DEVELOPMENT OF DATA ACQUISITION SYSTEM FOR THE WATER-AIR LOOP OF THE CDTN THERMAL HYDRAULIC LABORATORY

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Abstract. The Water-Air Loop of the Thermal Hydraulic Laboratory at Nuclear Technology Development Center (CDTN), a research institute of the Brazilian Nuclear Energy Commission (CNEN), has been used to evaluate devices present in fuel elements of a Pressurized Water Reactor (PWR). Currently, a rod bundle segment with 5x5 rods and spacer grids is being tested. To carry out the measurements of pressure drop along this bundle, a data acquisition system based on Basic language was used. Although this system is efficient and robust, its resources are very limited. Therefore, it was decided to use the LabVIEW® software to implement a data acquisition system and facilitate procedures related to experiments underway at the Water-Air Loop. This paper describes this new data acquisition system, and presents some results. Some of the parameters monitored are: temperatures, density, dynamic viscosity, Reynolds number and the flow rate relative to these values were the same as expected. The values of standard deviations, mean and uncertainty of an arbitrary channel also are calculated. The system was installed in the circuit and tested in real experimental conditions were it showed satisfactory results.

Keywords: Water-Air Loop, LabVIEW®, thermal hydraulic, data acquisition system, PWR reactors

1. INTRODUCTION

The Water-Air Loop of the Thermal Hydraulic Laboratory at Nuclear Technology Development Center (CDTN), a research institute of the Brazilian Nuclear Energy Commission (CNEN), has been used to evaluate devices present in fuel elements of a Pressurized Water Reactor (PWR). Currently, a rod bundle segment with 5x5 rods and spacer grids is being tested. To carry out the measurements of pressure drop along this bundle, a data acquisition system based on Basic language was created. Although this system is efficient and robust, its resources are very limited. Therefore, it was decided to use the software LabVIEW® to implement a data acquisition system to facilitate procedures related to experiments underway at the Water-Air Loop. The system was then installed in the Loop and tested in real experimental conditions were it showed satisfactory results.

The more versatile and modern system in development will contribute to the modernization of the methods used for monitoring operational parameters observed during tests. The proposed system comprises a data acquisition board (DAQ NI USB 6211, National Instruments) connected via a USB cable to a computer. The test model incorporates up to 32 channels of analog inputs (AI) and up to two analog outputs (AO), of which 9 will be used to receive signals from two thermocouples and seven pressure transmitters. In the LabVIEW® code, the signals from the DAQ board are acquired from a repeating structure ("loop producer") who sends the data in parallel as a two dimensional array to another structure ("loop consumer"), which will be responsible for processing the data. As the time to execute one iteration is greater in the "loop consumer", it becomes necessary to use queues to avoid losing data. Thus, while data is acquired for each channel in a set of n samples, their respective values of average, standard deviation and uncertainty are calculated. Soon after, these values are used by other functions to calculate the value of dynamic viscosity, fluid density, flow rate and Reynolds number. Every acquisition updates the graphics and indicators with measures. The program also allows the user, through a simple interface, to modify the coefficients for the calculation of total uncertainty and conversion of current signal coming from the board in convenient quantities. If you need to register a document format ".txt" with the values of measurements obtained, just select that option. From an application that simulates a DAQ board, input values were inserted to test the code. The values of standard deviations, mean and uncertainty of an arbitrary channel, the density, the dynamic viscosity, the Reynolds number, and the flow rate relative to these values were the same as expected.

2. THE FORMER DATA ACQUISITION

The old supervisory program used in the Water-Air Loop was developed with the software VisiDAQ made by Advantech Co. (2003). This most recent version was done in 1994 and ever since it has not been modernized, therefore it presents several disadvantages as, for example, it can only be used with Windows 98.

Along the thermal hydraulic loop were installed thermocouples and pressure transmitters that send signals to the conditioning board PCLD-789D (gains of 50, accuracy ± 0.0244% of range) and signal conversion board PCL-818HD (gain 1, accuracy ± 0.01% of range), both of Advantech. Then the signals are processed by a Basic language program that converts data, and displays the results on the screen of a personal computer, as shown in Fig. 1.

