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Reactor Protection Systems for the Replacement Research Reactor, ANSTO

Abstract

The 20-MW Replacement Research Reactor Project which is currently under construction at ANSTO will have a combination of a state of the art triplicated computer based reactor protection system, and a fully independent, and diverse, triplicated analogue reactor protection system, that has been in use in the nuclear industry, for many decades. The First Reactor Protection System (FRPS) consists of a Triconex triplicated modular redundant system that has recently been approved by the USNRC for use in the USA's power reactor program. The Second Reactor Protection System is a hardwired analogue system supplied by Foxboro, the Spec 200 system, which is also Class1E qualified. The FRPS is used to drop the control rods when its safety parameter setpoints have been reached. The SRPS is used to drain the reflector tank and since this operation would result in a reactor poison out due to the time it would take to refill the tank the FRPS trip setpoints are more limiting. The FRPS and SRPS have limited hardwired indications on the control panels in the main control room (MCR) and emergency control centre (ECC), however all FRPS and SRPS parameters are capable of being displayed on the reactor control and monitoring system (RCMS) video display units. The RCMS is a Foxboro Series I/A control system which is used for plant control and monitoring and as a protection system for the cold neutron source.

This paper will provide technical information on both systems, their trip logics, their interconnections with each other, and their integration into the reactor control and monitoring system and control panels.

By
Charles R Morris
Senior Instrumentation and Controls Engineer
Australian Nuclear Science and Technology Organisation
New Illawarra Road, Lucas Height, N.S.W., 2234, Australia
Email: crm@ansto.gov.au

Reactor Protection Systems for the Replacement Research Reactor, ANSTO

1. Introduction

The 20-MW Replacement Research Reactor Project, which is currently under construction at ANSTO will have a combination of a triplicated computer based reactor protection system, and a fully independent, and diverse, triplicated analogue reactor protection system. The First Reactor Protection System (FRPS) consists of a Triconex triplicated modular redundant (TMR) system that has recently been approved by the USNRC for use in the USA's power reactor program. The Second Reactor Protection System is a hardwired analogue system supplied by Foxboro, the Spec 200 system, which is also Class1E qualified and has been installed in many power reactors.

The functions of the FRPS include control rods insertion when safety parameter setpoints have been reached and containment isolation valves closure on high stack release activity. The SRPS is used to partially drain the reflector vessel, and since this operation would result in a reactor poison out due to the time it would take to refill the tank, the FRPS trip setpoints are more limiting. The FRPS and SRPS have limited hardwired indications on the control panels in the main control room (MCR) and emergency control centre (ECC), however all FRPS and SRPS parameters are capable of being displayed on the reactor control and monitoring system (RCMS) video display units. The RCMS is a Foxboro Series I/A control system which is used for plant control and monitoring and as a protection system for the cold neutron source.

This paper will provide technical information for both the FRPS and SRPS , their trip logics, their interconnections with each other, and their integration into the reactor control and monitoring system and control panels.

2. The First Reactor Protection System

The FRPS is a Safety Category 1 System, implemented using a Triconex Triple Modular Redundant (TMR) system, qualified for use in nuclear safety shutdown applications. This system initiates the fast insertion of control rods, called a Trip 1 action, via the First Shutdown System whenever the FRPS monitored parameters exceed pre-established limits. This action is aimed at avoiding reactor fuel damage and preventing the release of radioactive material from the reactor pool. The FRPS also initiates actions to isolate the Reactor Containment in case of the detection of radioactive material in the stack, and incorporates a number of interlocks that prevent reactor start-up when certain systems are unavailable.

The FRPS is comprised of three redundant and separate trains. A train is made up of measurement channels that monitor various system parameters. Whenever a channel determines that its monitored parameter exceeds the safety limit setting, the train in question is in the tripped state for that parameter. Whenever two out of three trains are in a tripped state, for the same parameter, the reactor is shutdown or a protective action initiated. The FRPS inputs information to the Reactor Control and Monitoring System using qualified Class1E isolation devices and Foxboro proprietary data management software (known as the FoxGuard Manager). The FRPS trip/interlock and containment isolation parameters are shown in Table 1.

