DEVELOPMENT OF A DEDICATED SYSTEM OF DATA ACQUISITION FOR ALTERNATIVE SOURCES OF ENERGY

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Abstract – **This paper describes a new control and monitoring dedicated system to be applied in alternative energy sources as fuel cells, wind generators, photovoltaics and solar panels. The main goal of this project is the development of a controller, using the communication between personal computers and microcontrollers to bridge machine versus energy systems. The following characteristics were considered important: user friendly, low cost, versatility, adaptability, and easy installation and handling. A thorough discussion will be presented in this paper with fully detailed study.**

Keywords - **alternative sources of energy, signals processing, digital controller, energy quality control.**

I. INTRODUCTION

One of the characteristics of the alternative sources of energy is their interdisciplinary aspects, involving a wide spectrum of knowledge spreading from basic electronics, theory of information, statistics, civil engineering, chemistry up to great interactions between power generation and environment, power systems and distributed generation, quality and control. As a matter of fact, power electronics and digital controls have been permeating most of the applications in the current power control all over the world. In the case of energy systems, it was verified that power electronics and microprocessors are the prime motivation for their spectacular development in the last few years. As such, this area of knowledge in engineering became a border of performance and coexistence between engineers and technicians of huge power systems with tinny electronics in a very broad way. In this border of enormous differences, the engineering side demands a lot of versatility so that it can have a harmonic and productive understanding.

This paper intends to reduce the differences between these two specialties of engineering by proposing a dedicated data acquisition system aided by the personal computer parallel interface. As a result, it is expected that this system constitutes a simple, friendly and cockroach way of monitoring and controlling power converters and energy systems for distributed generation and injection of energy into the public grid. It is also intended to reduce costs of the monitoring and controlling systems allied with the ease implementation for alternative energy systems and energy processors.

Purchase and use of the available data acquisition boards in the market can be a reliable and fast option for the system designer. However, most of them are expensive, have closed platform and software, give generic resources and sometimes, they operate at relatively complex way. With dedicated software and hardware, the researchers in the area of power generation with alternative sources can have a monitoring option for systems without much additional costs. Obviously, all that is helpful if the application do not need such powerful equipment in terms of speed and amount of data processed.

In the case of energy sources with dc current output (as in the case of fuel cells, solar panels, batteries, etc.), it is necessary that the connection with the alternating current grid be made through autonomous inverters. Differently of the synchronous machines or induction generators, commonly used in small hydro and wind power systems, the autonomous inverters do not possess a natural synchronism between the active output power and frequency, nor between the output voltage and its reactive power needs. In the inverter connection to an infinite bar, for instance, it is necessary that these relations be processed by a control system in order to maintain a stable operation. Inverters usually present a PWM control system, where a sinusoidal reference of the voltage supplied to the controller is generated through signals with width and frequency defined by the grid. Through this control, the inverter can generate active power or absorb reactive power, according to the need [6]. To allow monitoring of these processes in real time by any engineer or designer, the CEEMA-UFSM group decided to implement their own energy dedicated controller. In this controller, a data acquisition plate (PAD) can receive signals from an externally conditioning power circuit, process them, and send them to the computer at a rate, at least, twice as high the largest frequency of interest in the controlled process [4]. This transfer rate is limited to a maximum limit of 77 kSamples/sec. The built-in hardware is based on a PIC microcontroller, model 18F452 which has an A/D converter with multiplexed inputs that allow alternate acquisition of up to eight channels. Obviously, the sampling rate of the external signals will fall as increases the number of used channels. The communication of the microcontroller PIC with the computer allows the voltage data acquisition or any other data such as current, power, temperature, pressure, gas flow, etc. once they are converted into voltage signals. Hence, it is possible for the system operator to monitor and interact with the process using a conventional computer with a language in which he/she is really acquainted to.

Monitoring and control systems can be clear when the PC-user interface is openly and graphically analyzed. This is made through a virtual instrument (VI) developed in LabVIEW™, looking at and filling the system with a simplified data manipulation.

