Remote level radiation monitoring system for the brazilian IEA-R1 nuclear research reactor for routine radiation protection procedures and as a support tool in case of radiological emergency

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Abstract. Nuclear facilities must monitoring radiation levels to establish procedures for radiological protection staff involving workers and the public.

The Instituto de Pesquisas Energéticas e Nucleares – IPEN has 5 important plants and in case of accident in one of them, the Institute keeps operational an Emergency Response Plan (ERP). This document (ERP) is designed to coordinate all procedures to assure safe and secure conditions for workers, environment and the public.

One of this plants is the IEA-R1 reactor, it is the oldest nuclear research reactor (pool type) in Latin America, reached it first criticality in September of 1957. The reactor is used 60 hours/week with continuous operation and with nominal power of 3.5 MW, with technical conditions to operate at 5 MW thermal power.

This reactor has a Radiological Emergency Plan that establishes the implementation of rules for workers and people living at the exclusion area in the case of an emergency situation.

This paper aims to describe the implementation of a computational system developed for remote radiation monitoring, in a continuous schedule of IEA-R1 nuclear research reactor containment building. Results of this action can be used as a support mean in a radiological emergency. All necessary modules for radiation detection, signals conditioners and processing, data acquisition board, software development and computer specifications are described.

The data acquisition system operating in the reactor shows readings concerned to radiation environment such as activity, doses and concentration in real time and displays a periodical data bank (Data Base) of this features allowing through the surveillance of the operation records anytime, leading to studies and analysis of radiation levels. Results of this data acquisition are shown by means of computer graphics screens developed for windows environment using Visual Basic software

KEYWORDS: Radiation Protection, Incidents & Accidents

1. Introduction

The Instituto de Pesquisas Energéticas e Nucleares -IPEN has 5 important nuclear or radioactive installations and in the case of an accident in any one of them, the Institute has a Radiological Emergency Plan (PER). This plan is designed to coordinate all procedures to secure safe conditions for workers in these installations, for community living in the neighborhood and the environment.

One of major nuclear installation at IPEN is the IEA-R1 research reactor. It is an open swimming pool type reactor operating since 1957. The reactor presently operates 60 hours a week of continuously with a nominal 2MW thermal power [1].

The reactor has a specific Radiological Emergency Plan – REP that establishes procedures and rules for its workers and for other people, living at the exclusion area, in the case of an emergency situation. Among these procedures, there is one, which requires that the installation has technical conditions to obtain precise information regarding radiation levels of the affected areas in the case of an emergency situation.

2. Objetives

In a emergency situation at IPEN there is an implementation of REP with action of measures to be taken inside the facility. Within the procedures, there is a needing for information regarding radiation levels of the affected area.

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In order to measure the radiation level at different points inside the reactor building without unnecessary exposure risk to workers an instrumentation designed for radiation monitoring was developed. This system will allow a remote surveillance of radiation levels, registering radiation doses as well as activities of some specific radioisotopes inside the reactor containment building.

In order to implementing this evaluation without workers exposure to unnecessary risks, it can be used a monitoring system instrumentation designed to manage radiation monitoring, allowing a remote surveillance of radiation levels, acquiring exposition measurements as well as isotopes activities and radiation doses inside reactor containment.

It will be described here the implementation of a computational system for remote monitoring in a continuous schedule of IEA-R1 reactor containment building. The results of this continuous monitoring can be used as a support in a radiological emergency situation. The radiation level data are shown by means of a computer graphics screen developed for Windows environment using Visual Basic software [2].

3. Materials and Methods

In the reactor building, the radiation monitoring is carried out by means of area and duct radiation monitors installed at different places as follow:

MA1, MA2 - reactor core support bridge
MA3-north face in the pool hall
MA4 - near Beam Hole #8 – first floor
MA5- experimental hall – first floor
MA6- south face of pool – first floor
MA7- machine room
MA8- east face of pool – first floor
MA9- water treatment system – machine room
MD1- air exhausts system of experimental hall – First Floor
MD2- air exhaust system pool hall
MD3- general air exhausts system
MD4- gas outlet in the chimney Noble gas monitor- in the pool hall ^{131}I monitor- in the pool hall

Area radiation monitoring is made through a detector model 897A-210 and a signal processing module 956A-201 both from Victoreen.

