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Online Monitoring System for Water Chemistry in the Primary Coolant Circuit of TRIGA Reactor

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1. Introduction

More than 95 percent of all nuclear reactors in the world are water-cooled. Controlling the chemistry of the coolants is vital for safe operation, thus chemical control is quite important from the consideration of plant radiation levels, material integrity, and fuel performance [1] [2].

The IPR-R1 TRIGA Mark I reactor is an open pool type research reactor located at *Centro de Desenvolvimento da Tecnologia Nuclear/Comissão Nacional de Energia Nuclear* (CDTN/CNEN). It has been in operation since 1960 and has been used in several research activities, isotope production, and as an analytical irradiation tool of different types of samples [3]. Among the several reactor structural and operational safety requirements, the chemical quality control of the primary circuit cooling water is one of the most important, since it works as an additional neutron moderator and as a biological shield. The coolant also surrounds the main parts of the reactor including the core and the fuel elements and must be treated and controlled to minimize the corrosion of the reactor components maintaining its pH close to neutrality and low electrical conductivity [4].

To support reactor operation a variety of analytical chemical tasks is needed in the coolant and the operating organization should provide adequate laboratory methodologies taking the requirements of the water chemistry program and appropriate standards. Consideration should be given to the use of online monitoring of water control parameters as the preferable monitoring method for evaluating physical and chemical conditions, allowing to control and monitor the quality of the reactor water. An online analyzer can be used to determine and provide alarms for key chemistry parameters meeting the safety basis for the facility. A Data Acquisition System (DAS) should be assigned to the online monitoring system and the results of the control measurements should be recorded and stored properly, for eventual data review and analysis [5] [6].

This paper presents the work to provide the instrumentation of the IPR-R1 TRIGA reactor with a modern real-time monitoring system for coolant quality control. For this, three pieces of digital equipment were acquired to monitor the water chemical conditions, being two electrical conductivity monitors and one pH monitor. LabVIEW® (Laboratory Virtual Instruments Engineering Workbench) is the most popular software used in virtual instrumentation. It contains a comprehensive set of tools for acquiring analyzing, displaying, and storing data. A Data Acquisition System (DAS) was also developed to recorded the results of analytical and quality control measurements.

2. Methodology

2.1 Data Acquisition System (DAS) and Equipment Operability.

Two different programs were used to developing a Data Acquisition System (DAS) for the online monitoring and archiving of variables. The first was GeniDAQ® software from the same manufacturer of the acquisition board while the other software used was the LabVIEW® from National Instruments [7]. The software acquires the data from two different conductivity/resistivity transmitters, model 8850-2, GF Signet from Nivetec and a pH meter, model Dosatronic PH1000 TOP, from Provitec. The analogical signs sent by the instruments are received in a card model PCLD-789 by Advantech Co. connected in cascade making make the connection for a unique analogical output (multiplex action) to computer connection. Conductivity, temperature, and pH monitoring tests were performed on water samples taken from the reactor pool, as well as samples with variable values of these parameters. Those experiments were conducted to evaluate the accuracy and use viability of the system.

2.2 Analysis of possible interference of the conductivity meters cable length and temperature on the measurements

Both the conductivity meters used have two different cables, made from the same material and technology which can be used, one cable with 1 m to be used in the top of the reactor and the other with a length of 5 m to be used in the bottom of the pool. To evaluate if the length of the cables may interfere, tests were conducted by varying the cable used and the temperature of a previewed analyzed water sample from the reactor. A full factorial experimental design was conducted correlating both cable and two different temperatures, 25 ºC and 60 ºC.

3. Results and Discussion

The visual interface of the program developed to monitoring the cooling that shows the measures of conductivity and pH is shown below in Figure 1.

