DATA ACQUISITION AND SIGNAL PROCESSING SYSTEM FOR IPR R1 TRIGA MARK I NUCLEAR RESEARCH REACTOR OF CDTN

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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. The main operational parameters were monitored by analog recorders and counters located in the reactor control console. The reactor operators registered the most important operational parameters and data in the reactor logbook. 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 in some 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 were not measured, like the power and the coolant flow rate at the primary loop, are monitored now in the computer video monitor. The developed system allows measuring out all parameters in a frequency up to 1 kHz. These data is also recorded in text files available for consults and analysis.

INTRODUCTION

The IPR-R1 Reactor 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 as others TRIGA Reactors. 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 temperature and flow sensors were included in the equipment, due to the recent experiments on thermal hydraulics and the reactor power calibrations [1] [2]. It was also necessary the development of a data acquisition system to make possible these experiences performance. The video monitor provide real time information, shows all reactor operations graphics and displays the operating parameters and the data acquisition system saves all the operational information in the hard disk.

SYSTEM DESCRIPTION

The analog signs collected by the data acquisition system are outputs of the back stage rack transducers, of the reactor control console instrumentation, of some digital indicators or directly of 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.

DATE ACQUISITION CARDS

Amplifier and Multiplexing Board

The analogical signs are received in two cards model PCLD-789 [3] connected in cascade (Figure 1), each one with 16 channels what totals 32 inputs. These cards condition the signs (they amplify and filter the noises) and they make the connection for an alone 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 of 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);

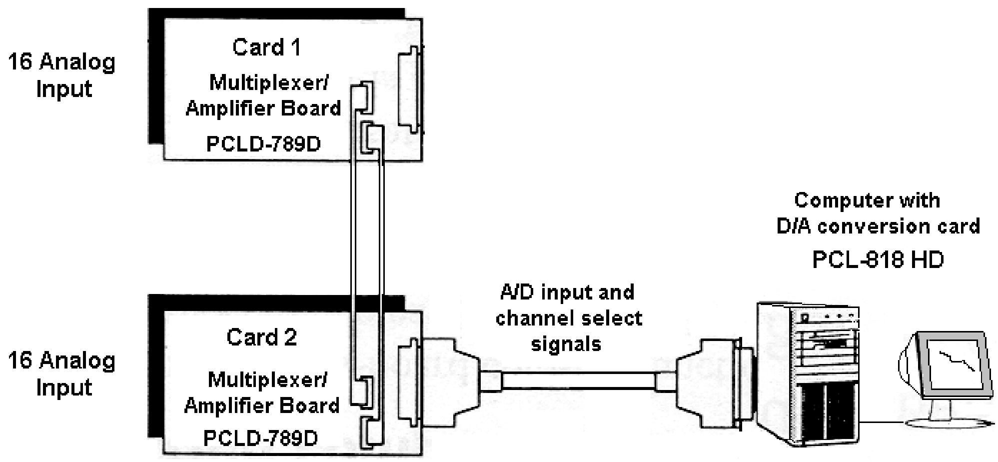

Figure 1 - Data Acquisition Connection Cards

Tables 1 and 2 show the identifications of each signal collected by the cards. In the first column it is presented the number of the entrance 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 sign were obtained.

Table 1 - Signals Distribution in the Card 1, Gain = 50

Channel	Analogical Input	Collected Sign
0	TMP 1	Sub Channel Temperature (upper), (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 Well, (thermocouples, -6 to 55 mV)
5	TMP 5	Water Temperature of the Well (upper), (thermocouples, -6 to 55 mV)
6	TMP 6	Water Temperature of the Well (medium), (thermocouples, -6 to 55 mV)
7	TMP 7	Well Temperature (lower), (thermocouples, -6 to 55 mV)
8	TMP 8	Table Water Temperature, (thermocouples, -6 to 55 mV)
9	TMP 9	Sub Channel Temperature, lower side (thermocouples, -6 to 55 mV)
10	AI 21	Water Temperature of the Well, (PT-100, 4 to 20 MA)
11	AI 4	Inlet Temperature of the Secondary Circuit, (PT-100, 4 to 20 mA)
12	AI 5	Outlet Temperature of the Secondary Circuit, (PT-100, 4 to 20 mA)
13	AI 1	Water Flux in the Primary Circuit, (4 to 20mA)
14	AI 2	Inlet Temperature of the Primary Circuit, PT-100, (4 to 20 mA)
15	AI 3	Outlet Temperature of the Primary Circuit, PT-100, (4 to 20 mA)

