(b) presents the assembly in a rear view, showing that the left hand monolite is a Chopper with two IGBT modules, while the right hand one is an Inverter with three IGBTs modules. The DC link filter is also shown.
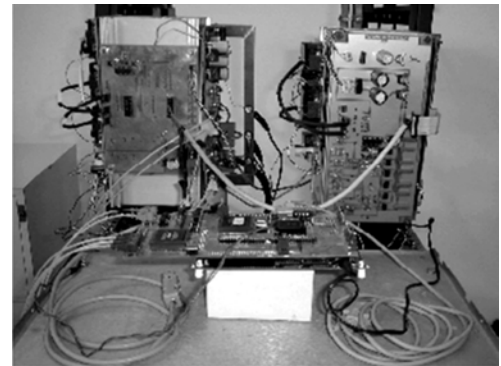
Software description

One of the new programming aspects of Plataforma III is related to the implementation of a dynamic load system using a torque controlled DC motor. The DC motor's torque is controlled as a function of the shaft speed, in order to provide the AC motor with a shaft load that has the torque/speed characteristic of the mechanical load that is being emulated in the test. This new feature will make possible to study the converter-motor dynamic system behavior using new control strategies under any type of load conditions, including time changing loads. The basic routines for controlling the DC motor torque have been programmed following the procedure shown in figure 19.

Experimental tests

In order to test the new Sensor card and the Data Acquisition and Control card designed for Plataforma III, a delta control technique was programmed in the DSP, and current measurements were performed with both the coprocessor module in the Expansion Card of Plataforma II and the new card. Figure 20 presents two AC induction motor phase currents, directly measured with a 500 MHz digital oscilloscope (Tek. TDS3054, 2GS/s) using a Hall effect current probe. The commutation band defined by the delta modulation can be clearly observed in this figure.
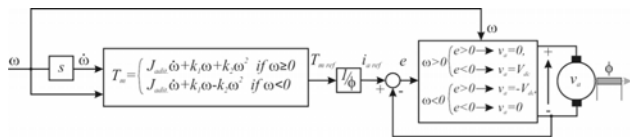

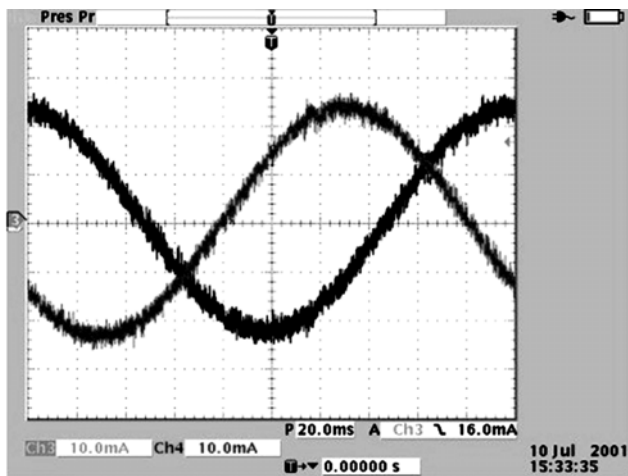**Figure 19**. Control strategy for the dynamic load.

Figure 20. AC induction motor phase currents.

Figure 21(a) shows the currents sensed with the Hall effect sensors, just before the A/D converters as measured in Plataforma II Sensors card while figure 21(b) presents the same

