UPGRANDING OF THE IPR-R1 TRIGA NUCLEAR RESEARCH REACTOR INSTRUMENTATION AND CONTROL

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Abstract. *The IPR-R1 TRIGA nuclear research reactor is a pool type reactor cooled by natural circulation with a maximum thermal power of 250 kW. The IPR-R1 reached its first criticality on November 11th, 1960 at Nuclear Technology Development Center (CDTN). At that time the maximum thermal power was 30 kW and an electron tubes (vacuum tubes) control console were used. The power monitoring (neutronic flux) was made using mechanical strip chart recorders. This control was built in conformity with the American electrical and nuclear technical norms in that time. The control system of the IPR-R1 was changed in 1995. Although since the year's 80 was generalized the use of microprocessor technology and video monitors for visual interface, in the IPR-R1 control room it was used analogical system by relay-based logic, and were maintained the mechanical strip chart recorders (ink-pen drive) to measure, monitor and store the operational parameters. It was maintained the measure and the control of, practically, the same variables of the original system, although the reactor power already have been upgraded to 100 kW and began the studies to increase it to 250 kW, which is the current core configuration. For 250 kW operation the fuel heat transfer become important and new parameters should be used as safety operational limits. A state-of-the-art instrumentation and control system using microprocessor technology is proposed to replace the present analogical systems. The new system can eliminates most manual data logging, provides automatic or manual reactor operation modes, provides complete real-time operator display, replays historical operating data on monitor or printer, eliminates spare parts replacement problems and meets all applicable international standards as NRC and IEE specifications. This paper describes the research project in process in CDTN, supported by the "Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG)", that has as objective the modernization of the IPR-R1 TRIGA reactor instrumentation and control of the operational variables. The project also will improve the accomplishment of neutronic and thermal-hydraulic experiments, foreseen in the CDTN research program.*

Keywords: *TRIGA research reactor; instrumentation, control; instrumented fuel element; nuclear reactor.*

1 .INTRODUCTION

A research reactor is defined as a designed to support a self-sustaining neutron chain reaction for research, development, educational, training, or experimental purposes, and the production of radioisotopes. The TRIGA IPR-R1 (Training, Research, Isotopes, General Atomic) is a Mark I type, cooling by light water, open-pool design and having as fuel an alloy of zirconium hydride and uranium enriched at 20% in ^{235}U. The IPR-R1 has been operating for 49 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. The TRIGA console, installed in the 1990s, use discrete component, solid-state devices.

The CDTN intends to adopt its laboratories to ISO's standards (International Organization of Standardization) to show reliability in its results (ISO, 2009). The international standardization began for the electrotechnical field, with the formation in 1906 of the International Electrotechnical Commission (IEC, 2009). This commission, which Brazil is member, is an international organization of electric electronics and related technologies standardization, and some of its norms are developed together with ISO. According to ISO 9000 standard an institution must follow some steps and take care of certain requirements to be certify. For example: it calibrate the processes parameter to assure the quality of product or service; to implement and to keep adequate registers and necessary to ensure the traceability of the process, a systematic review of procedures and quality system to ensure its effectiveness. The IPR-R1 instrumentation upgrade also contemplates the International Atomic Energy Agency (IAEA) recommendations, for safe research reactors operation (IAEA, 1999a).

2. THE IPR-R1 TRIGA REATOR

The IPR-R1 TRIGA at CDTN is mainly used for neutron activation analysis, isotope production, neutronic and thermal hydraulic research, and for training of Brazilian nuclear power reactor operators. The regime of operation of the reactor is about 8 hours per day, but only one day per week. Thus, its time of use is very low. Like other TRIGA reactor the IPR-R 1 could also be used in many diverse applications, including production of radioisotopes for medicine and industry, nondestructive testing, basic research on the properties of matter, education, neutron radiography, reactor physics including burnup measurements and calculations, treatment of tumors by boron neutron capture therapy (BNCT), prompt gamma neutron activation analysis (PGNAA), solid state physics, semiconductor doping, environmental studies and researches of advanced materials.

Dalle (2005) performed calculations for IPR-R1 reactor using the codes: Monte Carlo (MCNP), ORIGEN2.1 and MONTEBURNS. The results showed 4% of average burnup of ^{235}U in 45 years of operation. This represents a reduction of 96 grams of ^{235}U in mass in relation to the initial value of 2.3 kg. This burning is much less than the maximum recommended by the fuel manufacturer that is 20%. Therefore, if the IPR-R1 expands its research activities with daily operations, it is estimated that their life would be about 25 years more.