The main characteristics of the dedicated board of data acquisition of the Federal University of Santa Maria (PADUFSM), can be summarized as follows:

a) to monitor and control alternative sources of energy with the possibility of data storage for subsequent analysis and documentation, and specific applications for researchers in control of energy systems. Its features can also be expanded for other purposes and even for commercial applications in energy.

b) easy making and implementation, low cost, dispenses the need for installation of additional drivers (plug & play system), versatility (portability), speed of performance, highly configurable according to the user's needs, simple manipulation of the acquired data, acquisition in real time and parts easily found in the Brazilian market and third world countries.

c) the total hardware cost of the interface developed for this project it is estimated in less than US$70.00.

II. ATTRIBUTES OF THE DEDICATED CONTROLLER FOR POWER CONVERTER CONTROL (PADUFSM)

The initial UFSM development proposal of the data acquisition plate was the construction of an instrument capable of acquiring and converting analog to digital signals, in real time. This process should rely on analog channels (such as voltage, current, power, water level, flux of gases, temperature and humidity, etc, once they are converted into a voltage signal). This information is stored in a computer able to control a PWM circuit from two different pins in the micro controller. This is done by a parallel port to communicate with the industrial process to be controlled, using the user's own language typical of the technical terminology in energy systems. By doing so, it is met desirable characteristics such as: data transmission speed compatible with the control signal frequency, low cost, friendly programming and little computing time required for its implementation.

Construction of the PADUFSM is possible with a microcontroller PIC, family 18F, universally well known or adapted to a similar chip. In this project, the model used in the development the PIC18F452. The main reasons are:

I) It possesses an A/D conversion module upgradable up to eight analog channels with a 10-bit resolution, with very short acquisition and conversion times. This feature allows, for instance, in photovoltaic based systems, the detection of polarity inversion in batteries, short circuits across the load, reversing current of cells, excessive charge/discharge of battery, excessive heat-sink temperature and temporary inversion of polarity.

II) Two PWM control modules can simultaneously control two output channels, with a maximum 10-bit resolution. Such function allows, for instance, easy voltage/current controls in loads connected to photovoltaic arrays.

III) Physically, PADUFSM has 33 I/O pins, eight analog inputs and two PWM controlled outputs [3]. This is the fastest popular microcontroller available in the market, running its internal clock up to 40 MHz.

Other factors, as a set of instructions to make possible a clearer and dry programming, a 32 kB program memory and 1536 Bytes data memory, enough to be adapted virtually for most of the purposes related to power electronics in alternative sources of energy. The board process data mode allows an independent communication with the microcomputer established by a bi-directional parallel port. The user interface through an VI (Virtual Instrument) was developed using the software LabVIEW™, version 7, that can be executed in any operating system of the Windows™ family beginning with Version 98 (98, NT, 2000, XP). Also, G (the programming language of LabVIEW™) is a graphic language using icons in place of text lines to create applications. In contrast with a textual programming, where the instructions must be precise for the correct execution of a program, LabVIEW™ uses a programming by data flow, where the flow of the available data determines the execution of the application. [1]

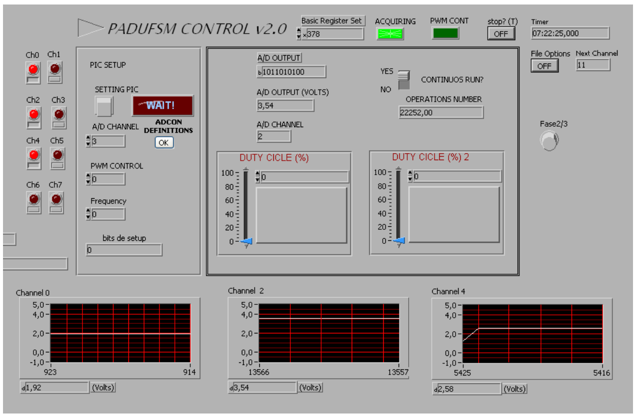

Fig. 1. Snapshot of the PADUFSM three sampling channels

In LabVIEW™ a user interface is built using a group of tools and objects. The user's interface is known as front panel. It is possible, then, to add codes using graphic representations of functions to control the objects of the front panel that are done in a block diagram. The application created in LabVIEW™ called Virtual Instrument (VI) (Figure 1) and, therefore, the files starting with *.vi or *.llb, if they are used, respectively, as a virtual instrument or a library for LabVIEW™.