Figure 1. User interfaces of the old data acquisition system

Although this system is efficient and robust, its resources are very limited. Therefore, it was decided to use the LabVIEW® software for the development of a more versatile and modern data acquisition system, whose main advantage is to provide a user-friendly and easy interface to be assimilated by any operator. This paper, therefore, describes the program implemented, providing details about the external components, the algorithms used, the display screens and functions that make it.

3. THE LABVIEW® SOFTWARE

The rapid adoption of the PC in the last 20 years catalyzed a revolution in instrumentation for test, measurement, and automation. One major development resulting from the ubiquity of the PC is the concept of virtual instrumentation, which offers several benefits to engineers and scientists who require increased productivity, accuracy, and performance. A virtual instrument (VI) consists of an industry-standard computer or workstation equipped with powerful application software, cost-effective hardware such as plug-in boards, and driver software, which together perform the functions of traditional instruments. The VI appearance and operation imitate physical instruments. Traditional hardware instrumentation systems are made up of pre-defined hardware components, such as digital multimeters and oscilloscopes. These systems are more limited in their versatility than virtual instrumentation systems. The primary difference between hardware instrumentation and virtual instrumentation is that software is used to replace a large amount of hardware. Virtual instruments are computer programs that interact with real world objects by means of sensors and that implement functions of real or imaginary instruments. They can acquire, simulate and analyze data. Virtual instruments represent a fundamental shift from traditional hardware-centered instrumentation systems to software-centered systems that exploit the computing power, productivity, display, and connectivity capabilities of popular desktop computers and workstations. Although the PC and integrated circuit technology have experienced significant advances in the last two decades, it is software that truly provides the leverage to build on this powerful hardware foundation to create virtual instruments, providing better ways to innovate and significantly reduce cost. With virtual instruments, engineers and scientists build measurement and automation systems that suit their needs exactly (user -defined) instead of being limited by traditional fixed-function instruments (vendor - defined). The synergy between them offers advantages that cannot be matched by traditional instrumentation (National Instruments, 2010).

The most popular software used in virtual instrumentation is the LabVIEW® programs. LabVIEW® (Laboratory Virtual Instruments Engineering Workbench) contains a comprehensive set of tools for acquiring analyzing, displaying, and storing data. This software is used in conventional plants and in some nuclear reactors, replacing the analog control system with modern, user-friendly digital control (Pederson, 2005). LabVIEW® , developed by National Instruments (2007), is an amazingly intuitive program. It allows you to create programs using a graphics-based programming language called G. This means there are no longer lines upon lines of text-based code with hard-to-remember syntax (e.g., C++, Fortran). You just drag the functions onto the screen and wire them together. Also LabVIEW® is equipped with some very easy-to-use functions that take care of the dirty low-level work of configuring the computer hardware to establish communication between the computer and the instrument.

LabVIEW® software was used, in the work present here, to simulating the neutronic parameter evolution of nuclear reactor. LabVIEW® VIs contain three components: the front panel, the block diagram, and the icon and connector panel. In LabVIEW®, the user builds an interface, or front panel, with controls and indicators. Controls are knobs, switches,

push buttons, dials, and other input devices. Indicators are graphs, meters, and other displays that simulate the front panel of a real instrument. The code and structures to control the front panel objects are added to the user interface. The block diagram contains this code. The block diagram resembles a flowchart (National Instruments, 2007).

Digital electronics technology has rapidly taken over the bulk of new electronic applications because of its vastly increased functionality, lower cost, improved reliability and reduced maintenance requirements. Microprocessors have revolutionized the instrumentation and control systems. With their capability for convenient programming of complex tasks, they have found applications in a phenomenally wide range of applications. The extraordinary increase in computing power and the simultaneous dramatic reduction in cost of computing hardware have made it possible to develop high- performance plant monitoring and control systems with a wide range of functions and features. Their most recognizable feature is user friendly human–machine interfaces (HMIs) with graphical displays (IAEA, 1999).