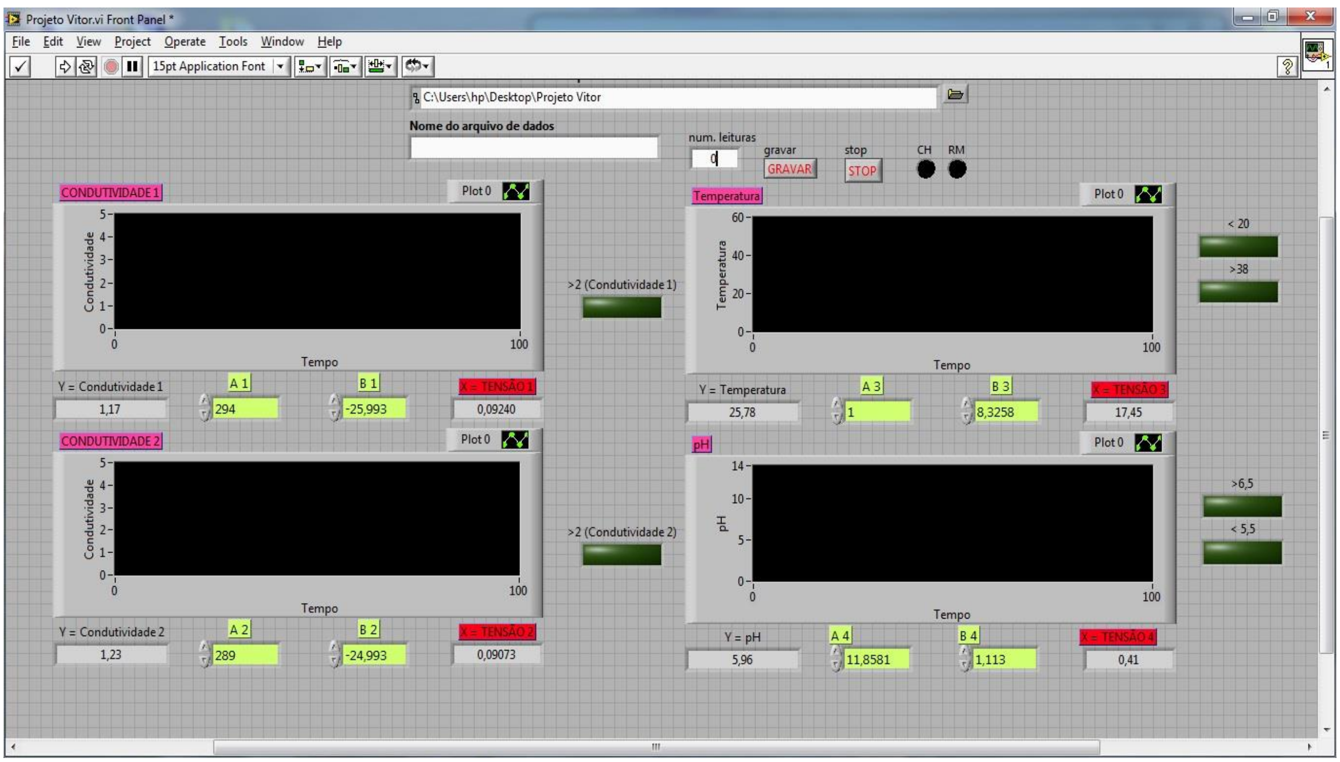

Figure 1: Visual interface in the LabVIEW® program for conductivity and pH

The conductivity meters were adjusted comparing the relationship between the transmitter's output signals (voltage) and the conductivity measured. Those parameters were taken and the operational equations of the instruments have been obtained. It was verified that the signal was proportional to the conductivity measured since the correlation coefficient has a value of 1. Experiments were conducted in some water samples from the reactor. The conductivity was measured by the two different conductivity/resistivity transmitters. Figure 2 shows the electrical conductivity measurements of the IPR-R1 pool samples by the conductivity transmitters, collected every 30 minutes.

