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AUTONOMOUS MONITORING UNIT, SIGNS AND REGISTRATION FOR COBALT-60 IRRADIATOR SAFETY SYSTEM

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ABSTRACT

The Cobalt-60 irradiator of IPEN / CNEN, a category IV facility, has a security system for inter locking doors or exposure of radioactive sources made simultaneously by a programmable logic controller (PLC) model S7-200 from Siemens and a relay logic. From a set of information, the both systems work together opening doors or exposing the sources. All incoming and outgoing information are sent serially via EIA232 communication to a personal computer with Windows® platform for a supervisory program which provides besides a monitoring the entire process by a synoptic table on the computer screen, also keeps records of all events on the computer's hard drive. The electronic management has proven to be efficient and has not produced any failure that had compromised the safety. The PLC along with the relay logic has always taken the right decisions ensuring proper radiation protection of operators and the integrity of radioactive sources, but it presented over the years of operation (beginning in 2004) less than a dozen flaws in system event log. The deficiency was found between the process of sending events via serial communication (EIA232) to the supervisory program. When failure occurs in a very short time, the PLC always took the right decision, but the registration process that had to go through the Windows® timeshare lost the information.
This work aimed to build a standalone electronics connect the inputs and outputs of the security system, fully optocoupled to avoid any interference to the security system. It records each event on a memory card, waits for the right decision of the security system and in case of an incorrect decision an independent alarm notifies its own synoptic picture, and sends a text message to a group of defined cellphones. The circuit uses two microcontrollers called "main" and "secondary". The main is responsible for the control and monitoring of peripheral inputs and outputs of the security system. The main is monitored by the secondary, thus creating a redundant. Again, if a wrong operation is detected an auxiliary alarm is triggered.

1. INTRODUCTION

The gamma radiation emitted by radioisotopes, electron beams and the X-rays are known as ionizing radiation. They are of high penetrating power, which to interact with the products, even within their packages, transfers its energy through collisions with electrons of the atoms that constitute the product.

This process causes the production of large amounts of excited atoms or group of electrically charged atoms, known as ions. The ionization products as ions, secondary electrons, atoms and excited molecules will also lose or transfer their energy to the atoms around it in order to reestablish a balance, in this case, the product being irradiated [1]. As a result of this energy transfer process, the main process for industrial application of ionizing radiation, consists in inactivating microorganisms by radiation which is caused partly by the action of direct collision with the radiation-sensitive regions of the cell and by indirect way, through formation of highly active chemical radicals, produced in the liquid cell by radiation. In the case of direct action, radiation ionizes a part of the DNA molecule, an enzyme or any other vital component of the cell, leading her to a state of bankruptcy or in inhibiting its reproduction. For the indirect route, the radiation causes at the water molecules present in the microorganisms, the formation of free radicals such as OH^-, H^+ and H_2O_2 molecules. These chemical species are highly reactive may interact with vital components of microorganisms causing indirectly lethal damage [1].

While this ionization process is desirable because of their deleterious traits to microorganisms, indiscriminate exposure of the humans or animals to ionizing radiation present the same damage and high values can lead to death. Due to these circumstances, the equipment used for irradiation are built and operated under strict standards of construction and operation.

From an operational point of view, the plants irradiation using gamma rays, X-rays and electron beam are similar. Basically, the products are transferred by automated transport systems into the irradiation chamber, where they are exposed for a certain time and follow transferred out, ending the process. In these installations, the sources are surrounded by thick concrete walls that aims radiation safety of operators.

Figure 1 shows an irradiator using cobalt-60, and the main difference with respect to an electron accelerator is the pool where the radioactive sources are dipped inside when there is need for intervention by operators (maintenance or inspection). In the case of high voltage accelerators machine is turned off stopping the radiation source. During processing by radiation, the irradiation chamber is closed by interlocks and safety systems.

