

## BUILDING A DATA ACQUISITION SYSTEM UPGRADE FOR THE IPR-R1 TRIGA NUCLEAR REACTOR

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### ABSTRACT

This paper presents the new supervisory program that has been designed at CDTN/CNEN using the graphical programming language LabVIEW by National Instruments in the Microsoft Windows XP Professional platform. It will replace the old data acquisition system for a modern, user-friendly soft, easy-to-maintain control system in a reasonable amount of time and cost. Reactor information could be transmitted via a high-speed Ethernet link from the Control Console System to the operator room or to a web browser of others computers.

### 1. INTRODUCTION

The supervisory program used actually in the IPR-R1 TRIGA Reactor Control Room was developed with the software VisiDAQ made by Advantech Co. This program 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. A new supervisory program has been designed, that using the soft LabVIEW (Laboratory Virtual Instrument Engineering Workbench) by National Instruments in the Microsoft Windows XP Professional platform.

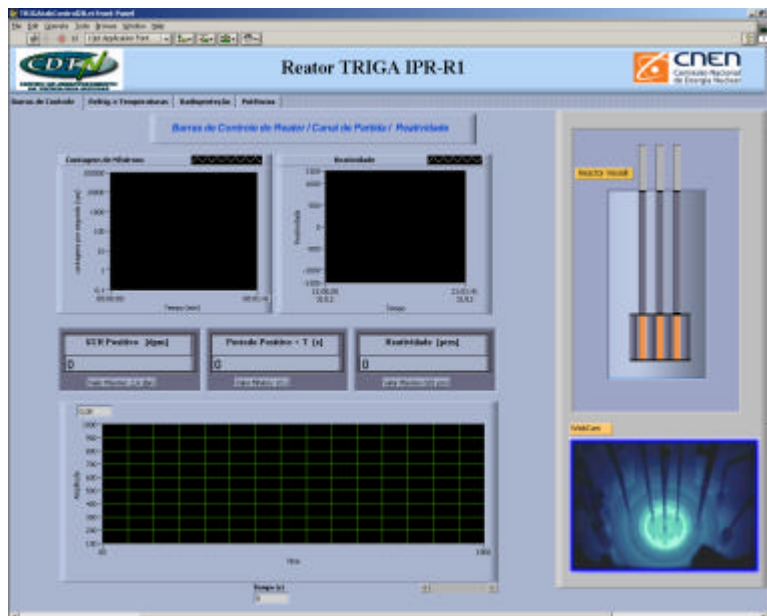


Figure 1. The New IPR-R1 TRIGA Data Acquisition System

The IPR-R1 TRIGA Research Reactor, located at the Nuclear Technology Development Center - CDTN in Belo Horizonte, Brazil, has been operating for 44 years. The operational parameters are monitored and displayed by analog meters located at reactor console. The reactor operators registered the most important operational parameters manually in a logbook. This process is quite useful, but it can involve some human errors, parallax error, time delay, etc. It is also impossible for the operators to take notes of all variables involving the process mainly during fast power transients in some operations. Due to the recent experiments on thermohydraulics and reactor power calibrations [1] [2] and [3], it was necessary the development of a data acquisition system to make possible the tests. This system [4] still in use, is obsolete, due to the fast development in computer science and instrumentation. Therefore, it has been developed a new supervisory program using LabVIEW version 7.1 by National Instruments [5], in the Microsoft Windows XP Professional platform.

The LabVIEW software offers direct control of the hardware on the Data Acquisition (DAQ) board still in service [6]. For 20 years engineers and scientists have been using LabVIEW that is a powerful graphical development environment, for signal acquisition, measurement analysis, and data presentation. LabVIEW also provides the flexibility of a programming language without the complexity of traditional development tools. It is programmed with a set of graphical icons which are connected with "wires". The combination of a DAQ board and LabVIEW software makes a virtual instrument or a "VI". A "VI" can perform like an instrument and is programmable by the software with the advantage of logging data flexibility that is being measured.