Some characteristics of the VI used in the PADUFSM project are:

a - use of an open DLL (Dynamic Link Library) to promote the PC-PAD communication, functions tuned in with the communication protocol to ease the communication between LabVIEW™ and PIC. The commutation process between phases of execution is made by choice of the appropriate DLL function by LabVIEW;

b - some configurations are made when the VI starts, as in the case of the address value of the base register;

c - visualization of any one of the converted analog channels decided by the operator;

d - possibility of data saving of any of the A/D channels in an .xls or .txt file.

e - percent PWM control (%) of two independent PWM modules as in the PIC microcontroller;

f. - full functionality in most popular versions of the Windows operating system (98, 2000, XP, etc.);

g. - during initialization, VI creates, automatically, a directory in hard disk to save the acquired data.

III. COMMUNICATION PROTOCOLS BETWEEN SOFTWARE AND HARDWARE

Communication of PADUFSM is established with a bi-directional parallel port, quite common in personal computers, composed of three registers: (1) data register 378H (bi-directional), with 8 available bits, (2) status register 379H (data input) with 5 available bits and (3) control register 37AH (data output), with 4 available bits. As a data register is used for either PC data input or output, such configurations can be implemented as follows (Figures 2 and 3).

Communication between microcomputer (PC) and microcontroller (PIC) is an asynchronous parallel communication, because the execution times of the two units are not the same. This discrepancy may be solved by a peculiar communication protocol between the two devices.

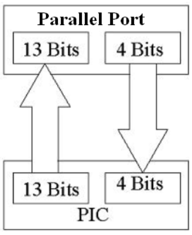

Fig. 2. Inputting data (13 Bits in and 4 out).

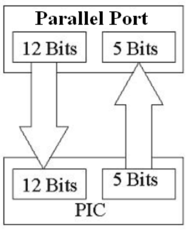

Fig. 3. Outputting data (12 Bits out and 5 in)

Communication between PC and PIC passes by three different phases: (1) PIC receives the user's configurations, (2) signal acquisition, in which PIC sends the A/D conversion results and (3) PWM controls, stage in which PIC receives the work cycle values for the PWM control. Figure 4 shows a diagram of phase 2 for data acquisition.

The conventional method of handshaking parallel communication has two fundamental bits of control - data valid (in which the generating entity of data tells that the data are available) and acknowledge (in which the receiving entity tells that the data were accepted). Besides that, there are other control and status bits, and eight bits of data. The number of bits required for data transfer between the PADUFSM execution phases is higher than eight bits. Such need is satisfied by the use of some control and status bits in the parallel port for data sending/receiving.

The configuration phase of the board (Figures 5 and 6), where PIC receives data, there will be two control bits corresponding to data valid and acknowledge, here called "stop bit" and "ready bit", being the other bits destined to send and receive data.