Table 2 - Distribution of the Signs in the Card 2, Gain = 1

Channel	Analogical Input	Collected Sign
0		Reserved to be used for air relative humidity
1	AI 6	Logarithmic Channel Power, (0 to 10 V)
2	AI 7	Lineal Channel Power, (0 to 10 V)
3	AI 8	Percent Power Channel, (0 to 10 V)
4	AI 14	Period, (0 to 10 V)
5	AI 15	Reactivity, (-10V to +10 V)
6	AI 16	Start Up Channel Counting, (0 to 10 V)
7	AI 18	Safety Control Rod Position, (0 to 2.5 V)
8	AI 19	Control Rod Position, (0 to 2.5 V)
9	AI 20	Regulation Control Rod Position, (0 to 2.5 V)
10	-	Aerosols Radiation (disabled), (0 to 10 V)
11	AI 9	Well Radiation, (0 to 10 V)
12	AI 10	Area Radiation, (0 to 10 V)
13	AI 11	Primary Circuit Inlet Radiation, (0 to 10 V)
14	AI 12	Ion Changer Radiation, (0 to 10 V)
15	AI 13	Inlet Secondary Circuit Radiation, (0 to 10 V)

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 to100 kHz with DMA transfer;
- Over voltage: continuous ±30 V max.

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, as shown in the Table 3.2. A description of all signs collected from the control console is 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 units of engineering. Thirty-one analog signs are collected now by the data acquisition system, only the water conductivity and level at the reactor pool are still not collected.

Five screens compose the program: the first one (Figure 1) is a navigation screen, where it is possible to access any of the four graphic interfaces divisions of the program by 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.

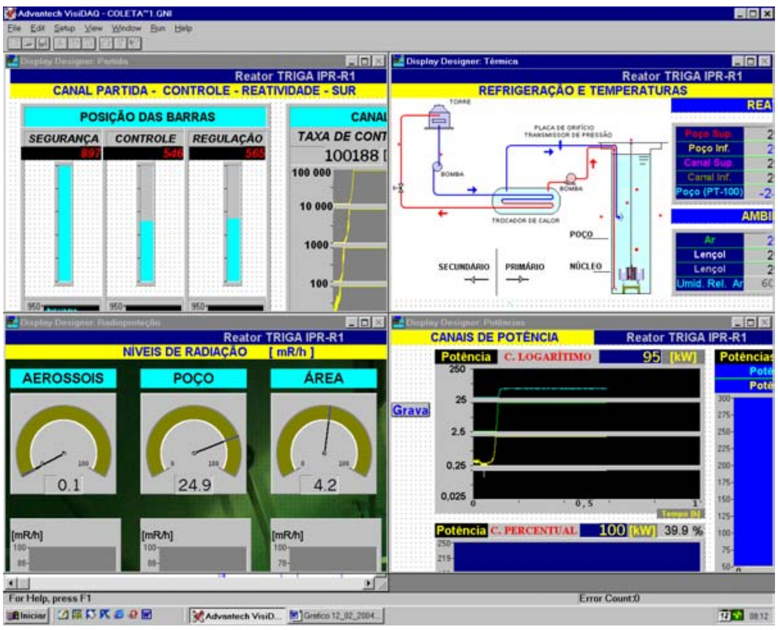

Figure 2 - Main Navigation Screen

Control, Start Up Channel, Period and Reactivity

In this screen, which is shown in Figure 3 the start up of the reactor can be accompanied through the evolution of the neutrons 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].