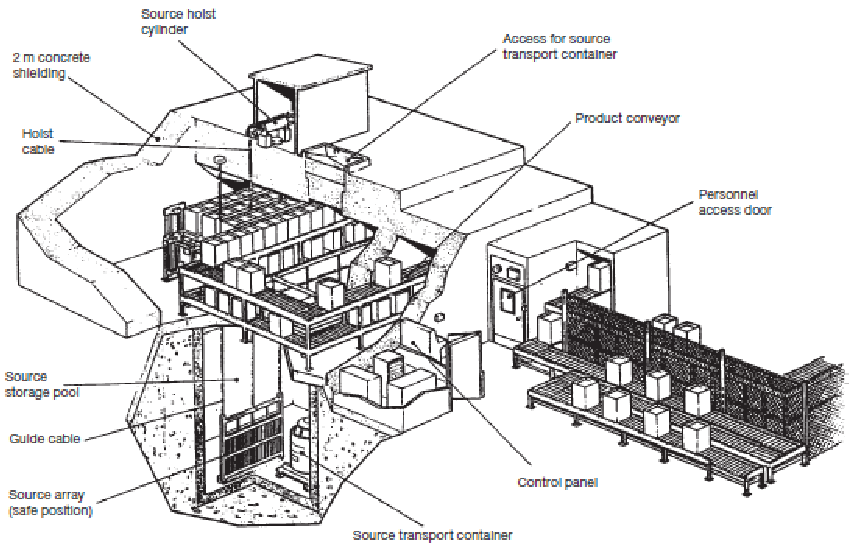

Figure 1: Scheme of a category IV, by the International Atomic Energy Agency (IAEA), radiation facility. Figure modified from IAEA - Specific Safety Guide No. SSG-8- [2].

The Multipurpose IPEN irradiator was designed attending CNEN NN 6:02 [3] for Radioactive Facilities Licensing and the system of interlocks and safety by the standard 115 Basic Safety Standards [4] and the Specific Safety Guide No. SSG-8 [2].
The electronic management of the doors inter-locks or exposure of radioactive sources are made simultaneously by a programmable logic controller (PLC) model S7-200 from Siemens [5] and a relay logic. From a set of setup information, and many of them with redundancy function, the assembly allows opening of doors or exposure sources. All incoming and outgoing information is sent by EIA232 serial communication [6] to a personal computer with Windows® platform to a supervisory program, InduSoft Web Studio® [7]. This software provides in addition to monitoring the entire process synoptic form on the computer screen also keeps records of all events on the computer's hard drive.

The electronic management has proved efficient and not presented any failure that had compromised safety. The CLP along with the relay logic has always taken the right decisions ensuring proper radiation protection of operators and the integrity of radioactive sources, but presented over the years of operation (beginning in 2004) less than a dozen flaws in system event log. The deficiency was found between the process of sending events via serial communication (EIA232) to the supervisory program. When the failure occurred in a very short time, the PLC always took the right decision, but the registration process that had to go through the Windows® platform timeshare on the computer lost the information.

This work proposed the development of an autonomous electronic system connected to the inputs and outputs of the control panel. It registers independently each event on a memory card, waiting for correct decision from de control panel and in the case of an incorrect decision, besides also registers this event, it will signal this with an independent alarm, notify in a proper synoptic picture, and send a text message to a group of defined cell.

2. DESCRIPTION OPERATION

Because of the large interaction between the various devices that include this project, this section aims to describe the basic operation of each part of the system and demonstrate its interactive features.

2.1. Main Microcontroller

The main unity is based on a Peripherical Interface Controller (PIC) from Microchip. [8] This microcontroller, in addition to the microprocessor, has an internal memory, communication ports and input and output devices, that can be programmed to control specific functions and actions of the device to which it is inserted. In this microcontroller is stored the software that reads de CLP control panel actions and checks its decisions.

The microcontroller selected to be the main was the PIC18F8722 model [9]. This microcontroller has 80 pins, and 69 of them can be configured as input and output. It own a 128 kB program memory, volatile data memory of the 4kB and a non-volatile data memory of 1 kB. It works with oscillators up to 64MHz, has 24 pins that can be configured as digital analog converters channels (ADC), disposes pins for serial communication (EIA232) among others. The main micro controller had 40 pins configured as inputs connected in parallel with the bus inputs and outputs control panel.