The TRIGA reactor uses uranium-zirconium hydride (U-ZrH) fuel, which has a large, prompt negative thermal coefficient of reactivity, meaning that as the temperature of the core increases, the reactivity rapidly decreases — so it is highly unlikely, though not impossible for a meltdown to occur. A reactor with a negative temperature coefficient of reactivity is therefore inherently self-controlling and safe.

When the fuel temperature reaches 550 ºC in the TRIGA reactors, occurs a phase transformation in the alloy U-ZrH, increasing the fuel volume and the pressure on the cladding. Operation above this temperature may cause failure in the cladding. Therefore, the temperature of 550 ^{o}C was defined as an operational limit for the IPR-1 TRIGA reactor (CDTN/CNEN, 2007).

The IPR-R1 TRIGA is an open-pool type reactor and the fuel refrigeration is done by natural circulation. The buoyancy force induced by the density differential across the core maintains the water circulation through the core. Countering this buoyancy force are the pressure losses due the contraction and expansion at the entrance and the exit of the core as well as the acceleration and friction pressure losses in the flow channels. Figure 1 shows the cooling process and a photograph of the reactor pool. The water enters into each core channel by a hole of 15.9 mm in diameter, located in the lower grid plate.

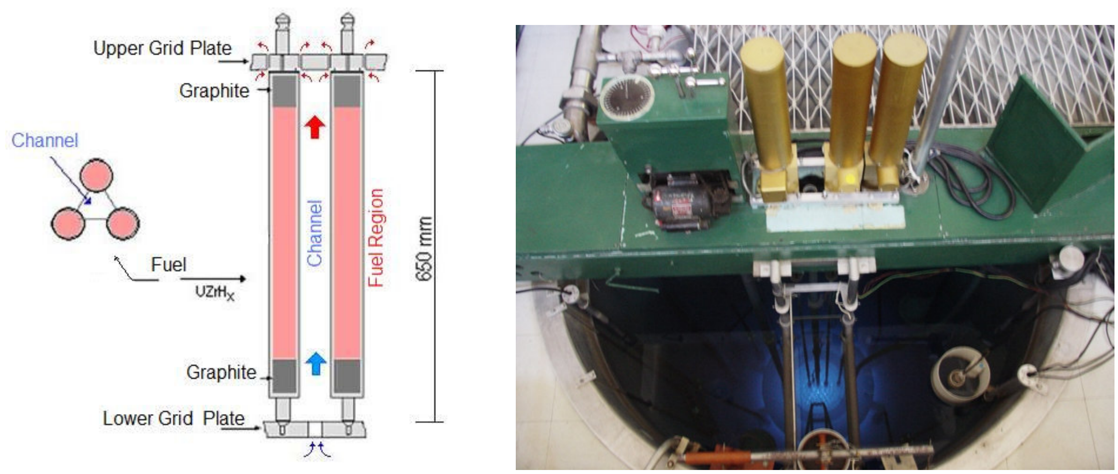

Figure 1. A schematic of a flow channel and top view of the IPR-R1 TRIGA pool and core

As the reactor core power increases, the heat transfer regime from the fuel cladding to the coolant changes from single-phase natural convection to subcooled nucleate boiling. Experiments carried out by Mesquita (2005) indicated that subcooled boiling occurs at the cladding surface in the central channels of the reactor core at power levels above approximately 60 kW. With the reactor operating in the power of 250 kW, the fuel temperature in the core hottest position is about 300 ^{o}C.

In 2004, was inserted in the IPR-R1 core a instrumented fuel element (purchased in 1971) to perform thermal hydraulic experiments during the commissioning tests to operate at 250 kW (Mesquita, 2005). The instrumented fuel element is in all respects identical to standard fuel elements, except that it is equipped with three chromel-alumel thermocouples (K type), embedded in the fuel meat. The sensitive tips of the thermocouples are located in the center of the fuel element. The instrumented fuel stayed in the core until July, 2007. During this time it monitored the temperature at the hottest core position, in all reactor operations. After about three years of monitoring the core temperature, the three thermocouples failed in their measures because of the rupture in the connector placed between the thermocouples wire and extension cables. On August 2007, the instrumented fuel element was removed from the core. On October, 2008 started the works to recovery the thermocouples continuity, and the works was concluded with partial success (Mesquita et al. 2009).

