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# DATA ACQUISITION SYSTEM FOR TRIGA MARK I NUCLEAR REACTOR AND A PROPOSAL FOR ITS AUTOMATIC OPERATION

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## ABSTRACT

The TRIGA IPR-R1 Nuclear Research Reactor, located at the Nuclear Technology Development Center (CDTN/CNEN) in Belo Horizonte, Brazil, is being operated since 44 years ago. During these years the main operational parameters were monitored by analog recorders and counters located in the reactor control console. The most important operational parameters and data in the reactor logbook were registered by the reactor operators. This process is quite useful, but it can involve some human errors. It is also impossible for the operators to take notes of all variables involving the process mainly during fast power transients operations. A PC-based Data Acquisition was developed for the reactor that allows on line monitoring, through graphic interfaces, and shows operational parameters evolution to the operators. Some parameters that never were measured on line, like the thermal power and the coolant flow rate at the primary loop, are monitored now in the computer video monitor. The developed system allows measure out all parameters in a frequency up to 1 kHz. These data is also recorded in text files available for consults and analysis.

## 1. INTRODUCTION

The IPR-R1 is a 250 kW TRIGA Mark I Research Reactor and has been used mainly for isotope production and activation analysis, nuclear power plants operators training and nuclear research programs. The operational parameters of the reactor are monitored and measured by analogue meters located at the reactor control console and the operator makes manually all the operation procedures and data registration.

New sensors of temperature and flow sensors were included in the reactor system, due to the recent experiments on thermal hydraulics and reactor power calibrations [1] [2] and [3]. It was also necessary the development of a data acquisition system to make possible these experiences performance. The video monitor provides real time information, shows all reactor operations graphics, displays and the operating parameters. The data acquisition system saves all the operational information in the hard disk.

## 2. SYSTEM DESCRIPTION

The analog signs collected by the data acquisition system are outputs from the back stage rack transducers, of the reactor control console instrumentation and from some digital indicators or directly from the thermocouples. Two input conditioning cards address these signs to an analog/digital card converter, which is installed in one computer. Some measure data are shown in the computer video monitor. Due to the high impedance of the cards input, they don't cause any disturbance in the indications at the reactor control console. The main components of the instrumentation are described in the next topics.

## 3. DATA ACQUISITION CARDS

### 3.1. Amplifier and Multiplexing Board

The analogical signs are received in two cards model PCLD-789 [4] connected in cascade (Figure 1), each one with 16 channels which totalize 32 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 (Card 1) was adjusted to amplify the signs with a gain of 50, receiving the signs directly from the thermocouples (range of ± 100 mV).

This card has a sensor that measures the temperature and makes the compensation of the cold junction adjusting the measured value. The second card was adjusted to amplify the signs with a gain 1 and receives the signs from the back stage instrumentation and from the control console (range of ±10 V). The main characteristics of the conditioning cards are:

- Accuracy: 0.0244% of the range ± 1 LSB;
- Input: 16 differential channels;
- Over voltage protection: ± 30 V continuous;
- Input range: ± 10 V maximum, varies with gain selection;
- Gain: 1, 2, 10, 50, 100, 200, 500 and 1000;
- Cold junction compensation: +24.4 mV/$^o$C (0.0 V at 0.0 $^o$C);

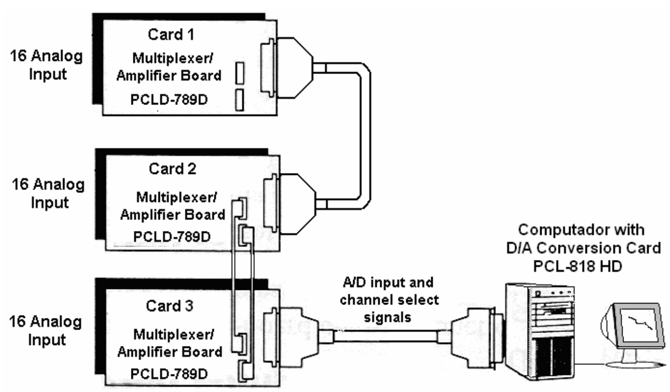



**Figure 1. Data acquisition connection cards**

### 3.2. Analog/Digital Conversion Card

The outputs of the two conditioning cards are addressed to the analog input plug of the data acquisition card, model PCL-818hd [4]. This is a high-speed data transference card installed in the computer module, which transforms the analog input signs into digital sign. This card has the following main characteristics:

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

## 4. DATA ACQUISITION SOFTWARE

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 back stage instruments and from the reactor control console and they are input in channels 1 to 15 of Card 2 (Fig. 1). 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. Thirty-one analog signs are collected tight now by the data acquisition system. The two parameters that still not collected are the water conductivity and the reactor pool level. The program presents five screens: the first one (Figure 2) is a navigation screen, where it is possible to access any of the four graphic interfaces divisions of the program using the mouse. From this screen it is also possible to start the data-recording key. It is possible to know the evolution of the reactor's parameters in each one of the interfaces at real time. These parameters were divided in the following way:

- Control, Start Up Rate Channel, Period and Reactivity,
- Levels of Radiation;
- Power Channels;
- Cooling System and Temperatures.