## **2. HARDWARE DESCRIPTION**

Three compensated ion chambers were located around the core, the detector's signals were amplified in a voltage amplifier. The amplified output voltage is between 0 to  $\pm 10V$  which is in turn the input sign of the Multiplexing Board and to the Analog to Digital Converter card of the PC with the associated software. The other analog signs collected by the data acquisition system are outputs of the reactor control console and from some digital indicators or directly from the thermocouples. Three input conditioning cards address these signs to an analog/digital converter card, which is installed in one Pentium 4 computer. The measure data are shown in the 19' computer video monitor. The main components of the instrumentation are described in the next sections.

## **3. DATA ACQUISITION CARDS**

### **3.1. Amplifier and Multiplexing Cards**

The analogical signs are received in three cards model PCLD-789 by Advantech Co [6] connected in cascade (Fig. 2), each one with 16 channels which totalize 48 inputs. These cards prepare the signs amplifying and filtering the noises and make the connection for a unique analogical output (multiplex action). One of the cards receives the signs directly from the thermocouples (range of  $\pm 100$  mV). This card has a sensor that measures the temperature and makes the compensation of the cold junction adjusting the measured value. The other cards receive the signs from the control console (range of  $\pm 10$  V). The main characteristics of the conditioning cards are:

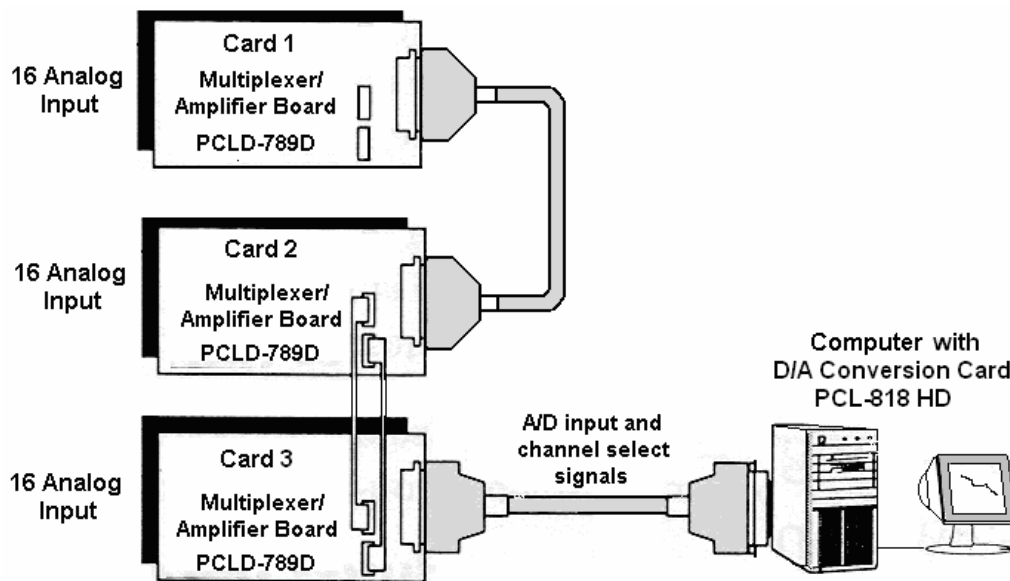
- Accuracy: 0.0244% of the range  $\pm 1$  LSB;
- Input: 16 differential channels;
- Over voltage protection:  $\pm 30$  V continuous;

- Input range:  $\pm 10$  V maximum, varies with gain selection;
- Gain: 1, 2, 10, 50, 100, 200, 500 and 1000;
- Cold junction compensation:  $+24.4$  mV/ $^{\circ}$ C (0.0 V at 0.0  $^{\circ}$ C);

Table 1 shows the identifications of each signal collected by the cards. In the first column it is presented the number of the channel in each card. In the second column it is presented the identification (code) that is used in the data acquisition program to equation the collected sign, where: AI = Analog Input and TMP = Thermocouple. Finally, the third column shows the description and range which the collected signs were obtained.