signals measured in Plataforma III Sensors card. As can be observed, both signals present the phase current switching between the prefixed limits, but the commutation band for the current in Plataforma II is broader than in Plataforma III due to noise effects, because in the first case, the measured signal had to travel from the Sensor card to the Expansion card to be converted in a digital signal, while in the second case the A/D converter is right behind the sensor output.
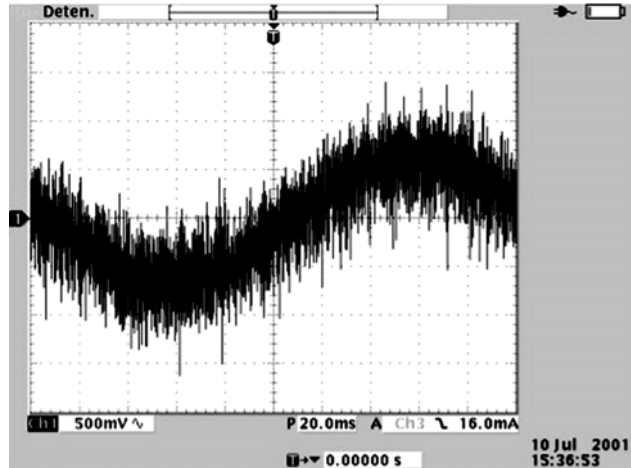
a) Plataforma II, wire connection.
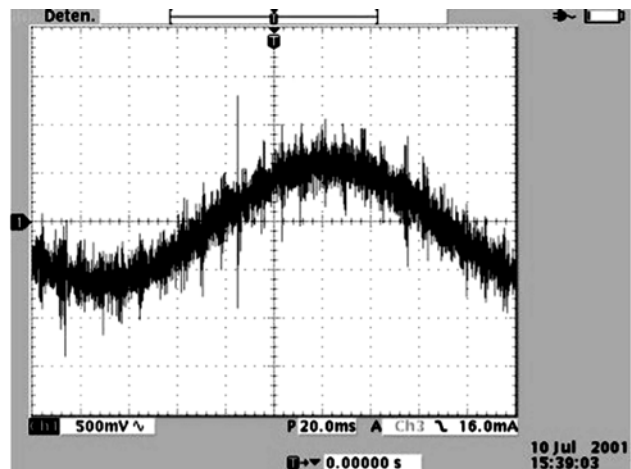
b) Plataforma III, plastic fiber connection.

Figure 21. Phase currents measured with the Hall effect sensors.

Figure 22 presents the phase currents acquired by the DSP systems for the two versions of Plataforma. The waveforms for Plataforma III are closer to the actual current waveforms presented in figure 20. This accuracy is a crucial point for a Test System, when a new strategy must be validated. The acquisition with the second version looks «cleaner», which means that it has lost part of the phase current information (the commutation band), giving less reliable results than those obtained with Plataforma III.

100

PLATAFORMA APPLICATIONS AND NEW DEVELOPMENTS

Plataforma III has been extensively used by the Power Electronics and Industrial Group of the Simón Bolivar University, to perform many different control strategies including space vector control, neural network control, DTC, PWM modulation, delta-modulation, mains harmonic reduction, on line parametric estimation, and sensorless speed measurement (Pagá *et al*. 2000; Restrepo *et al*. 2000; Pagá *et al*. 2000; Millán *et al*. 2003; Millán *et al*. 2004; Restrepo *et al*. 2005; Ortega *et al*. 2005; Viola *et al*. 2006). Figure 23 shows the complete arrangement from one of the laboratory tests carried out with PLATAFORMA in the GSIEP laboratory. Changing the control strategy in this Test System just implies writing a new subroutine set for the DSP. Usually no major changes in the hardware layout will be necessary. The versatility, reliability and precision of this Test System make it a very convenient resource for researchers and post-graduate students, especially with the last tools to facilitate the programming work.

Due to the fast development of DSP systems, the one employed in Plataforma III is becoming obsolete. Therefore, new work is being carried out to design a new Control Stage with a higher processing power DSP, the ADSP-21369 able to perform two GFLOPS when operating at 333 MHz. Additionally a Field Programmable Gate Array is connected to the processor, so that some math intensive operations can be performed in hardware. All this work will lead to an upgraded version of Plataforma.

