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PLATAFORMA: A Useful Tool for High Level Education, Research and Development

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***Abstract*—This work presents the PLATAFORMA system impact over the teaching and research activities of the lecturers and the post graduate students at Master and Doctorate levels working in the Power Electronics Industrial Systems group (Grupo de Sistemas Industriales de Electrónica de Potencia, SIEP) of the Universidad Simón Bolívar. PLATAFORMA is an integrated test system intended for experiments requiring validation of different types of new strategies and control schemes, based on vector control theories, parametric estimation, neural networks and fuzzy logic control systems, applied to machine drives, and it can be also used for analyzing the effect of these control strategies over the mains quality. The equipment includes driver power stages, an instrumentation stage and a signal processing and control stage. PLATAFORMA has eliminated most of the tedious work that every single researcher or post graduate student in the GSIEP group had to do in order to obtain experimental results, enhancing the quality of the thesis and papers produced by the group members.**

I. Introduction

From the point of view of 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 [1]. 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 [2].

To help students to fully understand and master this subject, it is necessary to include practical laboratory work [3], [4], [5], [6], [7]. 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 starts 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. [8], [9], [10]. 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 (Grupo de Sistemas Industriales y Electrónica de Potencia, 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 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 [11], [12], [13], [14], [15] through the years.

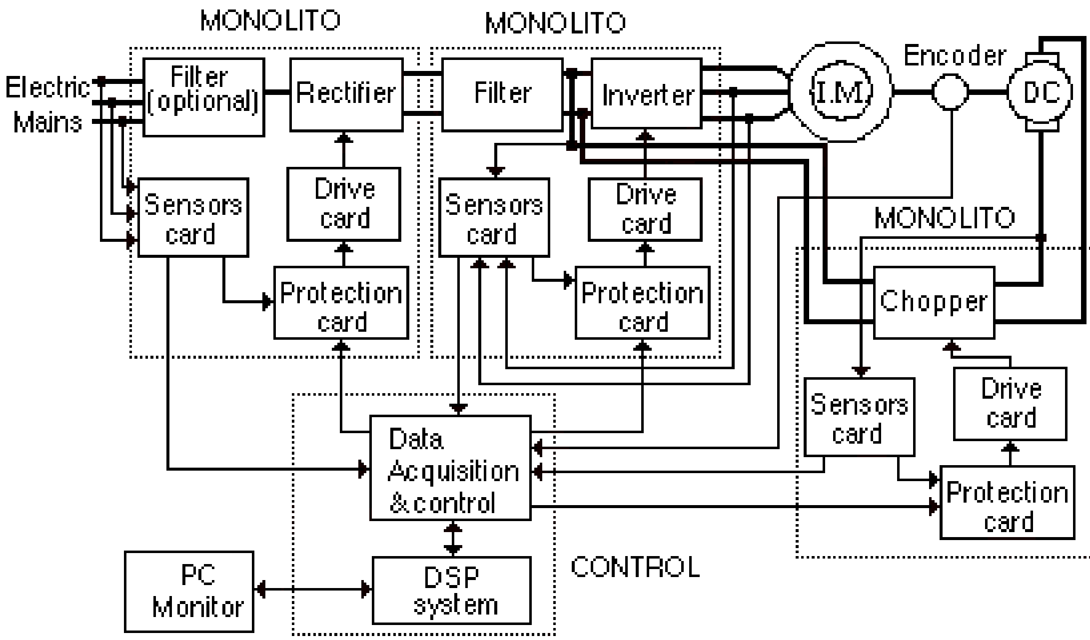

Fig. 1.- PLATAFORMA III Block Diagram.

This work includes a brief presentation of the last developed system, PLATAFORMA III and presents the big impact that this system has had over the teaching process for the Master, Doctorate and even under-graduate students in the GSIEP group.

II. PLATAFORMA III

A. The Power Stage

Fig. 1 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 Power 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).

Each power block is mounted over a free-standing H31 heat sink, which constitutes a MONOLITO. The power devices (IGBTs) are over one MONOLITO side, while the the Drive Circuits Card, the Sensors Card and the Protection card, are attached to the other three sides of the MONOLITO. Therefore, each MONOLITO includes all the power and auxiliary circuitry cards required by one converter, enhancing the system modularity. Additionally, some MONOLITOs 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 MONOLITOs can be used in those applications that do not require a controlled rectifier. When a MONOLITO 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.