For area monitoring there is a channel measurement for each one of 8 monitors (MA1 to MA8), each detector module is constituted of a Geiger Muller device as radiation detector and an electronic circuit that deliver pulses proportional to the local dose rate level. This pulses, from the detector module, follow to a signal processing module (total of 9) located in the reactor control room, displaying a digital information about local dose rate in miliroentgen or milirad per hour (mR/h). Fig 1 shows 4 of the 9 area monitor processing modules close up installed in the control room.

In the operational routine a radiological technician records the dose rate values in microSievert per hour (µSievert/h) using a math conversion in a 4 times a day schedule.

Figure 1 Area Monitors modules (MA1 to MA4) located in the reactor control room

Duct radiation monitoring is made through a photomultiplier-preamplifier detector 943-35 and a 942A-200 processing module both from Victoreen.

Processing is done using a crystal cintillator coupled to a photomultimplier device and an electronic preamplifier supplying pulses proportional to local dose rate. As in the case of area monitoring, this pulses follow to a processing module (total of 4) in the control room.

This module displays digital information in counts per minute (cpm). In practical routines this values are recorded by the radiological technician 4 times a day (routine operation). Fig.2 shows 4 monitors invlved in radiaiton duct monitoring.

Figure 2 Duct monitors modules (MD1 to MD4) located in the reactor control room

There are another 2 types of equipment for special monitoring:

- ^{131}Iode monitoring for dose evaluation (in cpm) at the pool room, constituted by a NaI crystal coupled to a photomultiplier device and a monochannel electronic module calibrate for the ^{131}I nuclide energy.

- Noble Gases monitoring (MGN), also in the pool room, to measure gases such as Kr, Xe, Br, Ar, Rd concentration, in Bq/cm^3.

4. Data acquisition system

Each one of area, duct or gases monitors process the signal from the remote detectors modules displaying the dose, dose rate or concentration in a digital form.

Table 1 shows the variables involved, their voltage level and the transfer function to convert volts (0 to 10V) to dose (cpm), dose rate (μSievert/h) or concentration (Bq/cm^3). This 0 to 10 volts signal are linked to a data acquisition board (AT-MIO-16E) from National Instruments, inserted in the motherboard of a PC computer and through an 8 diferential channels configuration does the data acquisition and processing through an specific developed software [3, 4-5].

Table 1: Sgnal from modules and respective transfer function

Signal from	Range signal	Transfer function
Area Monitor	0 – 10 volts	$10\,e^{(V*0,5-1)}$
Duct Monitor	0 – 10 volts	$10\,e^{(V*0,5+1)}$
Noble Gases Monitor	0 – 10 volts	$10\,e^{(V*0,5+1)}$
Iode Monitor	0 – 10 volts	$10\,e^{(V*0,5+1)}$
Dose rate algorithm	Volts=V	$0,0081\,e^{10,641V}$

4.1 System Software

The software development was made using Microsoft Visual Basic software version 6.0.

The 8 data acquisition channels were configured as follow:

Channel 1 – MA1 – dose rate (μSievert/h)

Channel 2 – MA2 – dose rate (μSievert/h)

Channel 3 – MA3 – dose rate (μSievert/h)
Channel 4 – MGN – concentration (Bq/cm^3)
Channel 5 – MD1 – dose (cpm)
Channel 6 – MD2 – dose (cpm)
Channel 7 – MD3 – dose (cpm)
Channel 8 – MD4 – dose (cpm)
The 8 channels of the acquisition board use signals ranging from 0 to 10 volts coming from the corresponding circuit modules (signals conditioning) in the Data Acquisition System (SAD) rack . Figure 3 shows relation data flux diagram and relation between program, data acquisition and the user.