As stated above the FRPS consists of three independent, redundant measurement channels. Each of these channels comprises of a sensor, a conditioning unit, and a Trip, Voting and Protective Logic Unit (TUVPLU), that is, the Triconex TMR. Analogue field signals are processed by the conditioning units (which produces a 4-20mA output). The outputs of these units are input to the TUVPLU where the channel value is compared to the trip setpoint. If two-out-of-three channels monitoring the same parameter are outside the trip setpoint, a signal from the associated channel is provided to one of the three redundant and independent output conditioning units that generate the required FRPS trip signal. This signal is then combined with the other channels signals of the same Function in a two-out-of-three logic to produce the final actuation signal in the First Final Actuation Logic FFAL which causes the initiation of the FSS. For digital field signals, the configuration is similar but without the need for a conditioning unit or trip setpoint comparison.

Table 1 FRPS Parameters

FIRST REACTOR PROTECTION SYSTEM PARAMETERS		
Description (all signals triplicated)		**Action**
First Shutdown System		
Assembly of First Shutdown System	enable	Protective Interlock
Compressed Air Storage Tank Pressure	low	Start-up Interlock/Alarm
Second Shutdown System		
SSS Trip	SSS Trip	Trip FSS
Isolation Valve Locked	not open	Start-up Interlock/Alarm
Primary Cooling System		
Pool Open End Gamma Activity	high	Trip FSS
Pool Water Level	low	Trip FSS
Primary Coolant Flow	low	Trip FSS
Core Pressure Difference	low	Trip FSS
Core Pressure Difference	high	Trip FSS
Core Temperature Difference	high	Trip FSS
Core Inlet Temperature	high	Trip FSS
Reflector Cooling and Purification System		
Reflector Cooling Flow	low	Trip FSS
Expansion Tank Level	v. low	Trip FSS
Reactor and Service Pool Cooling System*		
Rigs Cooling Flow	low	Trip FSS
Rigs Cooling Flow	high	Trip FSS
Flap Valve #1	not closed	Trip FSS
Flap valve #2	not closed	Trip FSS
Nucleonic Instrumentation System		
Start-up Neutron Flux	low	Trip FSS
Start-up Neutron Flux	high	Trip FSS
Wide Range Logarithmic Rate	high	Trip FSS
Wide Range Logarithmic Neutron Flux	high	Trip FSS
Wide Range Logarithmic Flux @ Low Power	high	Trip FSS
Wide Range Logarithmic Flux @ High Power	high	Trip FSS
Seismic System		
Seismic level	high	Trip FSS
Reactor Control and Monitoring System		
RCMS Availability	not available	Trip FSS
Reactor Containment System		
Stack Particulate Activity	high	Containment Isolation
Stack Iodine Activity	high	Containment Isolation
Stack Noble Gases Activity	high	Containment Isolation
Stack Particulate Activity Rate	high	Containment Isolation
Stack Iodine Activity Rate	high	Containment Isolation
Stack Noble Gases Activity Rate	high	Containment Isolation
Electrical Supply		
Loss of Off Site Power	trip	Trip FSS
Facilities		
Cold Neutron Source Protection System	trip	Trip FSS
Hot Neutron Source (Reserved)	trip	Trip FSS

* The rigs cooling flow signals are logically combined with the flap valve position status and the operational mode to determine if a reactor trip is required.

3. The Second Reactor Protection System

The SRPS is a Safety Category 1 System that is a hard-wired analogue system that initiates the partial draining of heavy water from the reflector vessel, called a Trip 2. The Trip 2 is initiated via the Second Final Actuation Logic (SFAL) which causes the partial draining of the reflector vessel whenever the SRPS monitored parameters exceed pre-established limits. This action is aimed at avoiding reactor fuel damage thereby preventing the release of radioactive material from the reactor pool. The SRPS is an independent and diverse safety system from the FRPS. They share no components in common thereby fulfilling the imposed diversity requirements.