It is emphasized here the importance of the presence of at least two instrumented fuel elements in the reactor core as current specification of General Atomics Electronic Systems Inc (2008), and the example of several existing TRIGA reactor in the world. The IAEA (1995) recommends the monitoring of the core temperature in all operations of research nuclear reactor. The fuel temperature is the principal operational nuclear reactor variable and there shall be a system that monitors this parameter and provides a signal that can be utilized in a automatic mode to prevent the value of the temperature from exceeding the safety limit. The fuel temperature was adopted in the IPR-R1 TRIGA Safety Analysis Reporter (CDTN/CNEN, 2007) with a safe operational limit. The fuel temperature should not exceed 550 ^{o}C. In some operations of the IPR-R1 reactor at 250 kW the fuel center temperature in the hottest core position reached 310 °C (Mesquita, 2005). As Böck and Villa (2004) in the TRIGA reactor at Vienna, which has two instrumented fuel elements in the core, the set-point for automatic shutdown occurs when the fuel temperature exceeds 350 ^{o}C. The instrumented fuel element is the main equipment used for operational parameters investigation in the neutronics and thermal hydraulics experiments performed in IPR-R1 TRIGA reactor. In addition to recover the present instrumented fuel element, it is recommended the purchase a new one, whose current price is about 80,000 €, as proposed by the manufacturer TRIGA International (2008).

Figure 2 shows the reactor cooling system diagram and the localization of the instrumentation used to monitor the operational parameter. Figure 3 shows the present IPR-R1 analog control console.

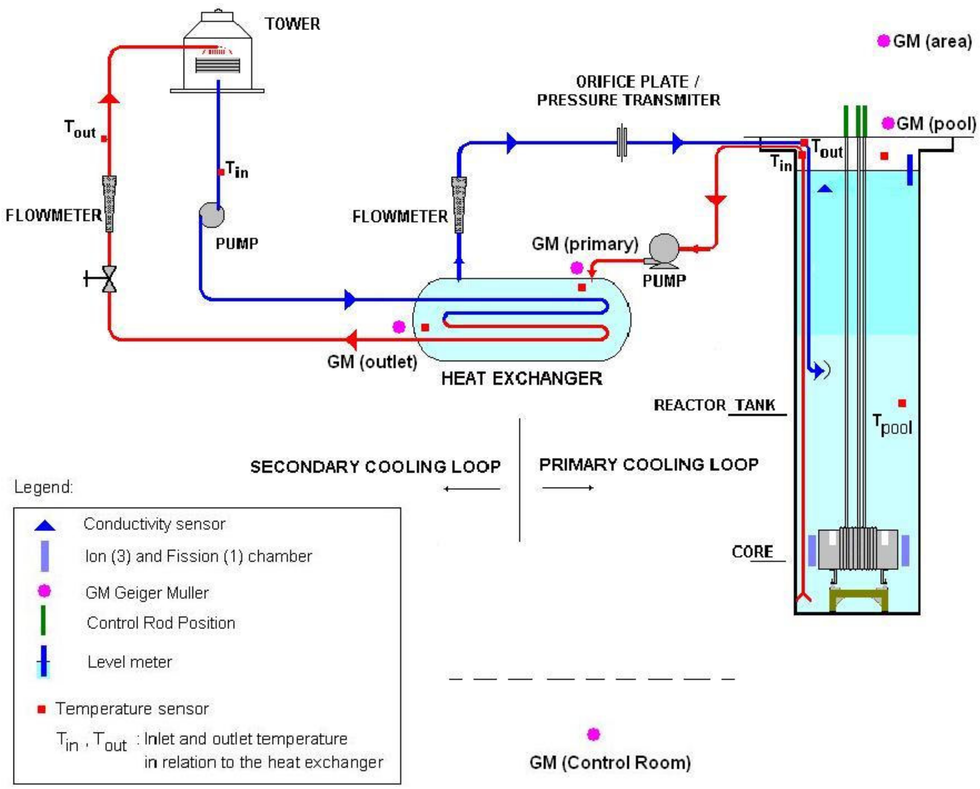

Figure 2. The IPR-R1 TRIGA reactor cooling system and instrumentation distribution

Figure 3. The present IPR-R1 TRIGA reactor analog control console

3. OPERATIONAL LIMITS AND CONDITIONS (OLC) AND SAFETY LIMIT (SL)

The operational limits and conditions are a set of operating rules which normally include safety limits and safety system settings on relevant variables and parameters of the reactor, limiting conditions on equipment and operational characteristics of the reactor, surveillance requirements and administrative requirements. The OLC are approved by the regulatory body for safe operation of the research reactor facility. Safety limits (SLs) are limits on process variables within which the operation of the research reactor facility has been shown to be safe. Safety limits are necessary to protect the integrity of the principal physical barrier that guards against uncontrolled radioactive releases in all operational states. For many research reactors this principal physical barrier is the cladding of the fuel rods, whose temperature is maintained below a certain limit by cooling so that cladding integrity is ensured. For some reactors, the principal physical barrier is the primary coolant boundary.