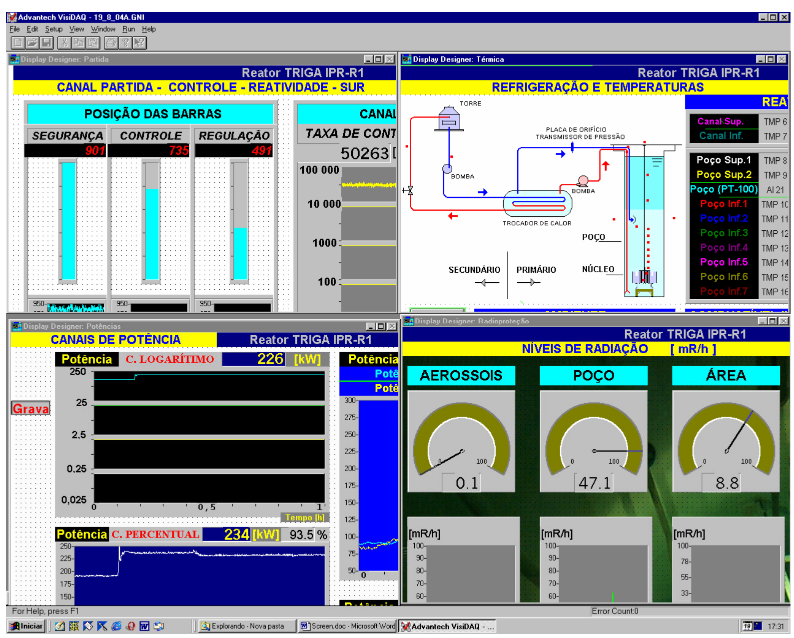



**Figure 2. Main navigation screen**

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

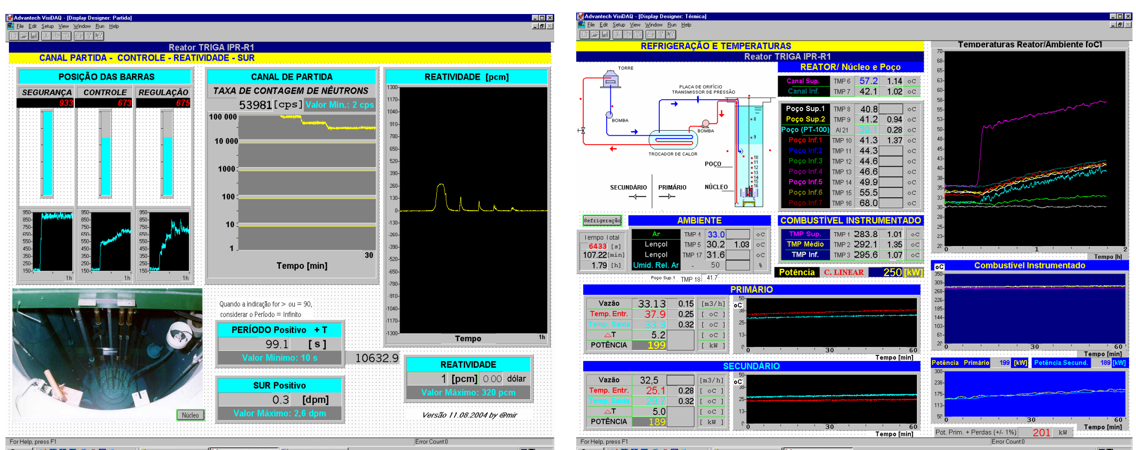
In this screen, which is shown in Figure 3.a the start up of the reactor can be accompanied through the neutron evolution counting rate. The positions of the three control rods of the reactor can be visualized in graphics of the rods or in digital indicators. Three graphics also show the evolution of 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].

### 4.2. Cooling System and Temperatures

In this screen, which is shown in Figure 3.b all parameters of the primary and secondary cooling loops are monitored. The following signals are shown at the screen:

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




a) b)

**Figure 3. a) Start up channel, control rods and reactivity Screen, b) Cooling system and temperatures screen**

### 4.3. Radiation Levels

The radiation levels at the reactor area are measured in the following positions: in the Control Room (AEROSOIS); 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).

The Figure 4 exhibits the screen, which shows the accompaniment of the radiation levels in the mentioned positions. The six radiation level monitoring channels are shown in analog and digital indicators and graphics, and give the evolution of the radiation levels in the last 60 minutes.


**a) b)**

**Figure 4. a) Radiation monitoring system, b) Power level channels screen**

### 4.4. Power Channels

In this screen, which is shown in the Figure 6, it is presented the evolution of the reactor powers supplied by three conventional neutron channels of measurement: Logarithmic channel, Lineal 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 of 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 by the increase of the temperature in the center of the instrumented fuel.

## 5. DATA RECORDING SYSTEM

The data are recorded in five separated text-files and these permit to register 40 parameters. In all the files the first column is always the time registration in [s]. The time among the data collection and the data recording can be adjusted starting from 1,0 ms (frequency of 1 kHz), but the frequency usually used is equal to 1 Hz.

## 6. CONCLUSIONS

The developed Data Acquisition System has been operated during normal operation and during all experiments realized with the reactor since July 2003. 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.

According the operation norms of TRIGA IPR-R1 Reactor, it is impossible control the reactor by an automatic way (departures, 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 mouse it's possible to execute all nuclear power plant operations. [5]. The TRIGA Reactor of the Pennsylvania University, in USA and other research reactors, have systems coupled to special program that controls the installation, from the departure at the end of the operation [6]. It is suggested with this paper initialize studies that permits automates the reactor TRIGA IPR-R1 Reactor operation.

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