Figure 3 Software block diagram for acquisition, processing and display the radiation variables
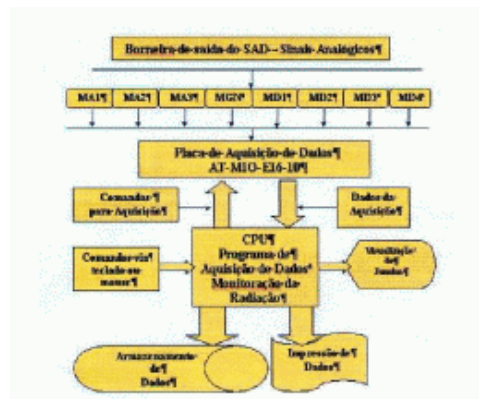
The software development requirements were the following:
a) to show the variables involved in radiation monitoring in a continuous form (real time);
b) to be able to generate files about radiation over the entire reactor schedule operation and in the reactor shut down situation;
c) to manage the following operation modes
- data acquisition and storage (NI DAQ Board)
- real time data screen
- data print
- build and manage a Data Bank of process (radiation) variables

5. Results

Eight screens were developed: presentation, radiation variables (industrial slider type), digital information (digital panel meter type), text display form, Data Bank (in Access MDB format) and 3 graphics screen. Fig. 4 shows the initializer process screen and the addressing to other related screen, each of them are showed below.

Figure 4 IEA-R1 Reactor core and the system initial screen


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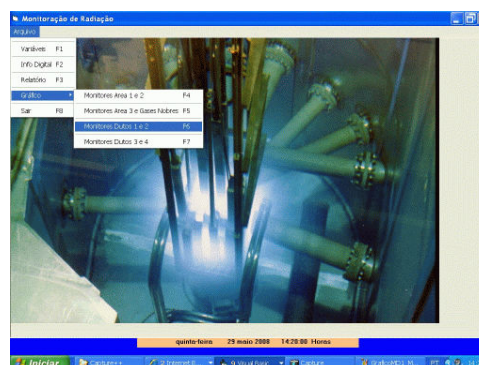
5.1 Software interfaces description

Figure 3 shows relation data flux diagram and relation between program, data acquisition and the user. User actions over the program are commands like start or end acquisition, screen calls and reports.

5.2 Software codes, screens and menus

Fig. 5 shows a screen with area, duct and nobles gases monitoring in digital form [2-5].

Figure 5 Digital information screen (Panel meter style) for area, duct and nobles gases monitoring
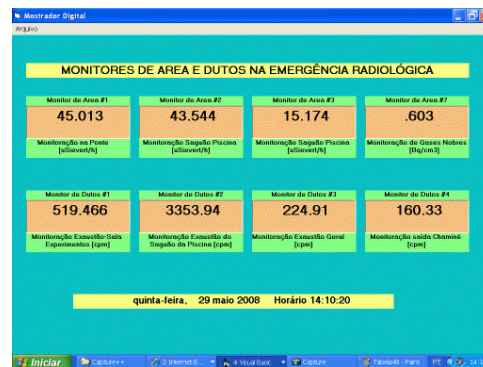
This data could be also presented in a industrial slider form for a fast verification of radiation levels as showed in Fig. 6 and Fig. 7 presents the report screen.

Figure 6 Information screen (industrial slider style) for area, duct and nobles gases monitoring

Figures 7 Report screen (Text style) for area, duct and nobles gases monitoring
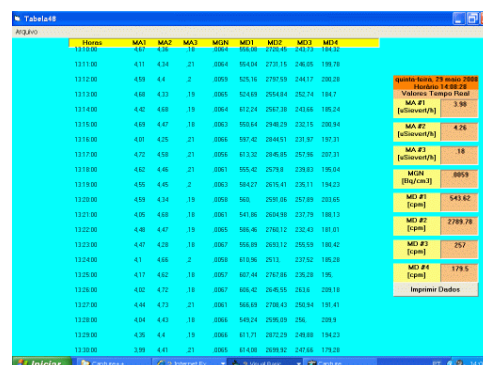

Fig. 8 shows the graphic of the area monitors MA1 and MA2 (dose rate) and Fig. 9 represents the response of MD1 and MD2 duct monitors.