The SRPS, like the FRPS has three redundant and independent trains, and inputs its information to the Reactor Control and Monitoring System (RCMS) via qualified isolation devices.

The SRPS is based on the Foxboro Spec 200 line of components that have been in operation in operating nuclear plants for many decades. Similar to the Triconex, the SRPS field sensors will generate 4-20mA input signals to the Spec 200 equipment via signal conditioning units. Internally, the Foxboro Spec 200 system converts the current signal to a voltage signal of 0-10Volts. This is the standard working signal for Spec 200. All signal manipulations, comparisons and modulations are done at this level. The outputs whether on/off or variable are accomplished using qualified output isolators.
The SRPS trip parameters are shown in Table 2.

Table 2 SRPS Parameters

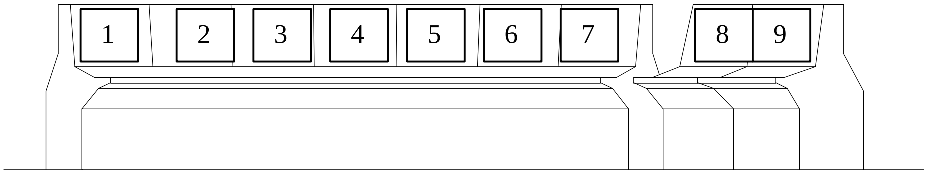
SECOND REACTOR PROTECTION SYSTEM PARAMETERS		
Description (all signals triplicated)		Action
First Shutdown System		
Failure of First Shutdown System	Fail	Trip SSS
Primary Cooling System		
Core Outlet Temperature	high	Trip SSS
Core Pressure Difference	low	Trip SSS
Pool Water Level (evacuation)	v. low	Trip SSS
Reflector Cooling and Purification System		
Heavy Water Make Up Pump	enable	Protective Interlock
Reflector Vessel Temperature	high	Trip SSS
Nucleonic Instrumentation System		
Power Neutron Flux Rate	high	Trip SSS
Power Neutron Flux Log (Low Power Mode)	high	Trip SSS
Power Neutron Flux Linear	high	Trip SSS
Seismic System		
Seismic Level	high	Trip SSS

4. Main Control Room and Emergency Control Room FRPS and SRPS Displays

The consoles displaying the FRPS and SRPS in the Main Control Room (MCR) and Emergency Control Centre (ECC) are basically identical with the exception of a lack of power mode switches on the ECC panels. The control consoles are pictured in Figure 1 and show that hardwired indication has been kept to a minimum.