For lower power applications, where the IGBTs are going to work well below their rated current, a simpler MONOLITO has been designed, which is mounted in a lighter metal structure with the same physical dimensions that the H31 heat sink. Therefore, the users can choose between two structures, depending on the type of experiments the have to carry on.

Each MONOLITO power circuitry is 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.

The drive circuits in each converter were implemented with three IHD280 integrated modules from CONCEPT. These modules and the required auxiliary circuits were mounted in the Drive Circuits Card.

Fig. 2.- PLATAFORMAIII assembly.

The Protection Card includes several logical circuits to avoid firing the two IGBTs in the same module.

In the chopper block, a single-phase full-bridge configuration is used, which is actually a standard Rectifier/Inverter block (MONOLITO) 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.

B. The Instrumentation Stage

In order to reduce the noise in all measurements, the analog to digital conversion of the measured signals is performed in the Sensors Card, and the digital signals are passed from one card to another though plastic fiber. Therefore, the Sensors Card includes the Hall effect current and voltage sensors, the circuitry for the DC bus voltage sensor (which is physically installed over the DC bus) plus a conversion circuit for each sensor with an amplification stage, two comparators to define the protection limits, and the analog to digital converter, whose output goes to 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.

C. The Signal and Control Stage

The Data Acquisition and Control Card incorporates plastic fiber transmitters and receivers required for conmunication with the new Sensors cards. It also has a motion coprocessor (ADMC201), which makes it able to receive voltage and current signals, and pass them to the DSP, if the card is used with Sensors cards from other PLATAFORMA versions. The motion coprocessor includes a PWM generator, a six A/D converter and a six bits I/O port for the IGBT control signals. The card also holds two FPGA circuits. FPGA 1 is dedicated to speed measurements and it operates only when the encoder 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 initialization signals 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.

D. Prototype assembly

Fig. 2 presents one application where two MONOLITOS are used, one as an inverter, to drive an AC induction motor (left) and the other as a chopper, to control the DC motor used as dynamical load (right). The inverter MONOLITO includes a non-controlled rectifier with six power diodes to rectify the three phase input signal. In this application, two MONOLITOs implemented with the lighter metal structure were chosen, instead of the H31 heatsink MONOLITOs because this is a low power test. The DSP and Data Acquisition and Control Card are over the lab table, connected to the two Sensor Card of both MONOLITOS (located in the left side of each MONOLITO, where the blue Hall Effects sensors can be observed) through plastic fiber connectors.

As can be observed, all the electric points are accessible for measurements with an oscilloscope. The measurements obtained by the Sensor Card are displayed in the PC and can be compared with the observed in the oscilloscope screen.

III. Plataforma iii in the MsC and PhD studies in Power Electronics

The MsC in Electronics Engineering Power Electronics option is a five term program, where each term is 12 weeks long and there are three terms per year. It includes 32 credits distributed between compulsory and elective subjets and a seminar, plus a thesis that is worth 12 credits. The Power Eectronics option core curriculum includes the following compulsory subjects: Electrical Machines, Power Electronics I, II and III, and Power Electronics Laboratories I and II. PLATAFORMA is being used in Power Electronics II and is the main issue in the Power Electronics Laboratories I and II.

One of the first term subjects is Electrical Machines, where simultaneously with the equation developments, the student has an introduction to simulated machine models and their main control strategies, developed in MATLAB.

On the other hand, the main purpose of the Power Electronics Laboratory I is the knowledge of PLATAFORMA hardware and basic software. Initialy the student becomes familiar with PLATAFORMA architecture, studies the DSP that controls all the system, and works using the adquisiton circuit, the PWM module and the I/O ports. The next assignements are the design of digital filters to process adquired signals, the use of interrupt signals and the development of machine models to simulate physical sytems that will be controlled in ulterior projects. The last assignement is a project where the student must apply the DC machine simulated in the DSP to design and implement an experimental control system, using all the PLATAFORMA capacities.