Virtual instruments, by virtue of being PC-based, inherently take advantage of the benefits from the latest technology incorporated into off-the-shelf PCs. These advances in technology and performance, which are quickly closing the gap between stand-alone instruments and PCs, include powerful processors such as the Pentium i7 and operating systems and technologies such as Microsoft Windows Vista and Seven. In addition to incorporating powerful features, these platforms also offer easy access to powerful tools such as the Internet. Traditional instruments also frequently lack portability, whereas virtual instruments running on notebooks automatically incorporate their portable nature. Engineers and scientists whose needs, applications, and requirements change very quickly, need flexibility to create their own solutions. You can adapt a virtual instrument to your particular needs without having to replace the entire device because of the application software installed on the PC and the wide range of available plug-in hardware (National Instruments, 2012).

It was used a system comprising a data acquisition card NI DAQ USB 6211 provided by National Instruments (2009) connected via USB cable to a computer. The card signals are processed by a LabVIEW software application also of National Instruments. The test model, NI USB 6211, incorporates up to 32 input channels (AI) and up to two analog outputs (AO), of which 9 will be used to receive signals from two thermocouples and seven pressure transmitters. In LabVIEW code, the signals from the DAQ board is acquired from a repeating structure ("loop producer") who sends the parallel data in the form of a two-dimensional array structure to one another ("consumer loop"), which will responsible for processing the data. In this matrix, the rows corresponding to the channel and the columns are associated with the number of samples acquired in each cycle of the "loop producer."

As the time to perform one iteration is higher in "consumer loop" no synchronization between the structures, making it necessary to use queues to avoid data loss. The data are acquired in a set of n samples and at a rate that is set by the user. Each channel is associated with their respective mean values, standard deviation and uncertainty. Then, the values are used for other functions to provide the value of dynamic viscosity and density of the fluid (in this case water), and the flow Reynolds number in the orifice plate and the test section. With each acquisition, the graphics update themselves with the measures and indicators, arranged in tabs panel interface. In a tab designed to display the values of pressure in the orifice plate, you can select the transmitter used to calculate the flow.

The program also allows the user, through a simple interface; modify the coefficients for the calculation of the total uncertainty and the conversion of current signal from the card in convenient quantities. If it is necessary to register a document format "txt" with the values of measurements obtained by simply selecting that option.

4. THE DATA ACQUISITION BOARD

The National Instruments USB-6211, shown in Fig. 2, is a bus-powered USB M Series multifunction data acquisition (DAQ) module optimized for superior accuracy at fast sampling rates. It offers 16 analog inputs; 250 kS/s single-channel sampling rate; two analog outputs; four digital input lines; four digital output lines; four programmable input ranges (±0.2 to ±10 V) per channel; digital triggering; and two counter/timers. The NI USB-6211 is designed specifically for mobile or space-constrained applications. Plug-and-play installation minimizes configuration and setup time, while direct screw-terminal connectivity keeps costs down and simplifies signal connections. This product does not require external power. This module also features the new NI signal streaming technology, which gives you DMA-like bidirectional high-speed streaming of data across the USB bus.

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Figure 2. The USB-6211 data acquisition module