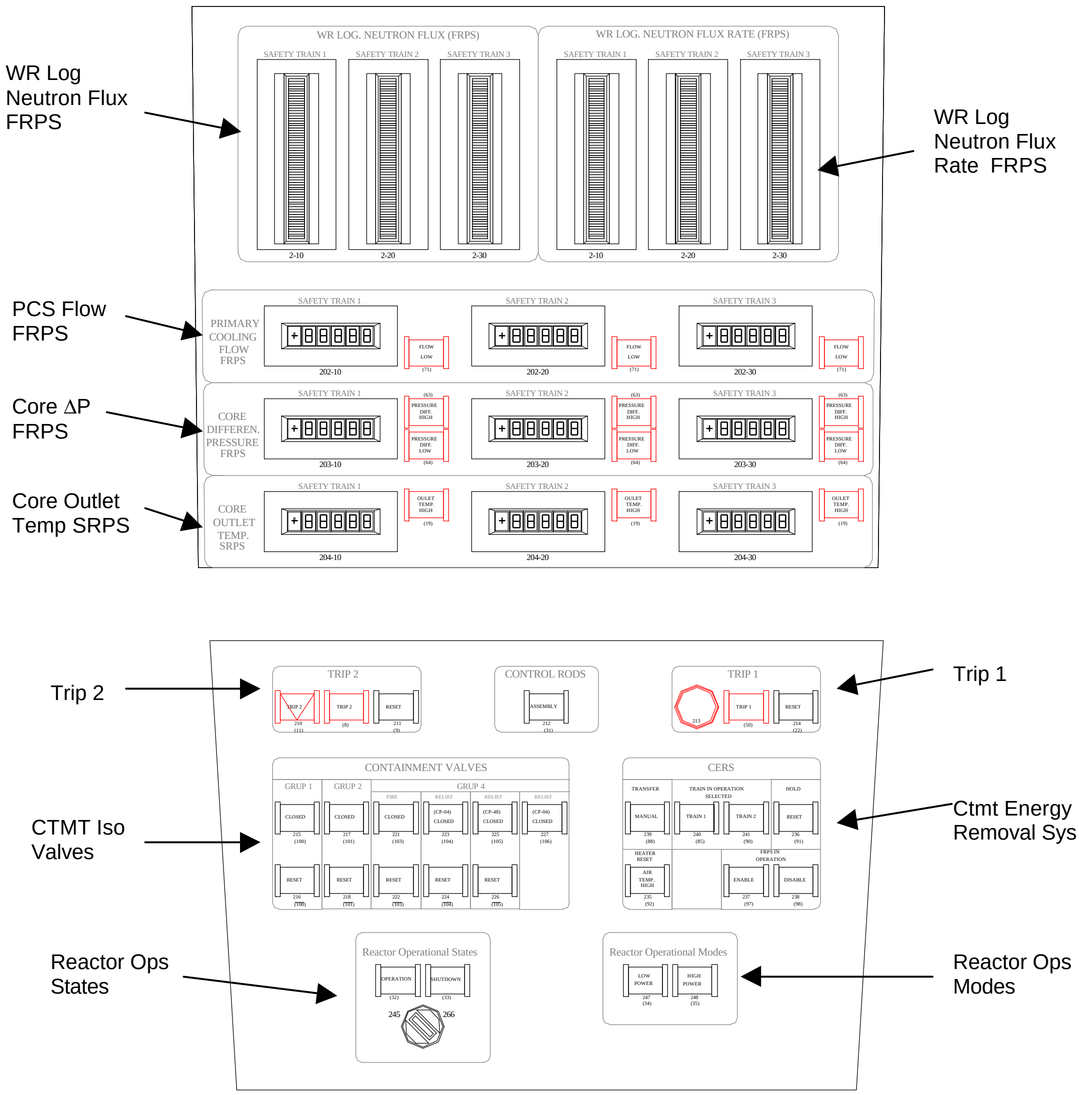
Figure 1 Control Panel Layout

The Main Console is divided into functional areas:



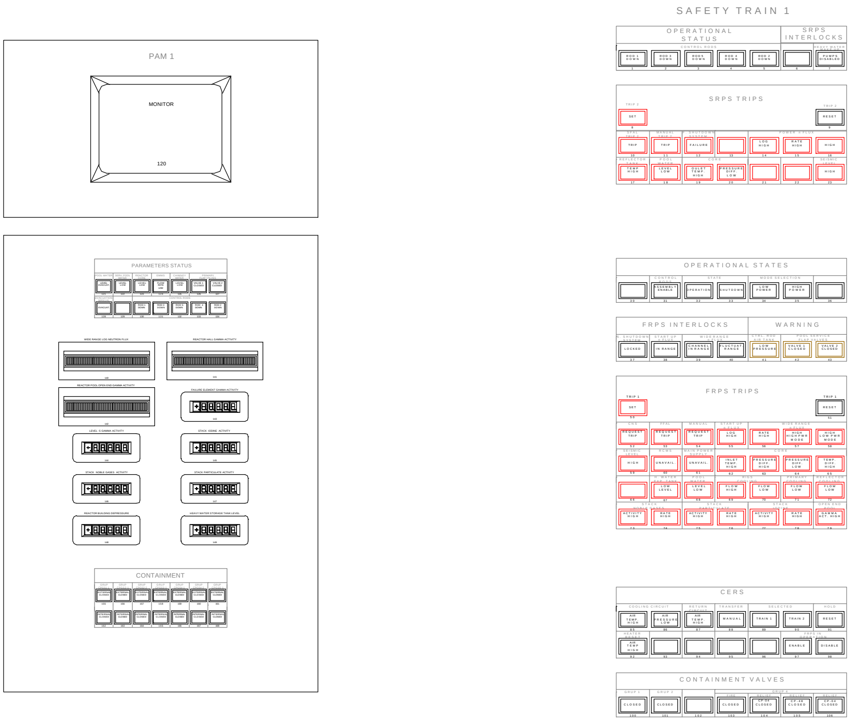
Module 1: VDU Alarms
Module 2: RPS
Module 3: VDU Operation
Module 4: Control Rods
Module 5: VDU Operation
Module 6: Communications
Module 7: VDU General - Radioprotection
Module 8: VDU General - Electricity.
Module 9: VDU Irradiations Facilities