**Table 1. Operational Parameter of the IPR-R1 TRIGA Reactor**

Channel	Input	Collected Sign
0	TMP 10	Water pool temperature (lower 1), (thermocouples, -6 to 55 mV)
1	TMP 1	Fuel temperature (upper), (thermocouples, -6 to 55 mV)
2	TMP 2	Fuel temperature (medium), (thermocouples, -6 to 55 mV)
3	TMP 3	Fuel temperature (lower), (thermocouples, -6 to 55 mV)
4	TMP 4	Air temperature above the pool, (thermocouples, -6 to 55 mV)
5	TMP 5	Ground temperature around the pool (thermocouples, -6 to 55 mV)
6	TMP 6	Outlet core channel temperature), (thermocouples, -6 to 55 mv)
7	TMP 7	Inlet core channel temperature (lower), (thermocouples, -6 to 55 mV)
8	TMP 8	Water pool temperature (upper 1), (thermocouples, -6 to 55 mV)
9	TMP 9	Water pool temperature (upper 2) (thermocouples, -6 to 55 mV)
10	AI 21	Pool water temperature , (PT-100, 4 to 20 mA)
11	AI 4	Water inlet temperature in secondary circuit, (pt-100, 4 to 20 mA)
12	AI 5	Water outlet temperature in secondary circuit, (pt-100, 4 to 20 mA)
13	AI 1	Water flow in the primary circuit, (4 to 20mA)
14	AI 2	Water inlet temperature in primary circuit, pt-100, (4 to 20 mA)
15	AI 3	Water outlet temperature in primary circuit, pt-100, (4 to 20 mA)
16	-	Reserved to be used for air relative humidity
17	AI 6	Logarithmic channel power, (0 to 10 V)
18	AI 7	Linear channel power, (0 to 10 V)
19	AI 8	Percent power channel, (0 to 10 V)
20	AI 14	Period, (0 to 10 V)
21	AI 15	Reactivity, (-10V to +10 V)
22	AI 16	Start-up channel counter, (0 to 10 V)
23	AI 18	Safety rod position, (0 to 2.5 V)
24	AI 19	Shim rod position, (0 to 2.5 V)
25	AI 20	Regulating rod position, (0 to 2.5 V)
26	-	Aerosols radiation (disabled), (0 to 10 V)
27	AI 9	Well radiation, (0 to 10 V)
28	AI 10	Area radiation, (0 to 10 V)
29	AI 11	Primary circuit inlet radiation, (0 to 10 V)
30	AI 12	Ion changer radiation, (0 to 10 V)
31	AI 13	Inlet secondary circuit radiation, (0 to 10 V)
32	-	Reserve
33	TMP 11	Pool temperature (lower 2), (thermocouples, -6 to 55 mV)
34	TMP 12	Pool temperature (lower 3), (thermocouples, -6 to 55 mV)
35	TMP 13	Pool temperature (lower 4), (thermocouples, -6 to 55 mV)
36	TMP 14	Pool temperature (lower 2), (thermocouples, -6 to 55 mV)
37	TMP 15	Pool temperature (lower 3), (thermocouples, -6 to 55 mV)
38	TMP 16	Pool temperature (lower 4), (thermocouples, -6 to 55 mV)
39	TMP 17	Ground temperature around the pool (2) (thermocouples, -6 to 55 mv)
40 to 48	-	Reserve



**Figure 2. Data Acquisition Connection Cards**

### 3.2. Analog to Digital Conversion Card

The outputs of the three conditioning cards are addressed to the analog input plug of the data acquisition card, model PCL-818hd by Advantech Co [6]. This is a high-speed data transference card installed in the computer case, which transforms the analog input signs into digital sign. This card has the following main characteristics:

- Accuracy: 0.01% of the range  $\pm 1$  LSB;
- Resolution: 12 bits;
- Sampling rate: up to 100 kHz with DMA transfer;
- Over voltage: continuous  $\pm 30$  V max.