Important process variables are measurable parameters that individually or in combination reflect the basic physical condition of physical barriers. They may include fuel temperature, reactor power, reactor coolant flow rate, reactor coolant inlet or outlet temperature, pool level, or coolant pressure. If the temperature is measured in only one location in the core, the measured temperature must be correlated to the maximum fuel temperature in the core.

The fuel temperature is the principal SL of an nuclear reactor, if there aren´t instrumented fuel element in the reactor core, this SL is expressed in terms of other parameters which are measured, such as thermal power level, coolant flow though the core, inlet or outlet temperature of coolant, coolant pressure and height of coolant above core. The selection of the SLs is of paramount importance. For example, onset of nucleate boiling, which is often used to establish an SL, represents an undesirable but not unsafe condition for the reactor. Departure from nucleate boiling and flow instability, however, are conditions which, if approached too closely, would present a safety problem and may therefore be used to establish SLs. For this reason, reactor operation is limited to a power level such that the maximum heat flux in the fuel element is only a fraction of the burnout heat flux. In some instances (e.g. for low power research reactors), the safety limits may be very conservatively set (IAEA, 1995).

The operating organization is responsible for the preparation and submission of the OLC to the regulatory body, as one of the bases for the grating of a license. The operating organization should consult the designer in preparing the OLC and should ensure that the operating personnel know them. In addition, the proposed OLC should be reviewed by the safety committee before submission to the regulatory body.

The operational limits can change if were observed inadequacy of existing parameter values or requirements, experience gained during reactor operation, or technological progress. Therefore, the OLC are normally reviewed and changed as necessary during the reactor lifetime. The operating organization shall keep adequate records to facilitate its audits and inspections to verify that the operation of the facility is compliance with the OLC.

For each parameter for which a safety limit is required, and other important safety related parameters, there shall be a system that monitors the parameter and provides a signal that can be utilized in an automatic mode to prevent the value of that parameter from exceeding the safety limit. The set point for this protective action that would provide the minimum acceptable safety margin is defined as the safety system setting. Safety system settings shall be established for all operational modes of the reactor. In the determination of a safety system setting, the process and measurement uncertainties, and the response of instrumentation and calculational uncertainties shall be taken into account (IAEA, 1995).

4. THE EVOLUTION OF INSTRUMENTATION AND CONTROL (I&C) FOR NUCLEAR REACTORS

Since the first criticality of a nuclear reactor carried out by Fermi and collaborators on December 2, 1942 at the Chicago University, there was concern in the monitoring with safety the parameters involved in the chain reaction. Fermi used in the pioneer experience: Geiger counters, oscilloscopes, thermometers and a strip chart recorder (galvanometer) to monitor the neutrons flux (U. S. Department of Energy, 1982). Figure 4 shows the record of the first self-sustaining chain reaction.

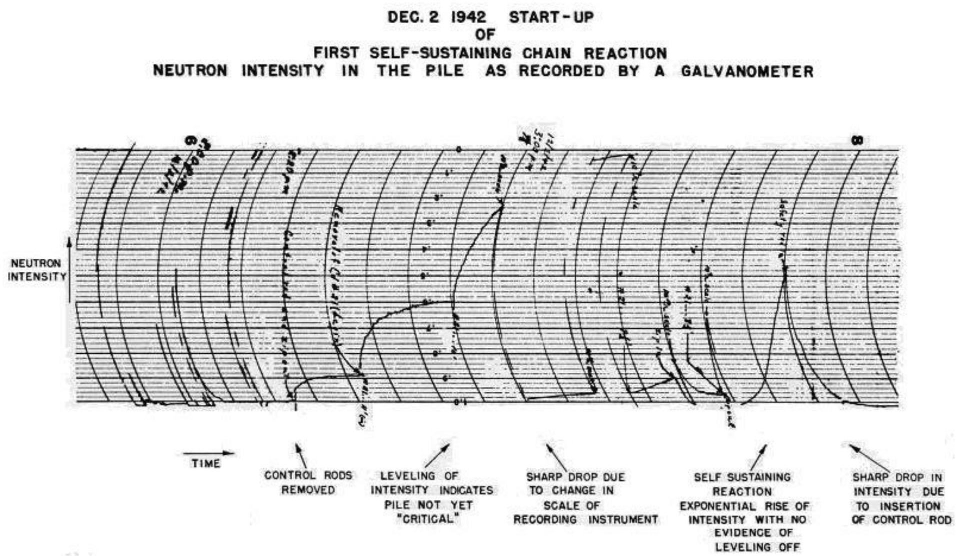

Figure 4. The "Birth Certificate" of the Atomic Age, the galvanometer chart that indicated the rise in neutron intensity associated with the first controlled chain reaction (U.S. Department of Energy, 1982)

The evolution of control systems used in nuclear power plants and research reactors is briefly described below. In general, this development follows the trend occurred in other processes of the conventional industry. Further information can be found in the following publications: NRC (2009), IAEA (1999a, b), Blake (2006), Holcomb e Wood (2006), Swaminathan (2005), Srivastava (2004) e Uhrig e Carter(1993).

