

Relevant Characteristics of the RA-10 I&C Systems

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Abstract. Since 2010, Argentina is carrying out the design, construction and commissioning of a new research reactor, the **Reactor Argentino Multipropósito RA-10**.

The CNEA and INVAP are working in close collaboration in the development of the engineering design and the managing of the project; CNEA as design authority and INVAP as main engineering provider.

The Project is now running the detailed engineering stage.

This work delineates the philosophy behind the design of the I&C systems. It describes the systems and their interrelation to allow integrated, efficient, controlled and safe operation of the plant.

We present innovative components on the design of the Reactor Protection System, the Nuclear Instrumentation System, the Control and Monitoring System, the Radiation Monitoring Systems and the Post Accident Monitoring Systems, such as:

- a. Internal diversity of each redundancy of the Reactor Protection System, focusing on the reliability of the safety function.
- b. Diverse Neutronic measuring systems focusing on detecting RIA events
- c. Abnormal movement of control rod detection system focusing on detecting RIA events.
- d. Autonomous Area Radiation Monitors, focusing on the operator's radiation protection.
- e. Separation, hierarchy, modularity and simplicity of the design of the Reactor Control and Monitoring System, the Experimental Devices Control and Monitoring System, the Cold Neutron Source Control and Monitoring System and Fuel Elements Irradiation Facility Control and Monitoring System.

The work is based on the basic engineering of the RA-10 design and presents, when possible, the advances of each system in the detailed engineering.

1. Introduction

Since 2010, Argentina is carrying out the design, construction and commissioning of a new research reactor, the Reactor Argentino Multipropósito RA-10.

The RA-10 reactor is designed for:

- consolidating and increasing the radioisotope production in order to assure the future needs,
- providing fuel and material testing irradiation facilities for supporting the development of national technology in this field,
- offering new applications in the field of science and technology based on neutron techniques.

The project is supported by national funding and is conducted by CNEA as design authority. It started on 2010 and will be finished with the reactor commissioning on 2018. Invap S. E. is the main contractor.

Main features related to the design basis are shown in Table 1.

Type	Open pool
Power	30 MW
Fuel elements	MTR, uranium silicides, 19.7% enrichment, 4.8 gU/cm ³ , with burnable poisons
Control rods	Hafnium plates, external to the fuel elements
Moderator and coolant	Light water
Flow direction in core	Upward
Reflector	Heavy water
Shutdown systems	Control rods and reflector tank emptying

Table 1: RA-10 reactor design bases.

The following facilities have been specified in the RA-10 reactor design:

- Intermediate thermal flux positions for bulk radioisotope production (Mo, ORI)
- High thermal flux positions for sealed cans radioisotope production (Ir/Lu)
- Sealed capsules irradiation positions with pneumatic devices for different purposes (PIIN)
- Silicon irradiation positions (6", 8" and 10" diameter lingots) (NDT)
- High fast flux irradiation positions for material testing irradiation rigs
- Intermediate fast flux irradiation positions for material testing irradiation rig
- MTR plates and fuel irradiation position
- NPP fuel test irradiation loop
- D₂ cold neutron source
- Cold neutron beams
- Thermal neutron beams
- In pool neutron radiography

2. RA-10 Instrumentation General Description

The RA-10 main instrumentation and control, I&C, components are grouped in the following systems:

- Reactor Protection System – RPS
- Control and Monitoring System – CMS
- Nuclear Instrumentation System – NIS
- Radiation Monitoring System – RMS
- Post-Accident Monitoring System
- Process Instrumentation

Figure 1 schematically shows I&C systems and their interconnections in the RA-10 reactor.