## 4. DATA ACQUISITION SOFTWARE

The LabVIEW is programmed with set of icons that represents controls and functions, available in the menu of the software. Such a programming is called *visual programming*. The user interface which is called a *VI* (Virtual Instrument) consists of two parts- a *front panel* and a *diagram*. This is similar to that of an instrument where a front panel is used for an input, output controls, and to display the data whereas the circuit resides on the circuit board. Similarly it can bring the buttons, indicators and graphing and display functions on the front panel. The VI also calculates mean and standard deviation of the data and plots it. Alarms have been set up so that if the temperature falls below or above a certain set value the alarm goes ON. The LabVIEW can be used to perform system simulations, since it contains filters many commonly used, digital signal processing, and statistical functions.

The main indications of the control console are collected by the data acquisition system, including the positions of the three control rods. These signs come from the rack of instruments and from the reactor control console and they are input in channels 1 to 15 of Card 2. A description of all signs collected from the control console is not presented in this paper. It was accomplished all the answers of the parameters collected and the found equations were introduced in the data acquisition program to transform the signals of Volt

into engineering units. The program presents four screens; one of them was shown in Fig. 1 (Start up Channel, Control Rods, Reactivity). The others screens are: Levels of Radiation (Fig. 3), Power Channels and Cooling System and Temperatures.

#### 4.1 Control, Start up Channel, Period and Reactivity

In this screen, which was shown in Fig. 1, the start up of the reactor can be accompanied through the neutron evolution counting rate. The positions of the three control rods of the reactor can be visualized in graphics of the rods or in digital indicators. Three graphics also show the evolution of the control rods position in the last 60 minutes. The reactivity of the reactor in [pcm] and in [dollar] is given by digital counters. This screen also shows the positive period of the reactor (T) in [s] and the start up rate (SUR) in [dpm]. A webcam films the reactor core and it shows the image in this screen.

#### 4.2. Radiation Levels

The gamma radiation levels at the reactor area are measured in the following positions: in the Control Room (AEROSSOIS); at about 30 cm above the reactor pool (POÇO); at 2 m above the reactor pool (AREA); at the inlet piping of the primary cooling loop heat exchanger (ENTRADA PRIMÁRIO); in the ion exchanger system (RESINAS); and at the outlet piping of the secondary cooling loop heat exchanger (SAÍDA SECUNDÁRIO).

Figure 3 shows the screen of the radiation levels monitoring. The six radiation levels of the monitoring channels are shown in analog and digital indicators and graphics, and give the evolution of the radiation levels in the last 60 minutes.