5. RESULTS

It was built an interface simple understanding, whose startup screen allows the user to select a determined task. In addition to information about the developers, the screen provides information about the sub VIs composing the program, as can be seen in Fig. 3.
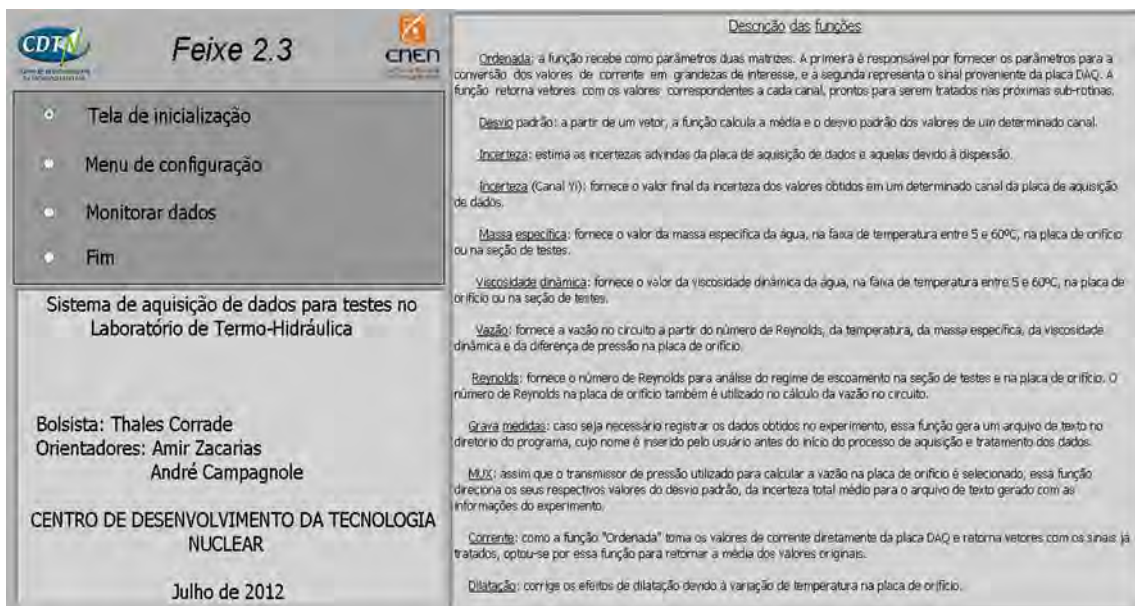

Figure 3. Screen of the Setup Menu

In the "Setup Menu", the user defines the linear and angular coefficients of each channel, responsible for the conversion of current signals from the DAQ board in quantities consistent

In addition, there are the "uncertainty of measurement", which will be defined after the start of testing. Figure 4 shows a small text to assist the user. On the screen there are the parameters assigned to each channel and quantities to be observed throughout the experiment.

Figure 4. Configuration Menu

Figure 5 shows a part of the block diagram where the functions are present responsible for calculating of the mean, the standard deviation, the uncertainty, the flow, the Reynolds number, the density and the dynamic viscosity, as well as a portion of the code responsible for preparing of the document text. Figure 6 shows a block diagram developed in this project.
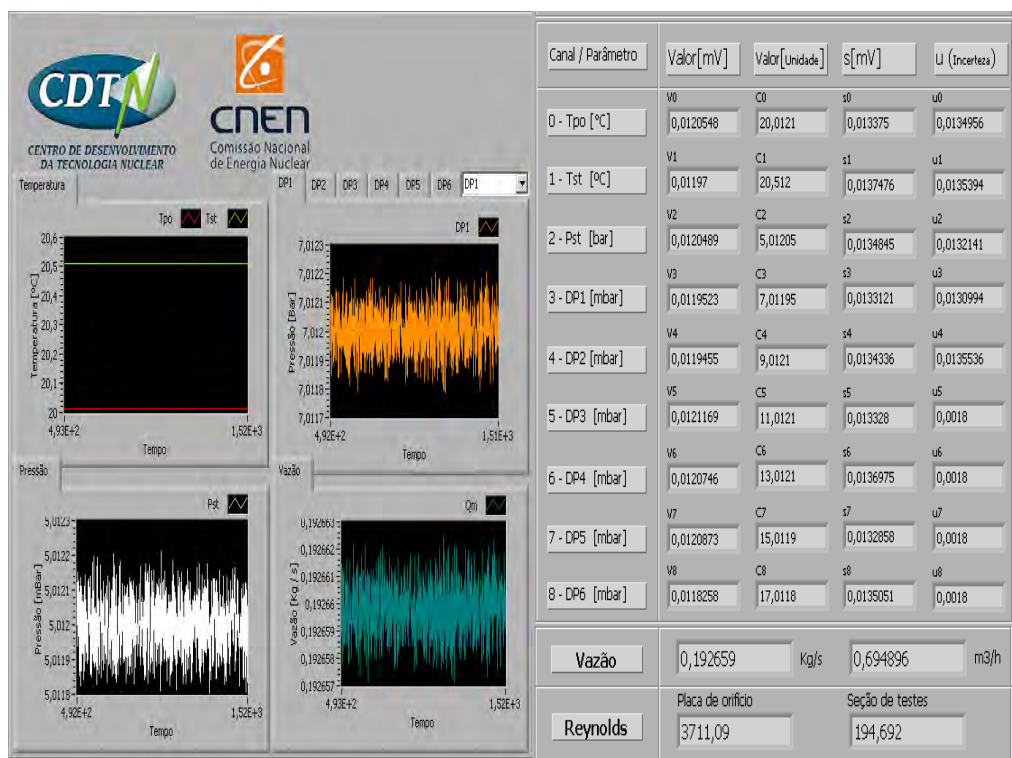