- From 1950 to 1960, on the first nuclear reactors, vacuum tube electronics were used in the control system. The visualization of variables and its record were made by mechanical strip chart records, and the control logic was made by electromagnetic relays.
- From 1960 to 1970, discrete transistorized solid state devices were used in the instrumentation. The operational parameters were displayed on Cathode Ray Tube (CRT) video monitor for monitoring. The variables were still stored in strip chart records, and the protective and annunciation system of the plant is relay-based logic.
- In the 1970s, the transistors were used in almost all electronic devices. Start up the use of digital techniques and integrated circuits. The control systems were analog and the main measurement instruments have become digital, i.e., have memory and can be programmed.
- In the early 1980s, the integrated circuits dominate the electronic, and informatics technology is in wide expansion. Besides the digital measuring instruments, is also the start the digitalization of protection and security systems. The digital instruments allow the use of hardware and software for the process control. The control consoles are equipped with video monitors (CRT) for displaying the operational parameters; the values of the variables are stored on computerized operator information system. It is started the interconnection of computers through networks.
- Since 1998, with the expansion of the use of PLC's (programmable logic controllers), which appeared in the American automobile industry in the 70s, digital systems will be used in all the control process, including the control rod drive mechanism performed by an electric stepping motor (General Atomics, 2008).

Control engineering has evolved over time. In the past, humans were the main method for controlling a system. More recently electricity has been used for control and early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical control decisions. The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls. PLCs have been gaining popularity on the factory floor and will probably remain predominant for some time to come. Most of this is because of the advantages they offer:

- cost effective for controlling complex systems;
- flexible and can be reapplied to control other systems quickly and easily;
- computational abilities allow more sophisticated control;
- trouble shooting aids make programming easier and reduce downtime;
- reliable components make these likely to operate for years before failure.

5. NUCLEAR REACTORS INSTRUMENTATION AND CONTROL STANDARDS

From the inception of the IAEA in 1957, 15 years after the first criticality of the first nuclear reactor, there has been broad interest at the IAEA in the benefits to be derived from the safe operation of research reactors by IAEA Member States. The first publication of the IAEA on research reactor safety was as early as 1960 (Safety Series No. 4), year of the first IPR-R1 TRIGA reactor criticality. This edition recommended the monitoring and recording of operational parameters. This IAEA publication has received continuous attention adapted to engineering developments.

With respect to the safety parameters and operating procedures for research reactors the most recent publication is the Safety Series No. 35-G6 “Safety Guide Operational Limits and Conditions of Research Reactors” (IAEA 1995).

Specifically on instrumentation and control in nuclear reactors the IAEA's latest publication is the *Safety Guide* No. NS-G-1.3 “Instrumentation and Control Systems Important to Safety in Nuclear Power Plants”, of the series IAEA Safety Standards, related to power reactors (IAEA, 2002). With respect to the control rooms is introduced the concept of human-machine interfaces. Effective human–machine interfaces for systems important to safety are necessary to provide the operator with accurate, complete and timely information on plant status and to enable proper operation of the systems controlled by the I&C systems. The automatic performance is more reliable than the operator actuation on the process. The information system records or prints short and long term trends of process variables, important to safety for immediate or subsequent analyses, and for reporting within the operating organization and to external authorities. Records or printouts are maintained in and around the main control room (and are possibly stored on a computer hard disk for ease of access) for analog process variables and for binary signals, in order to make available chronological information about the performance and behaviour of the plant. This information is necessary as: (1) backup information for shift operators (giving short and long term trends), (2) general operational information for the plant management, and (3) long term analyses of operation and accidents (IAEA, 2002).

6. NUCLEAR REACTORS DIGITAL CONTROL

Digital instrumentation and controls (I&C) systems have been in use for over three decades in various applications. Fossil power plants and refineries have been using integrated digital I&C systems since the 1980s. Digital I&C systems are widely used in almost all industrial applications in one form or another. The use of microprocessors and computers is not new in nuclear power plants. Early applications were limited to programmable logic controllers and plant process monitoring computers. In the 1980s, digital technologies were integrated into control systems for various subsystems, starting with the auxiliary systems and then moving to primary systems. By the 1990s, microprocessors were being used for data logging, control, and display for many no safety-related functions (NRC, 2009).