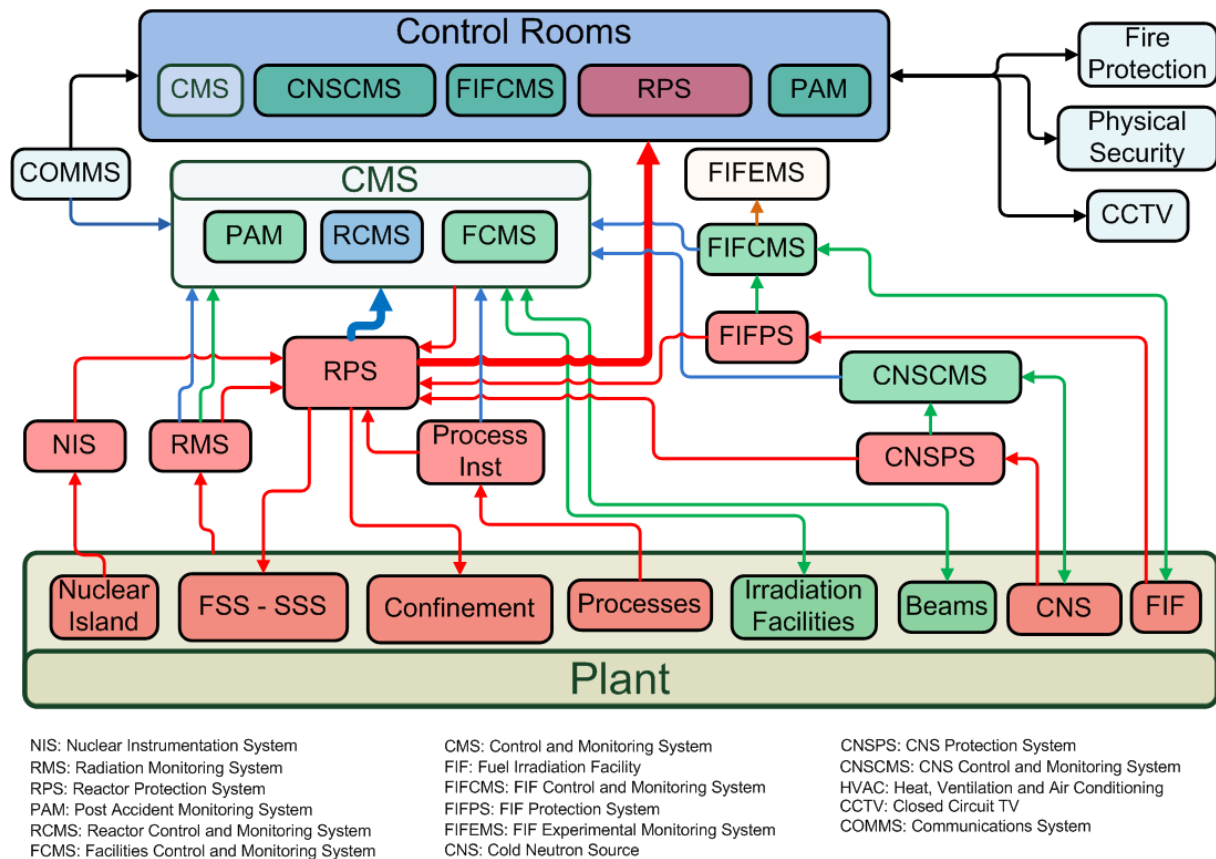


Figure 1: I&C systems in the Reactor Argentino Multipropósito RA-10

3. Reactor Protection System – RPS

3.1 Function

The Reactor Protection Systems, RPS, is the safety system that monitors the safety parameters of the plant, implements the safety logic and, in case of malfunctions, misoperation or external threaten, demands the actuation of the protective functions related to reactivity control and radionuclides confinement.

To do so, the RPS:

- Monitors the evolution of the variables and detects deviations beyond safe operation surpassing the threshold trigger.
- Implements the protective logic and demands the initiation of the protective actions to conduct the plant to a safe state.

- Provides the operator with means for manually starting protective actions.
- Shows safety parameters in the RPS desk and wall panels in the main and alternative control room.
- Supervises the safe operation of the SPR itself.

The RPS can demand the initiation of four protective actions:

- TRIP 1 – First Shutdown System, FSS. The FSS is the fast insertion in the core of all the control rods. This action is diversified in two sub actions: pressurized air injection inside the control rods cylinders and the disconnection the control mechanism drivers from the power source, releasing the kinetic chain to the action of gravity.
- TRIP 2 – Second Shutdown System, SSS. The SSS is the partial drain of the reflector tank, releasing part of the D2O to flow, by the action of gravity, to the D2O storage tank. The action is carried out opening the six valves in the lines between the reflector tank and the D2O storage tank.
- TRIP 3 – Reactor confinement ventilation reconfiguration.
- TRIP 4 – Evacuation alarm.

3.2 Architecture and Technology

The RPS is composed of three trains measuring the same variables. Each train implements the comparison of the value of variables with the threshold trigger, the voting logic, the protective logic and the final voting logic. Each train is fed by its own independent instrumentation channels. So the RPS is triple redundant system.

The initiating signals are voted in 2oo3 logic. The results of this voting are used to implement the protective logic. The results of this logic are the protective signals.