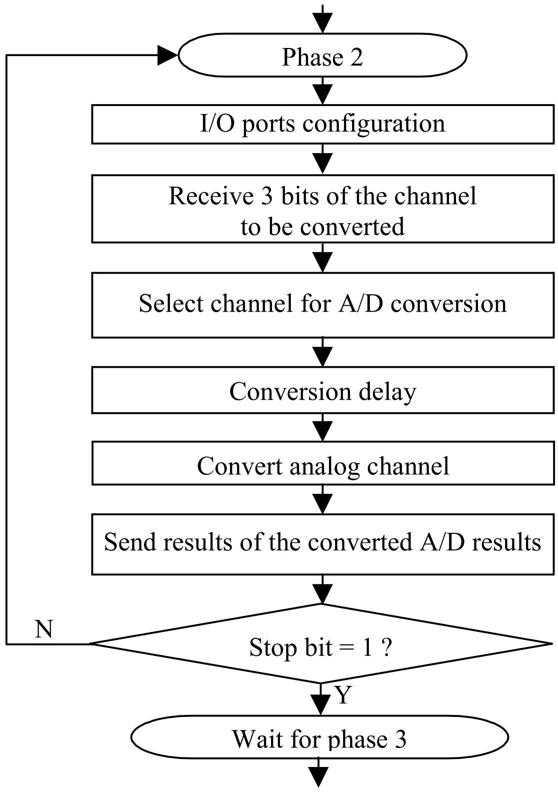

Fig. 4 Diagram blocks of phase 2

In the next execution phases (system acquiring data and accomplishing the action of a PWM control) there will be just the stop bit. PC will send this bit to PIC, telling when PC is ready to receive data (data acquisition) or informing that data are available to be read (PWM control). There is no need for additional status bits, knowing that the data transfer ratio by the parallel port is many times lower then the PIC transfer ratio, the synchronizing dynamics depends almost all on the parallel port response. The problem that would appear for the lack of a bit telling if data was transferred successfully (acknowledge), is compensated in these two execution phases by bits informing the analog channel being transferred (execution of the data acquisition) and actual PWM pin (when PWM control is being accomplished). Figures 6, 7 and 8 display the time diagrams for the developed communication protocols.

Equation 1 shows the maximum resolution (bits) for a given PWM frequency.

$$PWM_{(resolution(max))} = log\,\frac{\frac{F_{osc}}{F_{pwm}}}{log(2)} \cdot bits \qquad (1)$$

where:

F_{osc} – Internal clock

F_{pwr} – PWM frequency

$bits$ – duty cycle received from PC

Figure 5 shows the connections between parallel port and PIC microcontroller.

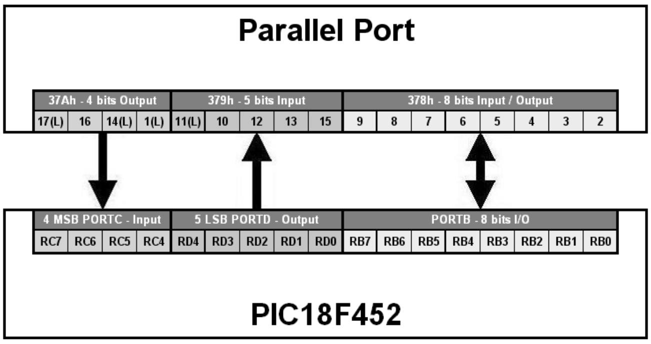

Fig. 5. PIC/Parallel Port Connection

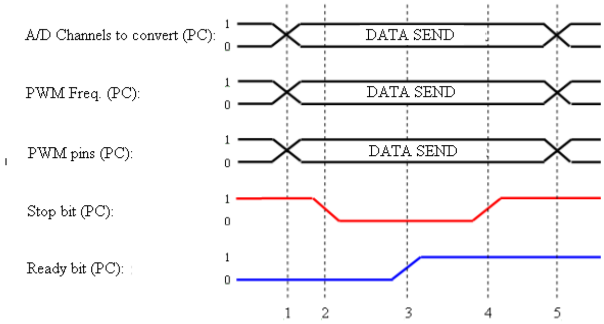

Fig. 6. Time diagram of the handshaking method for phase of configuration of the board

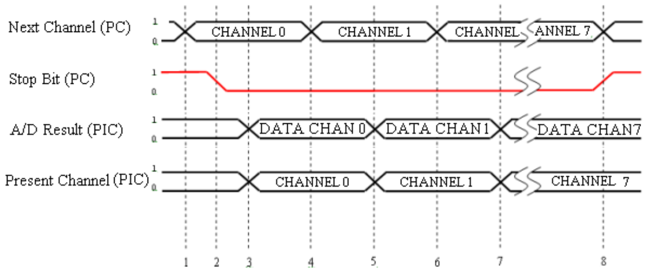

Fig. 7. Time diagram of the handshaking method for the signal acquisition phase

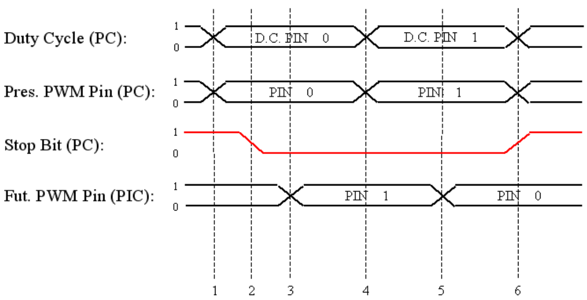

Fig. 8. Time diagram of the handshaking method for execution phase of the PWM control