In Power Electronics II, with the study of each AC machine, new simulations are performed, this time in the PLATAFORMA DSP, programming it in C language. The first experience is the induction AC machine fed with sinusoidal signals, which will be used for comparison purposes when other input signals are applied. Next the same machine is fed with PWM signals and the corresponding comparisons are performed. Then, an open loop constant voltaje/frequency (V/f) controller is included in the simulations, and the main machine variables, torque, flux and speed are recorded using several inputs with diferent frequency vs. time slopes. Next, a close loop V/f control is applied, trying to keep constant slip, and analyzing the torque, the flux and the speed for each tested condition. The following experience is the AC induction machine vector control. The machine dynamics is analyzed, studying the related equations and a first open loop vector control is simulated. Results are compared with those produced by the simpler V/f control, and the vector control advantages are demostrated, specially in the flux and torque behaviour. Next, the Direct Torque Control (DTC) technique is applied, and again the torque and flux time functions are analyzed. Some modifications are included to limit the starting current maximun value. Finally, a final project is assigned to each student. Students grades are awarded on the basis of their simulations results and the final proyect performance, therefore PLATAFORMA, and particulary its DSP system, is fundamental in this theorical subject.

It is important to stress that PLATAFORMA, through the graphical presentations in the PC screen, is a very conveniet way to observe the internal variables dinamic evolution (for voltage, current, machine torque, rotor flux, machine speed) in all the AC induction machine control strategies (sinusoidal, PWM, open and close loop V/f, vector control and DTC). Therefore the student can become familiar with the diferent dynamic behaviours and can evaluate the different solutions convenience and complexity.

The Power Electronics Laboratory II makes intensive use of all PLATAFORMA components, in order to perform experimental work over all the control system strategies studied and simulated in Power Electronics II: sinusoidal input, PWM, open and close loop V/f, vector control and DTC.

Figure 3 shows an example of the results obtained by the students in one of the experimental works: the simulated torque under open loop V/f control for three different values of ramp-up frequency during start.

After this course, the students are ready to use PLATAFORMA in their own particular experiments to test the new systems that are developing as their Master or Doctoral thesis works. The SIEP group has graduated several Magister and Doctorate students that have worked with PLATAFORMA in their final proyects in one of two ways: Participating in the design of one of the three versions or using it to obtain their experimental results. Up to know, several papers and conference presentations have been published [16]-[37], reporting the different contributions that have been made. In some cases, parts of PLATAFORMA have been used as a basis to special developments for particular applications [26], [34]-[36].

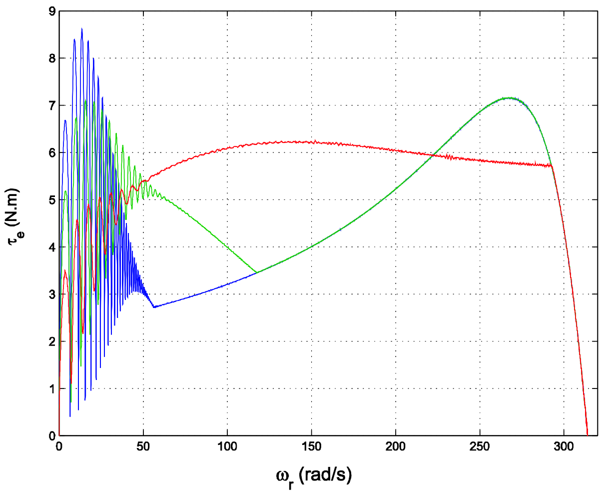

Fig. 3.- Example of a simulated torque under open loop V/f control for three different values of ramp-up frequency at start-up.

IV. Future work and Conclusions

A new DSP card is being used to design a more efficient control system, based on the ADSP-21369. Two Master students are performing this work, under the supervision of two lecturers. This work will be completed within a year, giving birth to PLATAFORMAIV.

As mentioned in the circuit description, no snubbers have been used up to now in PLATAFORMA, therefore there is still another area where new students can make their research.

PLATAFORMA has been a very useful tool to improve the SIEP group research work both in quantity and quality, as well to facilitate the teaching process in the Power Electronics field. Even a complete PLATAFORMA has been produced for another venezuelan university, helping in this way to improve their productivity.

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