All screens can be programmed for and acquisition every 1 second to 45 minutes schedule and automation variables data print every 30 minutes

Figure 8 Graphic screen of MA1 and MA2 area monitors response through the time
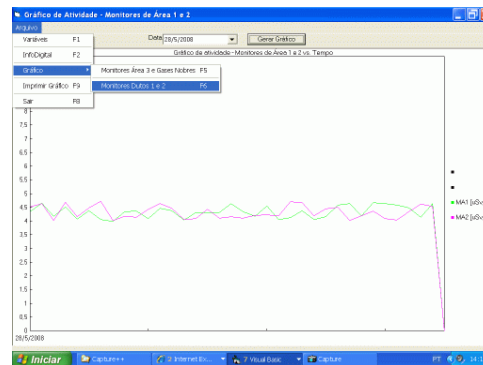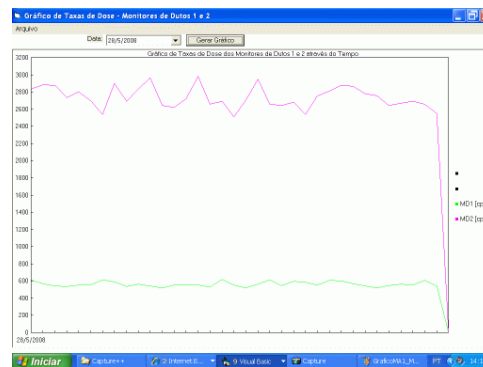

Figure 9 Graphic screen of MD1 and MD2 ducts monitors response through the time

This data acquisition system operating in the reactor shows readings concerned to radiation environment such as dose, dose rate and concentration in real time and store a periodical data bank (Data Base) of this features allowing operation records anytime, leading to studies and analysis of radiation levels. Fig. 10 shows the Data Bank screen.

Figure 10 Data Bank screen showing the data storage in MDB Access format with selected date
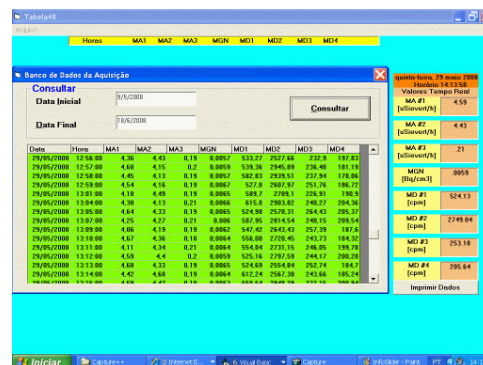
5.3 System requirements

The recommended system configuration is the following:
 - Motherboard with Pentium 1 CPU 1 GHz
 - Hard Disk 10 GB
 - LAN Board 10/100 MHz

- Microsoft Visual Basic 6.0 software
- Data Acquisition Board AT-MIO-16E-10
- Operational Driver for DAQ Board
- Software MONRAD for data acquisition and processing

6. Conclusion

The radiation monitoring instrumentation installed in the reactor (detectors, processing modules and displays) meets the necessary requirements for data acquisition but will require periodic calibration plan (each 2 years) in order to maintain the system reliability. The computational system works very well, allowing the automation of the reactor building radiation parameters and eliminating the necessity of radiation monitoring through health physics technicians in the case of a serious radiological emergency.

The data acquisition system shows parameters related to radiation environment such as activity, dose and concentration in real time and displays a periodic data bank (*.MDB files for ACCESS) of this features allowing the surveillance of the operation records anytime, leading to studies and analysis of radiation levels. The entire program (system) can be accessed from any computer in the IPEN through the intranet network just sharing the resident computer with a password.

The software developed shows the possibility of to implement a complete data acquisition system for the whole variables involved in reactor operation such as temperature, nuclear safety channels, primary and secondary cooling flux, pool level, etc, because the development of screens is unlimited and in terms of number of acquisition channels with a pair of NI DAQ Board, 64 channels in this case, all the task is done adding codes, menus, configurations as necessary, resulting in a simple and inexpensive software implementation.

Acknowledgements

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