Protective signals are generated in each train. This redundancy is solved, also, in 2oo3 logic at the final voting logic. The final voting logic generates the TRIP 1, TRIP 2, TRIP 3 and TRIP 4 signals, which demand the initiation of the four protective actions. Figure 2 shows this architecture.

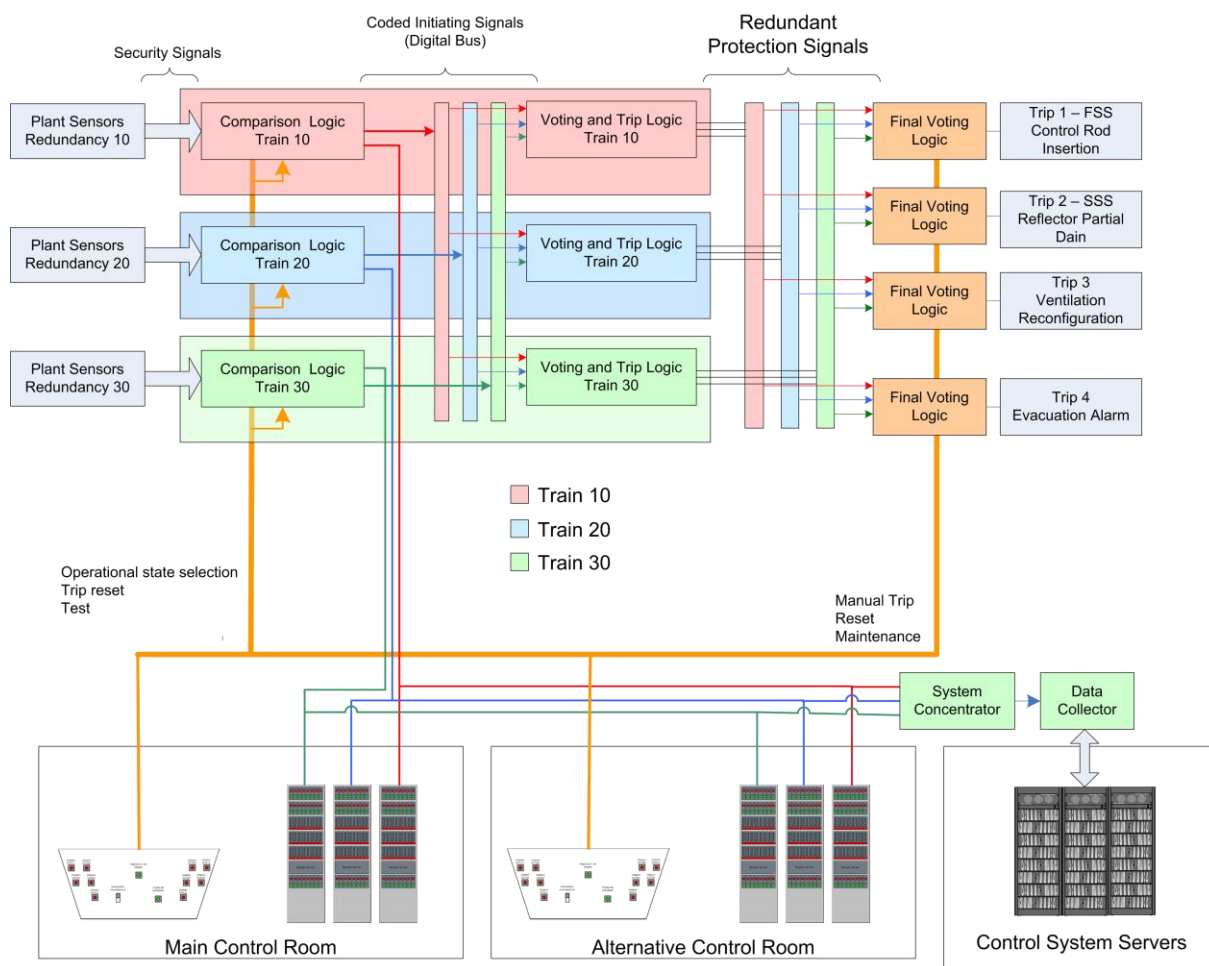


Figure 2: RPS architecture

The main components of the RPS are designed based on configurable logic devices such as FPGA. The proposed design for the implementation of the RA-10 RPS incorporates, beyond traditional concepts of redundancy, fail safe, self-check, etc.; internal diversity concept. This concept consists of implementing within each train, the security functions two times in parallel by means of two and independent diverse hardware: diversity #1 and diversity #2.