CONCLUSIONS

Plataforma is versatile and modular test system for power electronics and industrial system applications. Its development has been an evolutive one and the present stage incorporate enhancement produced in a 10 years span. The use of Plataforma greatly reduces the effort and time required to develop and test new strategies, controls and applications in motor control and power electronics fields. Plataforma has been used successfully in most works performed by the SIEP group including at least ten Ph.D. and M.Sc. dissertations and more than 50 conference and transactions papers. In teaching application Plataforma is been used for support in four subjects in the M.Sc. and Ph.D. programs at the Simón Bolívar University. And finally Plataforma has been adopted by a research group in Power Electronic at Carabobo University. New Plataforma stage is been develop using the same overall architecture, incorporating more powerful and faster A/D converters, FPGAs and DSPs, and more available and less expensive IGBT drives.

REFERENCES

ALLER, J. M. (1996). *Simple matrix method to introduce spatial vector transformation and oriented field equations in electric machine courses.* International Conference on Electrical Machines. *ICEM´96*. Vigo, Spain. III; 519-524.

ANALOG DEVICES. (1995). *Datasheet for the ADMC-201* motion coprocessor.

BAUER, P. & KOLAR, J. (2001). *Teaching power electronics in 21 Century*. *EPE Conference*, Graz.

BOSE, B. K. (1996) *Power Electronics and Variable Frequency Drives*. Technology and Applications, IEEE Press, New York (USA).

BUENO, A & J. M. ALLER. (1996). *Adaptive control of induction machine by oriented field using neural networks*. International Conference on Electrical Machines. *ICEM´96*. Vigo, Spain, 2, 223-228.

CABELLO, A., RESTREPO, J.A., GUZMÁN, V.M., GIMÉNEZ, M.I., LARA, J. (2006). *Direct torque control for the switched reluctance machine using a variable structure fuzzy controller.* Proccedings of the 41st. International Universities Power Engineering Conference, CD 1-5.

GIMÉNEZ M. I., ALLER, J.M., QUINTERO, F., GUZMÁN, V.M., RESTREPO, J.A. (1999). *An integrated test system for AC machine drives performance analysis*. Proceedings of the 8th European Conference on Power Electronic and Applications EPE'99, Lausanne, Switzerland. CD, paper 799.

GIMÉNEZ, M.I., RESTREPO, J.A., GUZMÁN, V.M., ALLER, J.M., BUENO, A. (2000). *Plataforma II: Un sistema integrado de pruebas para el análisis del rendimiento de las estrategias de control de motores*. Seminario Anual de Automática, Electrónica Industrial e Instrumentación SAAEI-*2000*, 259-262.

GIMÉNEZ, M.I., RESTREPO, J, MILLÁN, A., GUZMÁN, V., VIOLA, J., ALLER, J.M., BUENO, A. (2004). *Nuevos desarrollos para*

el sistema Plataforma III. Memorias del IV Congreso Venezolano de Ingeniería Eléctrica, CVIE 2004, 2, 475 – 480.

HEDLEY, M & BARRIE, S. (1998). *An undergrauate microcontroller systems laboratory*. IEEE Transactions on Education, 41(4).

KARADZINOV, L. V., D•EKOV, T.A., HAMILL, D.C. (2001). *Development of advanced courses on power electronics*. EPE Conference, Graz.

LENTIJO, S., MONTI, A., SANTI, E., WELCH, C., DOUGAL, R. (2003). *A New Testing Tool For Power Electronic Digital Control*. PESC Conference 2003, Columbia (USA).

MILLÁN, A., RESTREPO, J., GUZMÁN, V.M. GIMÉNEZ, M.I. (2003). *Rectificador PWM regenerativo con control de corriente neuronal y factor de potencia unitario*. Semanario Anual de Automática, Electrónica Industrial e Instrumentación SAAEI-2003, CD SO37ffvA 1-6.

MILLÁN, A., RESTREPO, J., GIMÉNEZ, M.I., GUZMÁN, V.M., VIOLA, J.C. (2004). *Determinación de los parámetros mecánicos de una máquina de inducción mediante mediciones en una máquina de corriente contínua acoplada a su eje*. Memorias del IV Congreso Venezolano de Ingeniería Eléctrica, CVIE 2004, 1, 418.