2.2. Secondary Microcontroller

For the higher reliability of the autonomous unit electronic circuit, it uses together with the main controller, a secondary that it is responsible for monitoring the main, thereby generating a redundant system safety. This microcontroller with the main return pulses at set time intervals. These periodic pulses serve to ensure that the system is operating and if they no longer received means that one of the micro controllers presented some fault and thus the other notifies the incident.

2.3. Real Time Clock and Calendar (RTCC)

At each event, the microcontroller collects the date and time through an integrated circuit clock and calendar, Real Time Clock and Calendar (RTCC) [11], and record the event occurred independently in a memory card Secure Digital card (SD card) [12].

2.4. SD Card

All records, regardless of their relevance, are recorded locally on memory, type micro SD Card. The goal is to have a local log record of all events that may subsequently be collected and analyzed by the official. This communication between the main microcontroller and the micro SD is accomplished through the SPI protocol.

2.5. Synoptic Framework

The synoptic framework besides notifies alarms, allow to the operator to interact with the system, collecting data recorded on the memory SD Card for analysis or simply to ask some logical state of the system. The synoptic framework is the man machine interface (MMI), an AIGT3100B Programmable Display allowing brief local real-time analysis.

2.6. General Packet Radio Services (GPRS)

In case of failure, the main microcontroller sends a message to the GPRS radio module to send a Short Message Service (SMS) [13] for the registered cell group reporting the incident.

2.7. Audible Alarm

If a failure occurs on the control panel or on the main micro controller of the Autonomous Monitoring Unit an audible alarm is triggered locally.

2.8. Control Panel

This unit incorporates the PLC system and the logic relays to perform the security functions of the facility. It sends all internal status from Control Panel to personal computer with Windows™ and Indusoft Web Studio™ supervisory software by EIA232 communication port.

The Figure 2 shows is the simplified diagram of Autonomous Monitoring Unit , allowing to view the peripherals that make up the system.