This characteristic also accomplishes the self-verification criteria in order to mitigate common mode failure causes. No one of the modules has priority over the homologue diverse module. This means that both diversities can generate the protective signal and the final decision at each train is solved in 1oo2 logic inside the train. This implementation is showed in Figure 3.

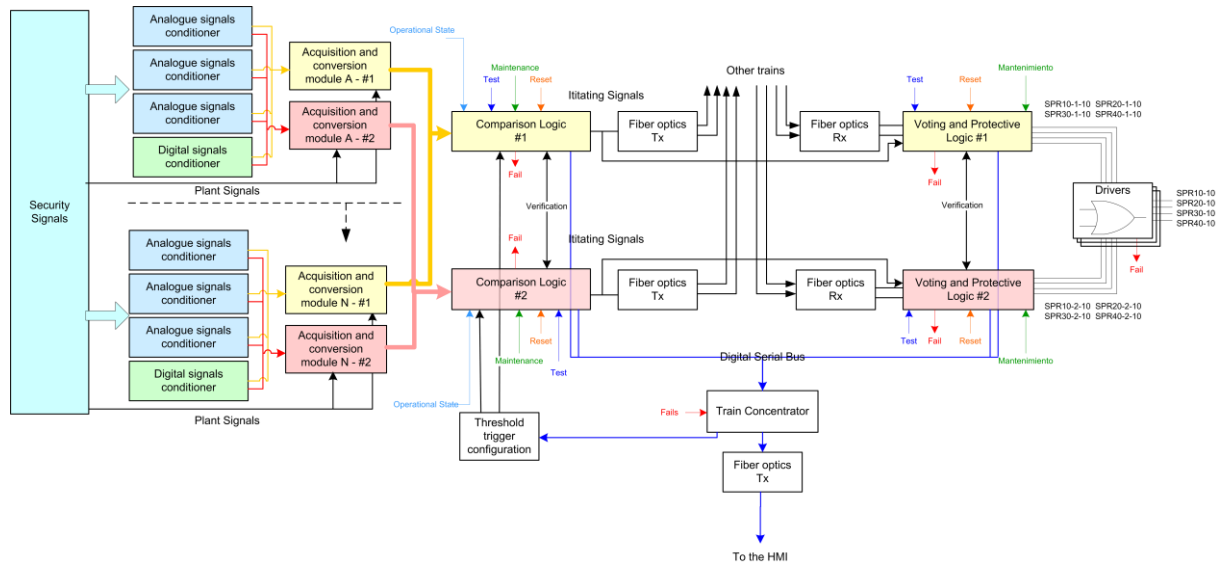


Figure 3: Internal train architecture

3.3 Related instrumentation

The RPS processes signals associated with the systems related to plant safety. These signals can be grouped in:

- Processes signals
 - Temperature
 - Flow
 - Pressure drop
 - Water level
 - Valve position
- Nucleonic signals
 - Wide range start-up channel – Log and Rate
 - Wide range normal operation channels – Log and Rate
 - Current Channels – Log and Rate
- Radiation monitoring signals.
 - Gaseous effluents
- Instrumentation related to the CMS
 - CMS available
- FSS instrumentation
 - Abnormal movement of Control Rods
- Seismic Sensors
- Manual Trip

4. Nuclear Instrumentation System – NIS

The NIS includes all the nuclear instrumentation related with the measurement of the neutronic flux on the operating range of the reactor. The system describes, in real time, the status of the reactor regarding neutron production and monitors the reactor power and its evolution.

4.1 Description

The SIN is composed for the following measuring channels:

- Wide range start-up channel
- Wide range normal operation channels
- Current channels
- Linear Auto Range channel
- N16 gamma channel
- Self-powered channels

Figure 4 shows the schematic architecture and main characteristics of the NIS.