To ensure that nuclear reactor continue to provide reliable performance and meet current safety standards, the I&C systems should be periodically modernized. The nuclear industry has faced problems in finding spare parts for analog I&C systems whose hardware was produced 20-30 years ago. Physical ageing of equipment combined with lack spare parts has increased failure rates and operation and maintenance costs. Furthermore, a number of vendors have reduced their support for analog systems, and there may be instances in which the original supplier is no longer in business. Owing to the considerable improvements in the reliability of digital electronics in recent years, many nuclear utilities have decided to replace old analog I&C systems by computerized systems (IAEA, 2002).

Advances in digital technology provide the following additional incentives for upgrades:

- more complex functions can be performed;
- greater precision can be achieved;
- a greater amount and variety of information can be compiled and used;
- the user interface can be made more flexible;
- it is easier for the system to detect and deal with anticipated internal faults;
- functional changes can be made without physical changes or even physical access;
- standard processors of known reliability can be used in many applications.

Digital computer systems are used in I&C systems important to safety to perform functions of protection, data acquisition, computation, control monitoring and display. If properly designed, they can offer the advantages of improved reliability, accuracy and functionality in comparison with analog systems. The computer system may take many forms, ranging from a large processor supporting many functions to a highly distributed network of small processors devoted to specific applications. Computer systems may be used to advantage in detecting and monitoring faults internal and external to plant systems and equipment important to safety.

The first fully digitalized I&C system was integrated into the Kashiwazaki-Kariwa boiling-water reactor (Japan) in 1996. This was followed by other Japanese reactors. United States, France, the United Kingdom, Korea, Sweden, and other countries have also implemented digital I&C systems in their nuclear power plants. All new nuclear power plants are being designed with integrated digital I&C systems as the backbone of protection, controls, alarms, and display and monitoring (NRC, 2009). Most research reactors built since 1980 have their controls performed by digital systems. Several reactors manufactured before this year, have changed their systems from analog to digital. In the documents IAEA (2000, 1998, 1999a,b); NRC (2006) e IEEE (2003), can be found characteristics and advantages in digital control systems utilization in nuclear reactors.

6.1 Relationship between reactor operators and instrumentation

The operator should not "be a part" of a safety channel, i.e. proper operation of the safety channels should never be dependent on an operator since he is much less able to perform a given operation consistently and reliably than an instrument. Instead, the safety system should be designed to safeguard the reactor in spite of any simple error operator might make. The designer is often faced with the choice of designing the control system so that either the operator performs a great number of functions or it is as automatic as possible and the operator is free to observe the instrumentation and to watch for any sign of malfunction. If the operator is given too many functions to perform, all his time may be occupied with repetitive actions involved in controlling the reactor or some equipment associated with the reactor. An instrument can generally do this better and more reliably than can a human operator (IAEA, 1965).

7. UPGRADE OF IPR-R1 TRIGA INSTRUMENTATION PROPOSAL

There are two projects in progress, supported by the *Fundação de Amparo à Pesquisa do Estado de Minas Gerais* (*FAPEMIG*), aiming to improve the IPR-R1 TRIGA reactor instrumentation (Mesquita, 2008 and Mesquita, 2006). The funds are being used to purchase new instruments of control and measure. To monitor the water from the primary loop were purchased two digital water conductivity transmitters and one digital pH meter. These instruments measure the water temperature and carry out the correction of the readings, and have output for data acquisition system. It also bought a USB interface card, and the supervisory software LabVIEW® (Laboratory Virtual Instrument Engineering Workbench).

Other instruments will still be purchased as: detector for monitoring the control room radiation level, equipment for visual reactor core monitoring, a nobreak for the control system, step motors for control rods, etc.

7.1 Full digital control system

The implementation of the new equipment described above and an efficient data acquisition system increases considerably the reliability of the IPR-R1 reactor instrumentation, even maintaining the current analog control logic. However, the total change of analog control for a digital one would place the IPR-R1 in the state-of-the-art instrumentation and control system. Bellow is presented, as an example, some specifications of a control system designed by General Atomics Electronic Systems Inc. (2008), the reactors TRIGA builder's, for the IPR-R1. The General Atomics (GA), since 1980 provides digital control console to its reactor and from other reactor manufacturers. As information provided by Ray (2008), the software developed by the General Atomics manages 13 research reactors around the world. The GA reactor instrumentation and control system shall be designed and manufactured to comply with the guidance given in American Nuclear Society (ANS), ANSI Guide ANSI/ANS 15.15-1978, "Criteria for the Reactor Safety Systems of Research Reactors" and the IAEA Safety Series 35-S1. The GA control system includes:

- most of manual data logging can be eliminated;
- provides automatic or manual reactor operation modes;
- provides complete real-time operator display;
- replays historical operating data on monitor or printer;
- eliminates spare parts replacement problems;
- meets all applicable NRC and IEEE specifications.