Figure 2 RPS Hardwired Panel Module 2



There are hardwired cabinets in both the MCR, and ECC that have individual alarms for all the FRPS and SRPS trip parameters for all three trains, see figure 3 below. Also on this panel are the two trains of the Post Accident Monitoring system which share some signals with the FRPS (nucleonic and reactor pool top area radiation monitors). The PAM system like the SRPS is based on the qualified Foxboro Spec 200 system components.

Figure 3 RPS Wall Mounted Indication Panels



PAM
INDICATION PANEL (IP)
SAFETY TRAIN N^{o}1 (OF2)

RPS
INDICATION PANEL (IP)
SAFETY TRAIN N^{o}1 (OF 3)

Note
The above indication panels are still undergoing detailed Human Factors design review and there will be modifications to what is shown above.

5. The Reactor Control and Monitoring System

The Reactor Control and Monitoring System is a Safety Category 2, computer-based, high availability system based on the Foxboro I/A Series Distributed Control System. The RCMS monitors all plant and reactor parameters, and displays them in the Main Control Room, Emergency Control Centre, and at local supervision centres (see Figure 4 below). The Reactor Control and Monitoring System functions include control of the reactor operation, process control, and overall information management. The RCMS is not part of the reactor protection systems however all signals from the FRPS and SRPS are input into the RCMS (via qualified isolators) so that these parameters are available for the operators at all RCMS visual display unit locations. There are 6 VDUs on the main console in the MCR and 4 on the main console of the ECC, which can be reconfigured by the operators to display any available screen.
The RCMS includes the following systems:

- Automatic Reactor Power Regulation System
- Radiation Monitoring System
- Vibration Monitoring System
- Facilities Control and Monitoring Systems
- Cold Neutron Source Protection System

These systems cover all necessary automatic and manual functions to operate and monitor the facility in normal conditions, and to ensure that safety actions are executed under interlock conditions or when limits are exceeded.

The RCMS, FRPS and SRPS are functionally, physically and electrically independent. FRPS and SRPS signals are sent to the RCMS, without feedback, using IEEE 384 qualified isolation devices. The RCMS does not perform any Safety Category 1 functions.

The RCMS is continuously running self-check routines that indicate a failure within the system. In case a fault or malfunction affects normal operation, a hard-wired trip request signal is sent to the FRPS for a reactor trip

6. Expected Performance

The Triconex system to be used in the FRPS, has only recently been qualified as Class 1E, however its use in highly critical safety systems world wide, has shown it to be a proven performer, with over 140,000,000 hours of operation without a false signal. These systems are typically used in offshore oil drilling platforms and at oil refineries where errors can be catastrophic.

The Foxboro Spec 200 systems used in the SRPS and PAM have been in service from the mid 1960s and are a robust and well proven performer in the nuclear power industry.

The Foxboro I/A system has been in use for many years in a wide variety of industrial applications. Recently it has been chosen as the system for the upgrade of the SCADA systems for the South Korean nuclear power program.

ANSTO believes that because the above suppliers are all part of the Invensys group the integration of these systems will be far easier then if different vendors had been chosen.

Figure 4 RCMS Architecture