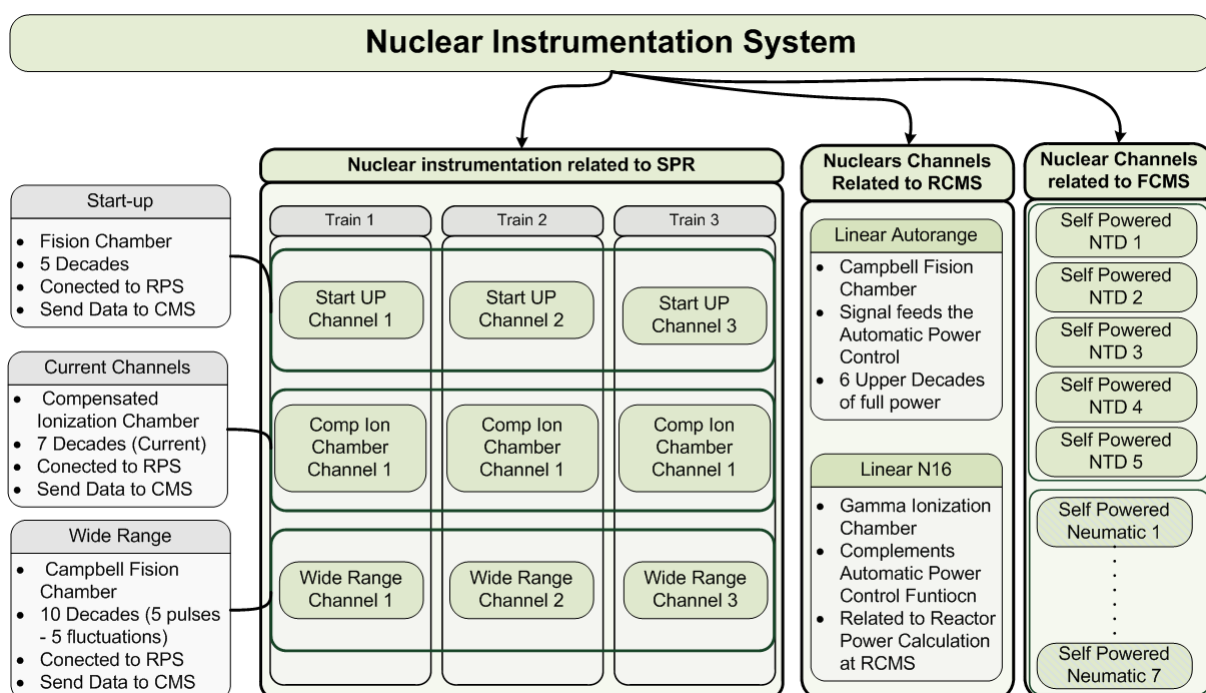


Figure 4: NIS schematic architecture and main characteristics

4.2 Wide Range Start-up Channel

The wide range start-up channels are used for fresh core reactor start-up or after long term shutdown periods. There are three identical channels connected to the RPS. The channels cover a maximum flux of 10^{10} nv at the selected position. After the start-up process, when the existence of photo-neutron is sufficient to operate the reactor with the normal operation channels, the detectors are removed to a position far from the core.

4.3 Wide Range Normal Operation Channels

The wide range normal operation channels are used to monitor the neutronic flux during routine operation of the reactor. There are three identical and independent channels connected to the RPS that cover the flux

measurement during 10 decades. The information of this channel is used also in a Post-Accident Monitoring situation.

4.4 Current Channels

The current channels re used to monitor the neutronic flux during routine operation of the reactor. There are three identical and independent channels connected to the RPS that cover the flux measurement during 6 decades.

4.5 Linear Auto Range Channel

The linear auto range channel reports to the RCMS and is used to implement the automatic power control algorithm. Is one channel and covers the neutronic flux during the last five decades.

4.6 N16 Gamma Channel

The N16 gamma channel measures the gamma activity on the primary cooling system over, at least, the last two decades of the operative range of the automatic power control function. The signal is used as complement of the linear auto range channel to implement the automatic power control algorithm.

4.7 Self-powered Channels

The self-powered channels are used to map the neutronic flux at specific positions related to the pneumatic and productions facilities. These channels reports to the FCMS.

5. Radiation Monitoring System – RMS

The RMS system includes all the instrumentation needed to implement the radiation monitoring function in the plant. All the information of the RMS is available in RCMS in both control rooms. Some information is sent directly to the RCMS and the channels related to the RPS and the PAM are sent to the RCMS using communication links between the systems.

5.1 RMS Functions and Subsystems

The subsystems of the RMS implement the supervision of radiation levels related to all the plant. This process includes:

- Liquid monitoring – Cooling systems and effluents
- Air and Gas monitoring – Ventilation and chimney effluents
- Area radiation monitoring – Equivalent dose rate
- Criticality monitoring
- Personnel supervision – Levels of eventual contamination inside the reactor and neutron guide buildings

Figure 5 shows the RMS subsystem, the main functions and the scope of each one.

The RMS subsystems related to the RPS are implemented with discrete hard logic. The subsystems related to RCMS and PAM are implemented using microprocessor technology with the capacity of digital communications between systems.