A static calibration curve of the voltage range is presented in Figure 9. It was noticed only a slight shift in the calibration curve with respect to the origin in less than 2%. Such negligible discrepancy for the majority of the applications in energy systems could be improved by an increased number of bits.

IV. APPLICATION AREAS IN CEEMA

In the present socioeconomic context, investors are more concerned with the costs of new technological implementations than the possibility of power generation in a decentralized way. It is normally considered only independent operation and the conditions of direct connection to the distribution system. Of course, the initial investment return, in other words, the installed kVA cost should be obtained within the shortest period, so that the generation from a renewable source, independent of the concessionaire, start to be worthy.

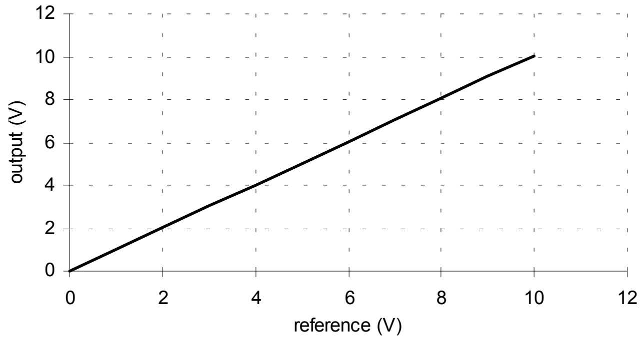

Fig. 9. Static calibration curve of the voltage range

The dedicated data acquisition interface here proposed is being used in CEEMA in the study of many types of alternative sources of energy, power electronics and digital control of processes. Among these, it can be pointed out: load controller, voltage and frequency in alternative energy sources, especially, for automation of fuel cells, wind energy, photovoltaic panels, and energy storage and processing. A static calibration curve of the voltage range is presented in Figure 4.

Refrigerating conditions should not be excessive or below certain values as specified by the manufacturers to avoid damages to any component of the fuel cell stack. PADUFSM is perfectly able to regulate (through PWM) the refrigeration system.

Another application is in the integration of energy systems constituted of wind generator, solar panel and battery bank controlled by a Hill Climbing Control (HCC). This algorithm searches for the maximum available power in each individual source. The acquisition board adapted for alternative sources of energy serves also for registration of the environmental variables and data reference for loading and stand-by conditions, making so, a reliable, robust and adaptable energy monitoring tool for integrated alternative sources.

V. CONCLUSION

Through tests in laboratory, PADUFSM carried out all functions for which it was programmed and developed.

Among these data acquisition facilities it may be mentioned the flexible programming of up to eight analog channels simultaneously, with any waveforms to a frequency of 20 kHz and point to point voltage levels between 0.3V and 5.3V. This fact becomes very important with regard to the active behavior of the primary sources for energy engineers and scientists, making easy modifications in the VI basic control algorithms. The PWM control made with the help of two pins to define the analog sampling channels, eases the PADUFSM application in activities of external variable control, as in the case of refrigeration of fuel cell stacks. The acquisition and storage of such data is made up to eight different analog channels in files *.xls or *.txt. The main features are:

a - high flexibility, due to several options available to the user and to the possibility of additional user programming created in LabVIEW^{TM};

b - capacity to accomplish up to 50.000 data transfer (reading/writing) between computer and microcontroller;

c - possibility of configuring the data acquisition hardware in PC with user pre-arranged configuring options. The characteristic of automatic configuration during the initialization period makes it very friendly being necessary to know only the number of variables to be acquired and if desired, what PWM action.

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