Instrumentation and control systems for all new TRIGA reactors have now evolved into compact, microprocessor-driven systems. As with previous generations of the I&C systems, they are designed to enable inexperienced students and nontechnical personnel to operate the reactor with a minimum of training, with simplicity afforded as a result of the inherently safe characteristics derived from the physical properties of the U-ZrH fuel. Four operating modes are typically available: manual, automatic, pulsing, and "square wave," the latter being a one-button startup sequence for bringing the reactor up quickly (a few seconds) to its operating steady-state power level. TRIGA reactors have also been licensed to operate in unattended mode, again as a result of the protection afforded by the safety characteristics of the U-ZrH fuel (Fouquet et al., 2003). Figure 5 shows the simplified control system block diagram, and it can be noted the monitoring of the fuel temperature. Figure 6 shows the design of the digital control system console.

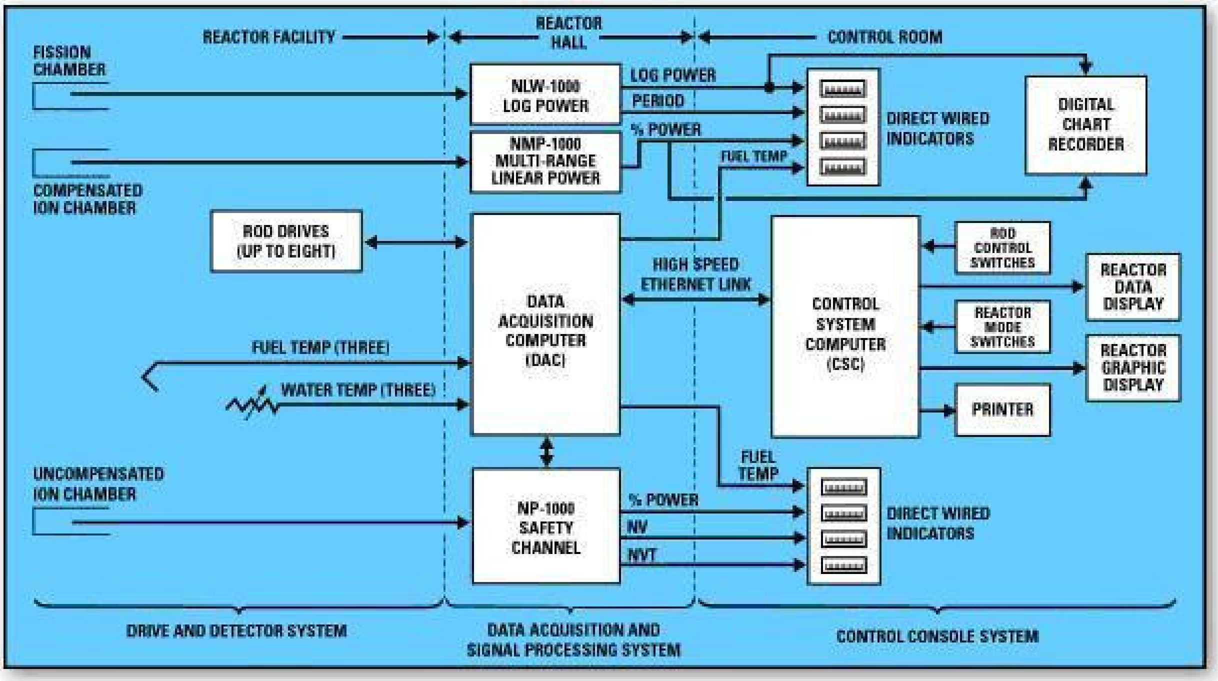

Figure 5. Nowaday simplified research reactor control system block diagram (General Atomics, 2008)