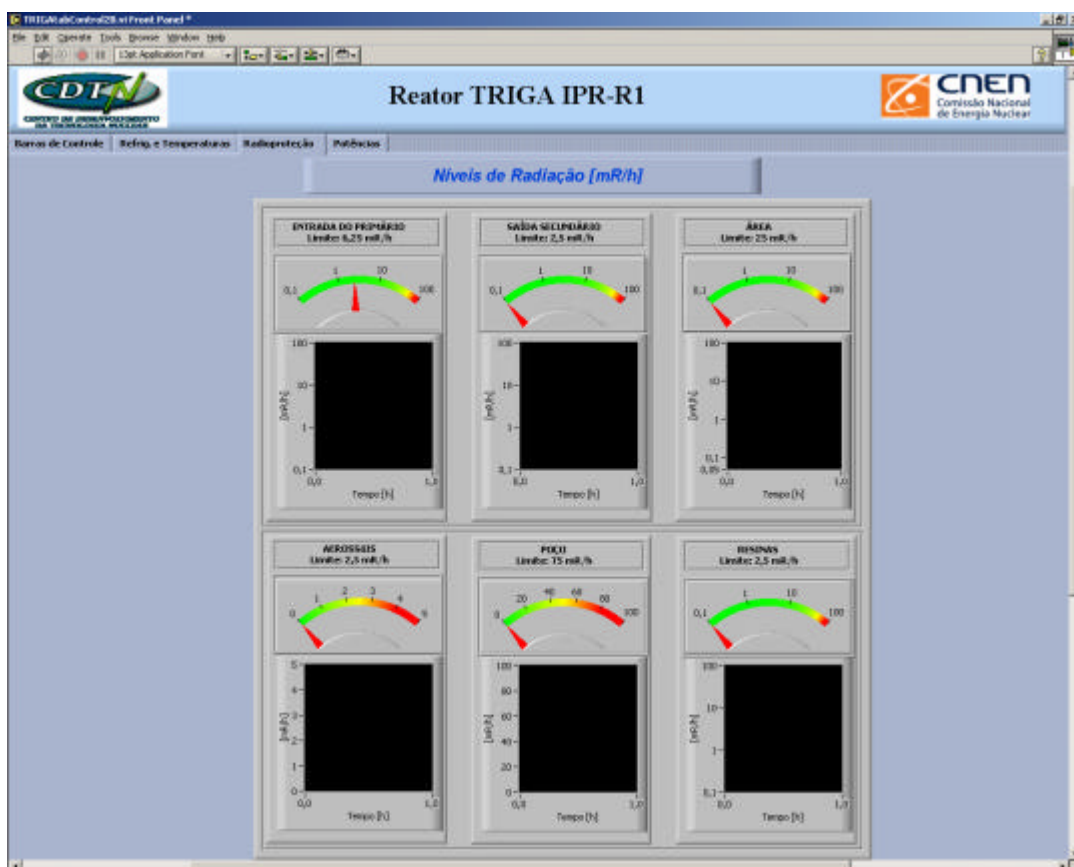


Figure 3. Radiation Levels Screen

### 4.3. Power Channels

This screen shows the evolution of the reactor powers supplied by three conventional neutron channels of measurement: Logarithmic Channel, Linear Channel and Percent Power Channel. The values are given by digital indication and by graphics that show the last 60 minutes. The evolution of the power dissipated in the primary and secondary-cooling systems is also shown. After several hours of reactor operation, when it is reached the thermal balance with the environment, the power of the reactor will be the closer to the power dissipated in the primary coolant loop and the thermal losses will be smaller. Those losses value are also indicated in the screen. The reactor power is monitored also by the increase of the temperature in the center of the instrumented fuel.

### 4.4. Cooling System and Temperatures

This screen shows all parameters of the primary and secondary cooling loops. The following signals are monitored and shown on the screen:

- The average value of the inlet and outlet temperatures of the primary and secondary loops and its standard deviations.
- The average value of the flow rate and its standard deviation.
- The power dissipated in the primary and secondary cooling loops.
- The average value of the temperatures in the reactor pool in three different positions and its standard deviations.
- The average value of the inlet and outlet temperatures in the core channels and its standard deviations.
- The temperature of the air above the reactor pool and in two points of the soil.
- The average value of the temperatures in the three thermocouples of the instrumented fuel element.
- The time elapsed from the program beginning in [s], [min] and [h].

## 5. CONCLUSIONS

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 IPR-R1 TRIGA Reactor. The operational parameters and information from the reactor console have been fed to the computer through an interface unit that includes hardware like multiplexer, A/D converter and computer interface. Information on all aspects of reactor operation is displayed on the Control Console System. The two color graphics monitors can display real-time operations data in concise, accurate, and easily understood formats. Bar graph indicators and visual and audible annunciators are also provided. Information displayed on the monitor can be recorded on hard copy using the graphics printer in the Control Console System. The DAC collects data during reactor operations and stores it in a historical database. Reactor 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 also has been useful to provide more information during the reactor operation and does not influence the original reactor measuring and control instrumentation by any way.

The IPR-R1 Reactor isn't controlled by the automatic way (startup, control rod movements and scrams). This operational philosophy was defined about 40 years ago, when the

automation means were limited. Today, with the technology developed and with the use of a computer it's possible to execute all nuclear power plant operations [7]. The TRIGA Reactor of the Pennsylvania University, in the USA and other research reactors, have systems coupled to a special program that controls the installation, from the start up at the start down [8]. It is suggested with this paper to initiate studies that permit to automatize the IPR-R1 TRIGA Reactor operation.

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