PAGÁ, T., BUENO, A., GIMÉNEZ, M.I., RESTREPO, J.A., GUZMÁN, V.M., & ALLER, J.M. (2000). *Sensorless speed control of the induction machine combining field oriented method and DTC*. Procedings of the Third IEEE International Caracas Conference on Devices, Circuits and Systems, ICCDCS-2000, Cancun, Mexico, P79-1 - P79-6.

PAGÁ, T., PESSE, G., GIMÉNEZ, M.I., RESTREPO, J.A., GUZMÁN, V.M., & ALLER, J.M. (2000). *Improved development of an optimun current torque sensorless vector control for permanent magnet synchronous motors*. Proceedings of the 9th International Conference on Power Electronics and Motion Control EPE-PEMC 2000, 7,139-144.

REIMONDEZ, J.J., GIMÉNEZ, M.I., GUZMÁN, V.M., MONCADA, R., RESTREPO, J.A. (1997). *Speed and position control of brushless DC machine employing neural networks*. 7th European Conference on Power Electronics and Applications, EPE'97. Trondheim, Norway, 2, 465-470.

RESTREPO, J.A., PEREZ, T., GIMÉNEZ, M.I., GUZMÁN, V.M. (1997). *DSP implementation of AC-machine sensorless speed measurement system using the Wigner distribution*.

7th European Power Electronics and Applications. EPE'97. Trondheim, Norway. 4, 524-527.

RESTREPO, J.A., CABELLO, A., ALLER, J.M., GIMÉNEZ, M.I., GUZMÁN, V.M., BUENO, A. (1999). *A DSP system for generic power control applications*. Proceedings of the 34nd. Universities Power Engineering Conference UPEC'99. Leicester, U. K., 2, 612-615.

RESTREPO, J.A., ALLER, J.M., PAGA, T., BUENO, A., GIMÉNEZ, M.I., GUZMÁN, V.M. (2000). *Direct torque control of the induction machine using field oriented method and time frequency transformation for speed estimation and parameter adaptation»*. Proceedings of the International Conference on Electrical Machines ICEM 2000, 1105-1109.

RESTREPO, J.A., GIMÉNEZ, M.I., GUZMÁN, V.M., ALLER, J.M., BUENO, A., MILLÁN, A. (2002). *Platform III: A new version for the integrated test system for AC machine drives performance analysis*. Proceedings of the Fourth IEEE International Caracas Conference on Devices, Circuits and Systems, ICCDCS-2002, IO36-1 – I036-6.

RESTREPO, J.A., VIOLA, J.C., ORTEGA, M., GUZMÁN, V.M, GIMÉNEZ, M.I. (2005). *A fuzzy-PWM direct torque control of induction machines for current limitation and reduced torque ripple*. Proceedings of the 11th European Conference on Power Electronics and Applications, EPE 2005, CD.

ORTEGA, M. I., RESTREPO, J.A., VIOLA, J.C., GIMÉNEZ, M.I., & GUZMÁN, V.M. (2005). *Direct torque control of induction motors using fuzzy logic with current limitation*. Proceedings of the The 31st Annual Conference of the IEEE Industrial Electronics Society, IECON2005, CD.

SIERRA, A., S. COA, V. HORNEBO. (2004) *Diseño de prácticas para el laboratorio de protecciones eléctricas de la facultad de ingeniería de la universidad de Carabobo*. CVIE, Caracas (Venezuela).

VIOLA, J.C., RESTREPO, J.A., GUZMÁN, V.M., GIMÉNEZ, M.I. (2006) *Direct torque control of induction motors using a fuzzy inference system for reduced ripple torque and current limitation*. 12th International Power Electronics and Motion Control Conference, EPE-PEMC 2006, 1161-1166.