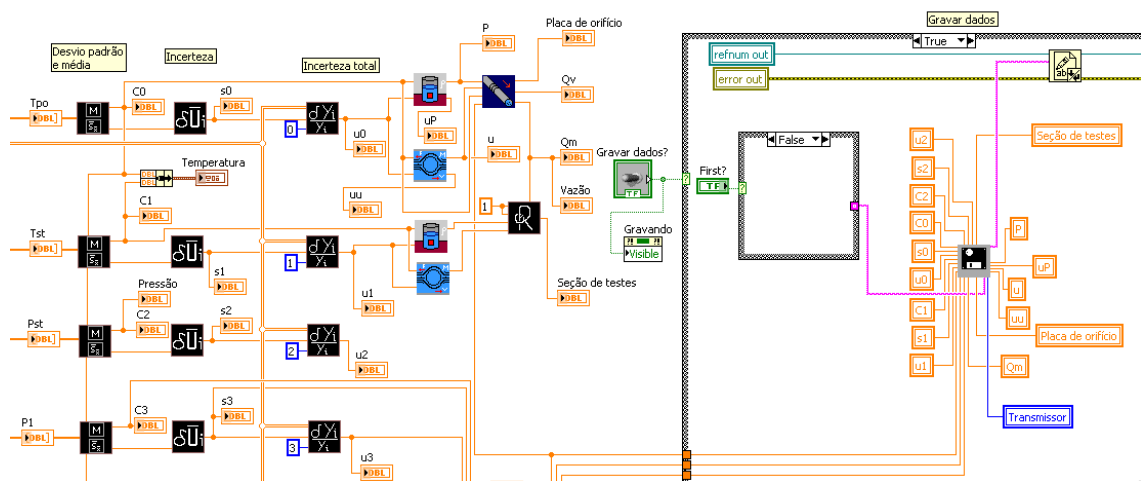Figure 5: Monitoring of parameters in real time

Figure 6: Block diagram

Figure 7 shows, in the foreground, a visual interface of the new data acquisition system, and in the back the Water-Air Loop.

Figure 7. The Water-Air Loop and the new data acquisition system

6. CONCLUSION

The new data acquisition based in the microcomputer has been designed and developed to allow the real-time collection of all operational parameters and information from the Water-Air Loop of the Thermal Hydraulic Laboratory at CDTN. The operational parameters and information from the thermal hydraulic loop fed to the computer through an interface unit that includes hardware like multiplexer, A/D converter and computer interface. Information on all aspects of circuit operation is displayed on the control console system. The color graphics monitors can display real-time operations data in concise, accurate, and easily understood formats. Information displayed on the monitor can be recorded on hard copy using the graphics printer in the control console system. The data acquisition system collects data during loop operations and stores it in a historical database. Some of the parameters monitored are: temperatures, pressure, density, dynamic viscosity, Reynolds number and the flow rate. The values of standard deviations, mean and uncertainty of an arbitrary channel also are calculated. The Water-Air Loop operations can then be replayed in real-time or slow motion. This record is a powerful tool that can be used for operations review and maintenance troubleshooting. The system was then installed in the circuit and tested in real experimental conditions were it showed satisfactory results.

7. ACKNOWLEDGEMENTS

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9. RESPONSIBILITY NOTICE

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