5.2 Liquid Monitoring

There are different subsystems related to the liquid monitoring in the RA-10 reactor. Those are:

- Damaged Fuel Elements Monitoring System. This system monitors online the presence of delayed neutrons in the water of the reactor and service pools in order to early detect damage in the fuels or the moly targets. There are to monitor. The system uses an aliquot of the water of the pools.
- Liquid Effluent Monitoring System. This system monitors, offline using spectrometers, a discrete sample of the water present in the water storage tank before it is dispatched.

- Active Liquids Monitoring System. This systems monitors de gamma activity bin piping of the primary cooling systems and pool cooling system. This measurement is complementary to the damaged fuel elements monitoring system.
- Secondary Cooling System Activity Monitoring System. This system measures the gamma activity in the secondary cooling system after the heat exchanger between the PCS and the SCS. The systems uses an aliquot of the water of the SCS.

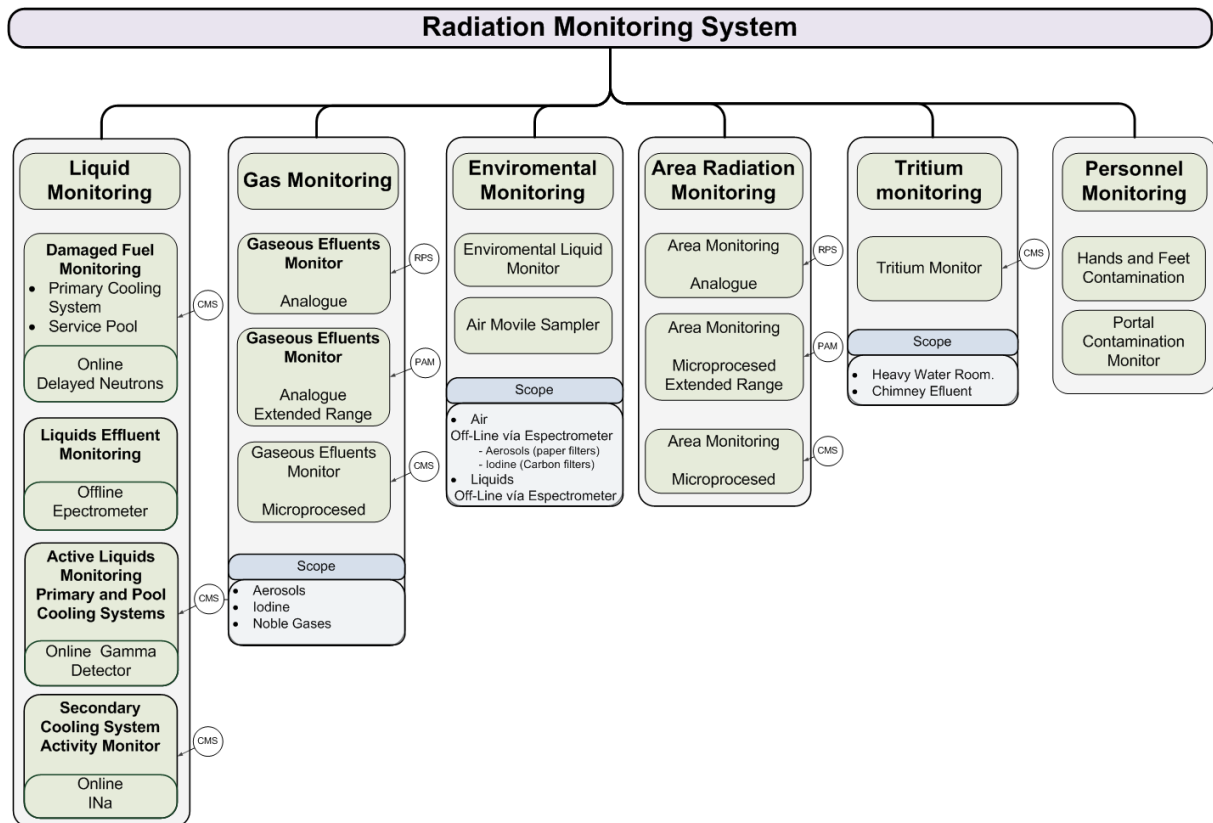


Figure 5: RMS schematic architecture

5.3 Gas Monitoring

The function of the gas monitoring system is to continuously and measures the activity of the gases emitted by the chimney, in normal operation conditions and in emergency conditions. There are three different gaseous effluent monitors at the chimney, one reporting to the RPS, one reporting to the PAM and the last used for normal operation and used to totalize the activity at the gaseous discharge. The gas monitoring also includes tritium monitoring on the chimney using fixed equipment and in the ventilation conduit of the heavy water room using mobile equipment.