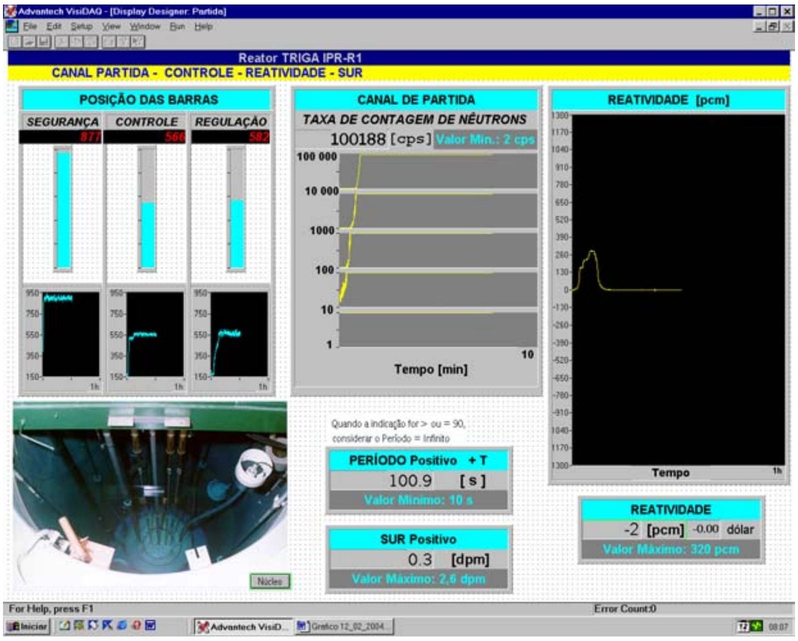

Figure 3 – Start up Channel, Control Rods and Reactivity Screen

Cooling System and Temperatures

In this screen, which is shown in Figure 4 all the 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 of the three thermocouples of the instrumented fuel
- The time elapsed from the program beginning in [s], [min] and [h].

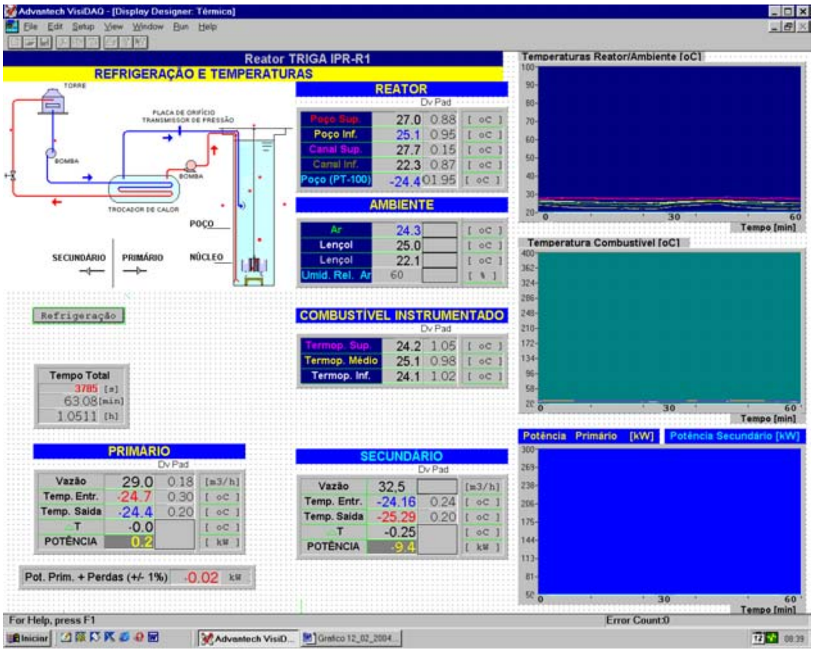

Figure 4 – Cooling System and Temperatures Screen

Levels of Radiation

The levels of radiation 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 (ENTR. PRIMÁRIO); in the ion exchanger system (RESINAS); and at the outlet piping of the secondary cooling loop heat exchanger (S. SECUNDARIO).
Figure 5 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, giving the evolution of the radiation levels in the last 60 minutes.