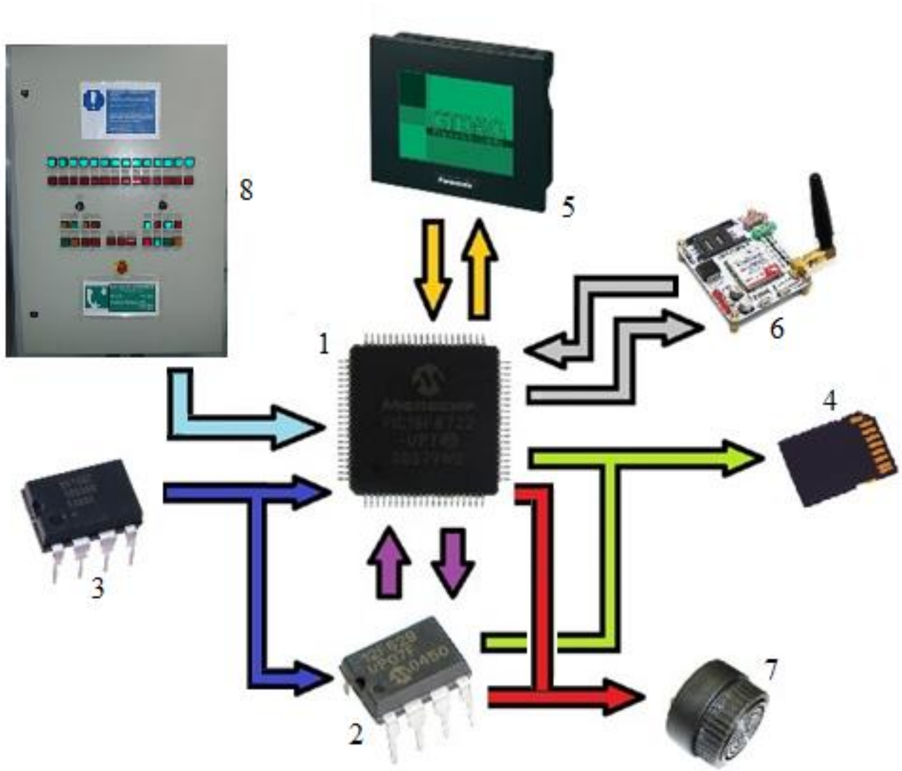

Figure 2: Simplified diagram of Autonomous Monitoring Unit, where 1 is the Main Microcontroller, 2 Secondary Microcontroller, 3 Real Time Clock and Calendar, 4 Secure Digital Card Memory, 5 Man Machine Interface, 6 General Packet Radio Services Module, 7 Audible alarm and 8 Control Panel

3. RESULTS

The system has been programmed to recognize a possible control panel failure. For this, simulations have been carried out to produce a failure and a wrong decision from the control panel, to check if the program within the main microcontroller recognizes an incorrect decision. The GPRS module has not yet been purchased, but trials have been done with a 3G modem USB HSDPA ZTE MF100 which is accessed by serial port of the computer where it is installed. This setting for the GPRS is only applicable for programming tests, because it is limited again by the computer software set. The simulations have been proved the necessity of GPRS returns to the Autonomous Monitoring Unit, a SMS from the cell group, to the unit understands that the information was received. The log recorded in a SD Card has been useful when it is necessary check the information in another computer, because it is easy to remove the data from the unit.

4. CONCLUSIONS

The autonomous monitoring unit was efficient, recording all simulated events, even in short times where the PLC acknowledged the failure but the MMI system via EIAS232, at the computer with Windows®, did not record the failure. The developed system was suitable as an auxiliary instrument in Multipurpose Irradiator security control and failures analysis.

REFERENCES

1. RELA , P.R. Utilização da Radiação Ionizante na esterilização de produtos médicos e farmacêuticos, *Revista da Sociedade Brasileira de Controle da Contaminação(SBCC)*, edição 4, 10-16, 2001.

2. INTERNACIONAL ATOMIC ENERGY AGENCY. ***Radiation Safety of Gamma, Electron and X Ray Irradiation Facilities***. Specific Safety Guide Nº SSG8. Áustria, 2010.

3. Norma CNEN NN 6.02 Resolução CNEN 166/14 Abril / 2014 LICENCIAMENTO DE INSTALAÇÕES RADIATIVAS Resolução CNEN 112/11 Publicação: DOU 01.09.2011 Resolução CNEN 166/14 Publicação: DOU 29.04.2014

4. BSS-115 International Basic Safety Standards for Protection against Ionizing Radiation and for Safety of Radiation Sources-IAEA, Vienna, 1966 –Safety Series N° 115.

5. Siemens. SIMATIC S7-200 Programmable Controller, Germany, 1999.

6. Eletronics Industries Association, ***RS-232,*** http://pt.wikipedia.org/wiki/RS-232, disponível em 19/12/2014.

7. Indusoft, Indusoft Web Ready Documentation and Literature, USA, 2013.

8. Microcontroller Microchip, **PIC,** http://www.microchip.com/pagehandler/en-us/products/picmicrocontrollers, available at 26/12/2014.

10. Ritchie, Dennis M. & Kernighan, Brian W. "The C Programming Language". Prentice-Hall, Inc., (1978).

11. Real-Time Clock and Calendar, **RTCC,** http://pt.wikipedia.org/wiki/Rel%C3%B3gio_de_tempo_real, available at 03/01/2015.

12. Secure Digital Card, **SD Card,** http://pt.wikipedia.org/wiki/Secure_Digital_Card, disponível em 03/01/2015.

13. General Packet Radio Services, **GPRS,** http://www.gta.ufrj.br/ensino/eel879/trabalhos_vf_2008_2/ricardo/3.html, available at 04/01/2015.