5.4 Area Monitoring

The function of supervision of the equivalent dose in the reactor is accomplished using the Area Radiation Monitors, ARM. The ARM measures the gamma dose in all the radiological relevant areas. There are three groups of ARM implemented with different technologies and characteristics. One group reports to the RPS. The monitors in this group are implemented using discrete hard logic. The second group reports to the PAM. These monitors are implemented using microprocessed technology and extended range detectors. The last group is used for normal operation. These monitors report to the RCMS and are implemented using microprocessed technology and normal range detectors.

5.5 Criticality

The criticality monitoring is made to estimate the post-criticality-accident integrated dose for neutron and gamma radiation.

There are permanent dosimeters located at the main control room, the reactor hall and the fresh fuel elements storage room.

The dosimeters are composed of activation foils for three neutron groups, thermal, epithermal and fast; and TLD for gamma radiation.

5.6 Personnel

The function of this system is to monitor the eventual contamination of the personnel. There are two types of monitors:

- Hands and Feet Contamination Monitor
- Portal Contamination Monitor

6. Control and Monitoring System – CMS

The Control and monitoring system is divided in three sub-systems:

- Reactor Control and monitoring system
- Facilities Control and monitoring system
- Cold Neutron Source Control and Monitoring System

6.1 Reactor Control and Monitoring System – RCMS

The RCMS performs the automatic, semi-automatic and manual functions required for the reactor normal operation and supervision. The design criteria for the system are:

- High availability
- Fail Safe
- Easy maintenance
- Defense in depth
- Criteria from the nuclear regulatory authority

The RCMS is a PC-PLC hierarchical system divided in three levels:

- Supervision
- Control
- Field

The supervisory level performs the human-machine interphase – HMI. It contains the supervision units, the operation stations, the engineering stations and the data base servers. These units are interconnected by a redundant fiber optic network.

The control level processes and executes the reactor control logic and concentrates the data transferred to the supervision level. This level consists of control units connected in a redundant fiber optic ring network. Each control unit has internal redundancy working in a fault tolerant configuration.

The field level accomplishes the data acquisition from instruments and generates the signal to the actuators. It is composed of field units and a redundant ring net.

Figure 6 presents the typical architecture used in all the PC-PLC systems in the control and monitoring systems of the RA-10 Reactor.