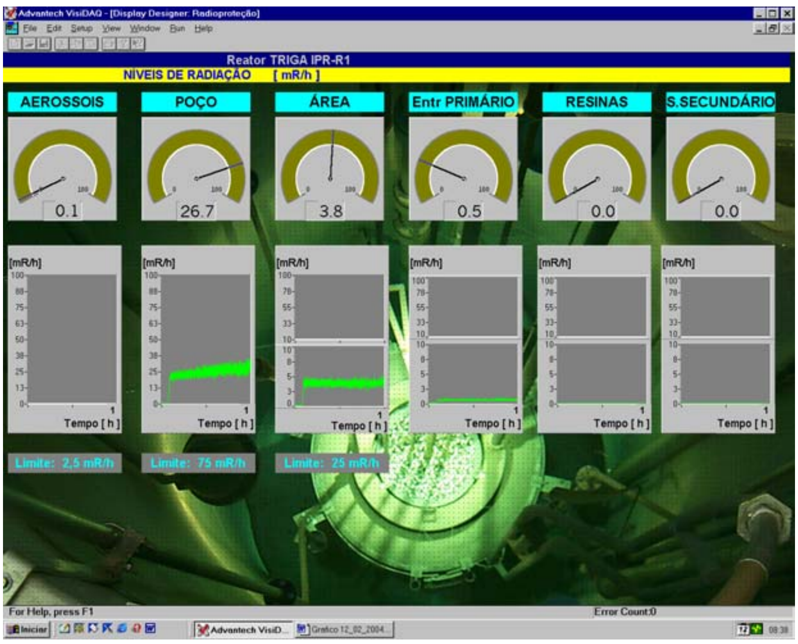

Figure 5 – Radiation Monitoring System

Power Channels

In this screen, which is shown in the Figure 6, it is presented the accompaniment of the reactor powers supplied by the 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 evolution during 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 accompanied by the increase of the temperature in the center of the instrumented fuel.

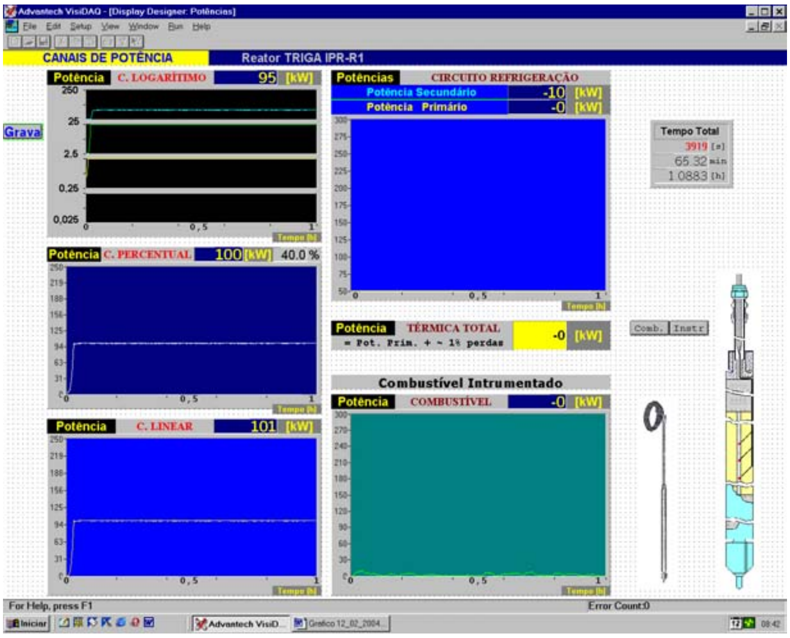

Figure 6 – Power Level Channels Screen

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 time of the data collection and recording can be adjusted starting from 1,0 ms (frequency of 1 kHz), but the frequency usually used is equal to 1 Hz.

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.

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