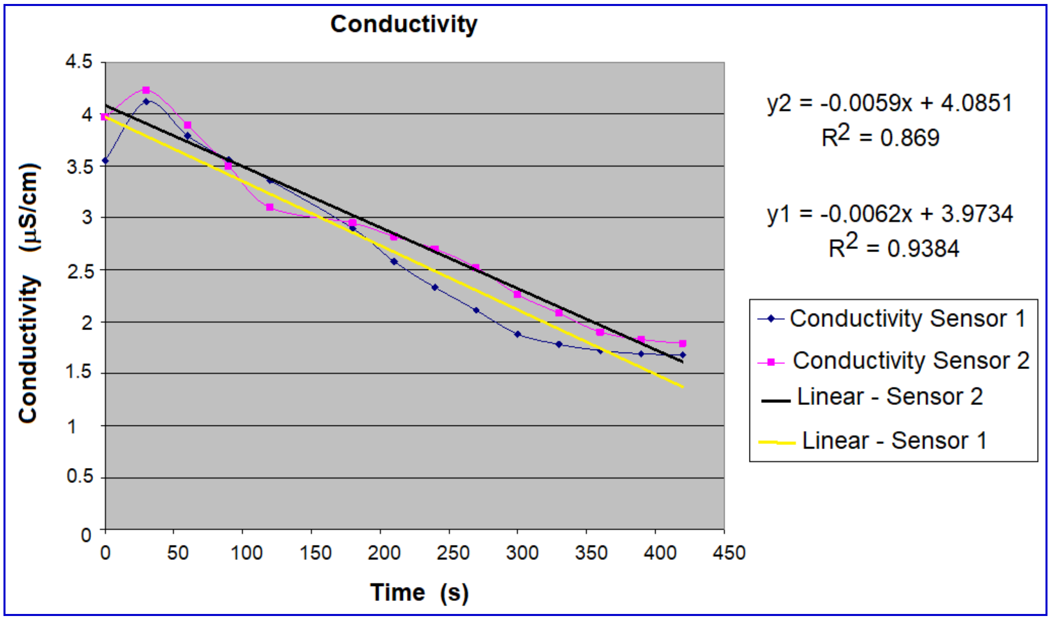

Figure 2: Comparison of conductivity measurements between the two transmitters

In the quantitative study was evaluated if either the temperature or the cable length would have intertwined as if they are complementary. The concept of P values and tests of hypotheses were conducted. The results are shown in Table I.

Table I: Effects of temperature and cable length in the conductivity measured

Conductivity Sensor 1			Conductivity Sensor 2		
Parameter	Effect	P-Value	Parameter	Effect	P-Value
Temperature (ºC)	0.13500	0.000	Temperature (ºC)	0.10167	0.000
Cable length	-0.1500	0.552	Cable length	0.00500	0.557
Temperature x Cable Length	-0.00833	0.153	Temperature x Cable Length	0.01167	0.1191
R^2	98.81%		R^2	95.35%	

It was considered whether the hypothesis is significant or not based on P-value. To quantify the strength of evidence against the null hypothesis it was advocated $P<0.05$ (5% significance) is a standard level for concluding that there is evidence against the hypothesis tested. As it was verified in Table I, the P values for temperature indicate effects on both conductivity sensors. Those results were predicted since the conductivity varies with temperature. By contrast, the length of the cables used in the conductivity meters has not shown any effect, which was expected since the material of both cables was the same and does not affect the measures.

4. Conclusions

This paper describes some tests performed with the equipment suggested to be added to the IPR-R1 Triga research reactor instrumentation. In this way, the IAEA's recommendations regarding online monitoring and parameters logging related to the coolant quality will be met. Many aging Triga reactor components worldwide have had to be replaced. The development of digital instrumentation and control systems has phased out the original systems based on now-obsolete vacuum tubes and obsolete solid-state circuitry, and many Triga research reactors had even to close down owing to the lack of end-users, budgetary constraints, or other issues. It is expected that the IPR-R1 Triga reactor at CDTN will have its instrumentation updated and that it will still be used for several years in research and training. The work presented here can be used for this purpose since the instruments used and the software developed demonstrated be a viable option to control the parameters of the reactor.

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