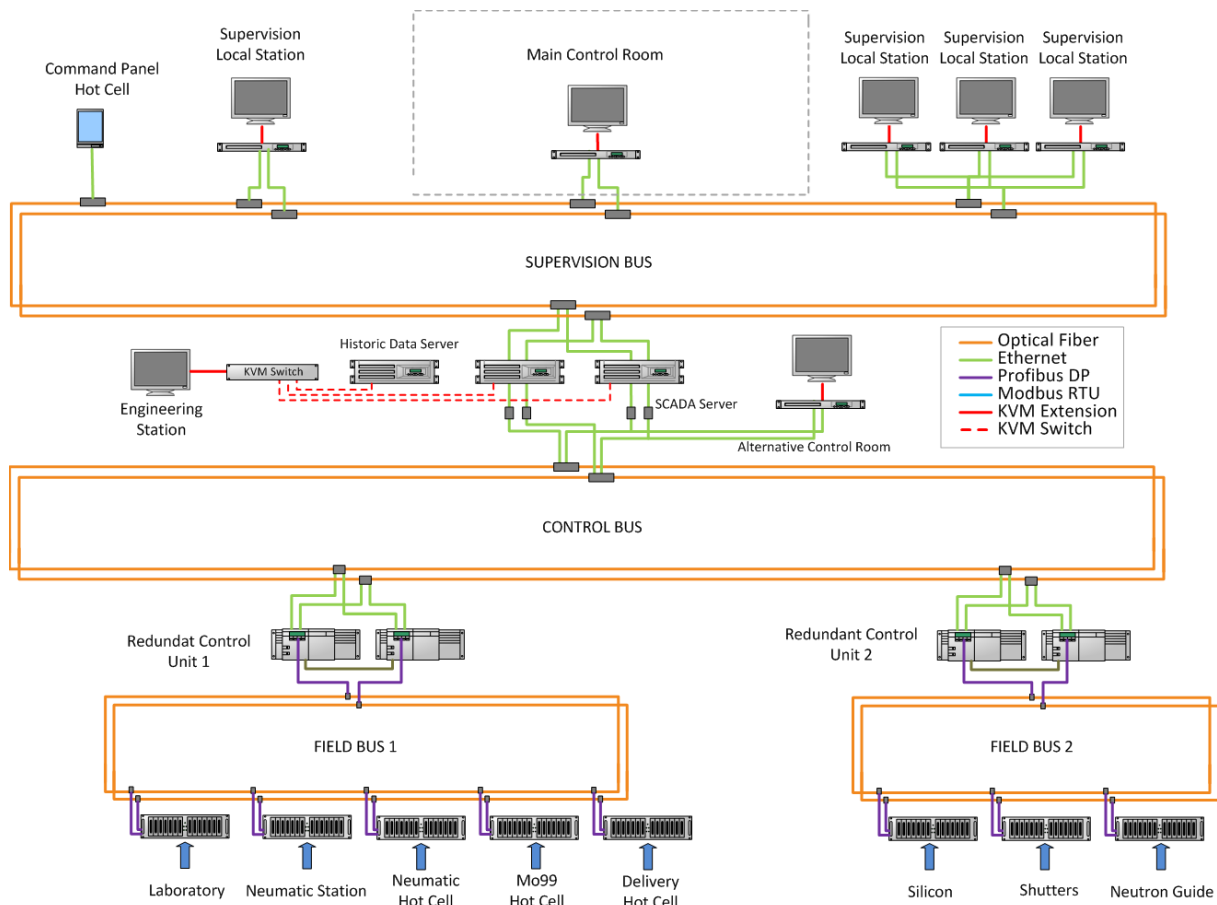


Figure 6: CMS typical architecture

The RCMS has a self-check that generates and sends a dynamic signal to the RPS. The RPS monitors this signal and demands TRIP when the signal is lost.

The RCMS implements the safety interlocks and the operation logics:

- Transitions between operational states logic
- Control rod move up inhibition logic
- Power reduction logic
- Bank Insertion logic
- Automatic power control logic
- Process system operation logics

6.2 Facilities Control and Monitoring System – FCMS

The Facilities Control and Monitoring System (FCMS) performs the automatic, semi-automatic and manual functions required for the facilities normal operation and supervision. The design criteria for the system are:

- High availability
- Easy maintenance
- Defense in depth
- Criteria from the nuclear regulatory authority

The FCMS is implemented with the same technology used in RCMS. It is a PC-PLC hierarchical system divided in the same levels as the RCMS. The supervisory level performs the facilities HMI. The control level implements the facilities operation logics and the unit control logics.

The FCMS evaluates two safety interlocks that area requested to the RCMS: start-up enable and bank insertion.

6.3 Cold Neutron Source Control and Monitoring System – CNSCMS

The Cold Neutron Source has two control systems:

- Cold Neutron Source Protection System – CNSPS
- Cold Neutron Source Control and Monitoring System – CNSCMS

The CNSCMS performs the automatic, semi-automatic and manual functions required for the cold neutron source normal operation and supervision. The design criteria for the system are:

- High availability
- Easy maintenance
- Defense in depth
- Criteria from the nuclear regulatory authority

The CNSCMS is implemented with the same technology used in RCMS and the FCMS. It is a PC-PLC hierarchical system divided in the same levels as the RCMS. The supervisory level performs the cold neutron source HMI. The control level implements the cold neutron source operation logic and the unit control logic.

The CNSCMS evaluates two safety interlocks that area requested to the RCMS: start-up enable and bank insertion.

The cold neutron source Protection System, CNSPS, prevents any damage to the In-Pile. The CNSPS is a hierarchical system independent of the CNSCMS. It is divided in two levels with full redundancy: field and control. Each variable monitored by the CNSPS is acquired at the field level by three instruments and then is voted in 2oo3 logic. The CNSPS monitors all the process variables and request TRIP to the RPS when any triggering threshold is trespassed.

7. Post-Accident Monitoring System – PAM

The PAM is designed to provide reliable information about the state of the reactor and the state of safety functions in events beyond the basis design.

The information is shown in the main control room and in the alternative control room. The design criteria for the system are:

- Passive System
- High availability
- Fail Safe tolerant

The MPA is a hardwire system without any software. It is independent from the RCMS and the RPS. It has two redundancies with own instrumentation. The instrumentation stands severe environmental conditions and extended range instruments when needed. All the information is sent to the RCMS using galvanic isolation communication. Each control room has two wall panels showing the information of each redundancy of the PAM.