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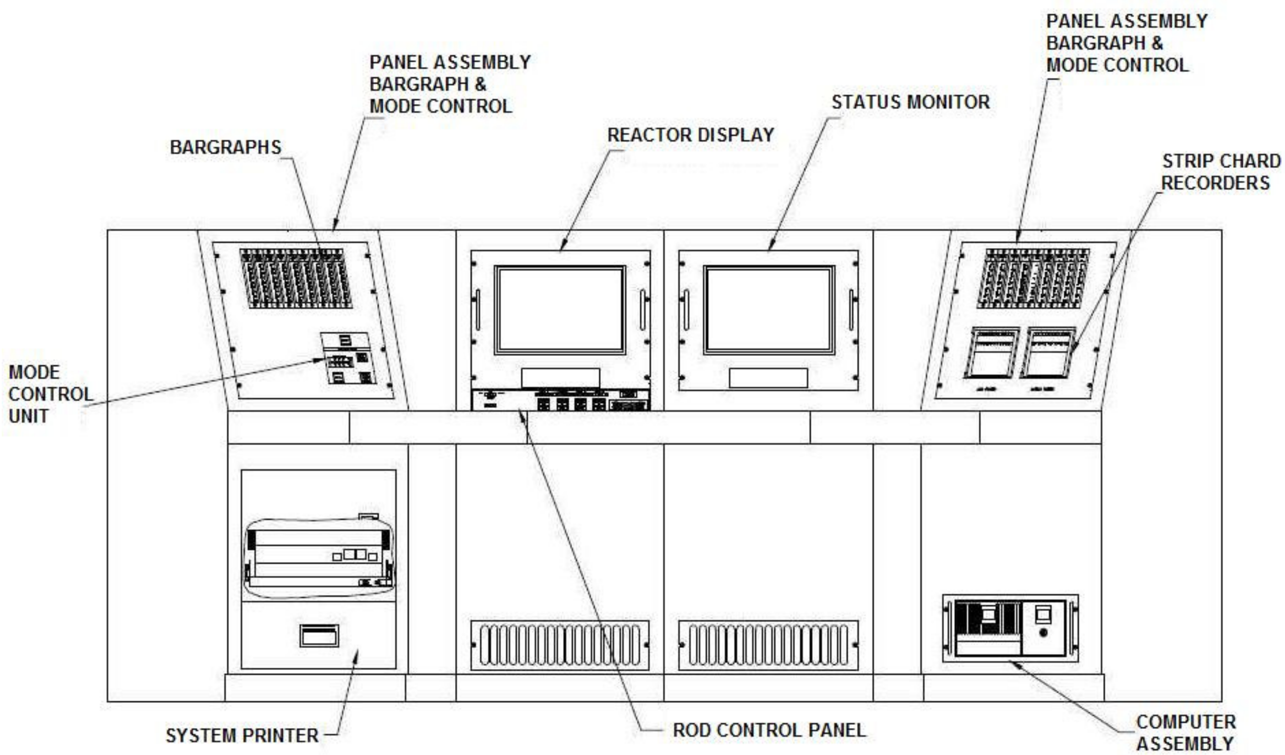

Figure 6. Digital TRIGA control system console designed by (General Atomics, 2008)

8. CONCLUSION

The instrumentation and control systems of a nuclear reactor have three major roles. Firstly, they are the 'eyes and ears' of the operator. If properly planned, designed, constructed and maintained, they provide accurate and appropriate information and permit judicious action during both normal and abnormal operation. They are therefore, with the human operator, vital for the safe and efficient operation of the plant. Secondly, under normal operating conditions they provide automatic control, both of the main plant and of many ancillary systems. This allows the operator time to observe the plant behaviour and also to monitor what is happening so that the right corrective action can be taken quickly, if required. Thirdly, the I&C safety systems protect the plant from the consequences of any mistakes which the operator or the automatic control system may make. Under abnormal conditions they provide rapid automatic action to protect both the plant and the environment (IAEA, 1999b).

The IPR-R1 TRIGA reactor instrumentation and control system is now over 20 years old and is no longer representative of a typical reactor control room. A IPR-R1 reactor control console is based on logic and action of electromagnetic relays and most of the existing instruments are the first generation (galvanometer). These systems are mechanical and are subject to waste and failure. From the 1980s, began to be used and digital indicators and now are being used virtual instruments (video monitors). 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 plant operations.

The new system would be based on microprocessor, and would utilize displays that are typical of state-of-the-art control rooms. The new reactors consoles were designed to provide the operation with safe and reliable in different modes as: manual, automatic, square wave, and pulse. All control functions can be implemented with computer technology. One of the design specifications was to use state-of-the-art digital equipment to improve reliability, increase the flexibility of upgrading, and reduce lifecycle costs. In addition, it provides a human-machine interface that the students would see in industry. The new control and safety system allows the IPR-R1 TRIGA to remain an active research center to educate students (from grade school through doctoral levels).

The IAEA has been stimulating its members to elaborate strategic planning for research reactors. The IPR-R1 TRIGA reactor has only 4% of average uranium burnup. With the retaking of the nuclear activities in Brazil, the increase is foreseen in the demand of use of the IPR-R1 in the nuclear power station operators formation, uranium characterization of new sources, tracer and radioisotopes production for the industry, etc. Considering that the reactor will be operate in the new power of 250 kW, and it happens an expansion in the service and research activities, it is foreseen that the end of the useful life of the reactor would happen in about 25 years.

9. ACKNOWLEDGEMENTS

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