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Conceptual Design of I&C Architecture for a New Research Reactor

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1. Introduction

A project to build and operate a new research reactor (NRR) by 2016 was launched by KAERI in 2012. The purposes of the project are to meet domestic industrial needs of a research reactor and to secure an internationally competitive NRR. For instrumentation and control (I&C) systems of the NRR, it shall also be designed to secure the competition of the NRR. The I&C should account for the competition in terms of three aspects: safety, performance and cost. A I&C conceptual design activity should be carried out at the early stage of the project to figure out the I&C on the high level. Constructing I&C architecture is to accomplish the high level design. During the I&C architecture construction, the three aspects should be taken into account. This paper conceptually constructs the I&C architecture for the NRR by comparing to the cases of a Jordan training and research reactor (JRTR) project and a RA-10 multipurpose research reactor. The JRTR is an on-going project launched by KAERI and DAEWOO consortium in 2011. The I&C of the JRTR was digitalized based on the I&C functions of the HANARO research reactor, as shown in Fig. 1 [1]. The RA-10 was launched by INVAP of Argentina in 2011. The digital I&C developed by INVAP was built in an OPAL of Australia, as shown in Fig. 2 [2].

2. I&C Architecture

The goal of constructing the I&C architecture is to layout I&C systems and interconnect the systems so that it provides information of overall interface and scale of the NRR I&C systems. The architecture persuades the simplicity by adoption of digital technology. The digitalization gives us merits of high integration and fast processing capabilities. For constructing the I&C architecture, the following criteria are established:

- Provision of systems in response to the design bases events such as design basis accident (DBA), anticipated operational occurrence (AOO), anticipated transient without scram (ATWS)
- Compliance with the criteria of single failure and defense-in-depth (DID)
- Connection systems using redundant backbone network
- Provision of analog equipment in response to the common mode failure (CMF) of digital systems

The architecture was constructed based on the JRTR I&C architecture and improves it for the international competition. The architecture was ensured to meet the criteria.

The NRR I&C architecture is constructed with the following considerations:

- Defining echelons of I&C systems on the basis of DID criterion
- Configuring Class 1E systems in response to the DBA and AOO, and ensuring that the systems comply with the single failure criterion
- Establishing an integrated information processing system with a redundant backbone network
- Deriving required systems and supplementary systems
- Connecting systems with considering the three aspects through the network and/or hardwire
- Transmitting Class 1E data to non-Class 1E systems in a one-way manner
- Establishing minimal analog backup equipment

Table 1 shows a design strategy to adopt the four echelons in NUREG/CR-6303 [3] for the architecture.

Table 1. Strategy to Adopt the four Echelons

Echelons	Design Strategy
Control System	Non-Class 1E control system to automatically and manually operate the reactor in the safe power production operating region
Reactor Trip or Scram System	Class 1E reactor protection system (RPS) and non-Class 1E alternate protection system to automatically and manually initiate a reactor trip signal
ESF Actuation System	Class 1E reactor protection system to automatically and manually initiate ESF component actuation signals
Monitoring and Indicator System	Non-Class 1E monitoring systems and Class 1E hardwired equipment to provide operators with means to react to unexpected events

Conceptual I&C architecture of the NRR was designed as shown in Fig. 3. In order to ensure that the systems comply with the single failure criterion in response to the DBA, the RPS was designed the same Class 1E 3-channel system with 2/3 voting logic as the JRTR's RPS except the followings:

- Replacing a test circuit with an on-line software testing routine.
- Combining an interface and test processor and an maintenance and test panel to a monitoring and test panel including a non-Class 1E processor for monitoring parameters, a Class 1E gateway for transmitting parameters' value to a monitoring system, and isolated Class 1E hardwired switches for commands to the bi-stable processor

RA-10's RPS consists of a digital FRPS that reactor trip and containment isolation, and a hardwired SRPS that partial draining of heavy water. It sends information to the RCMS via a Class 1E in one-way read only electrically isolated interfaces. The FRPS monitors the "healthy" signal from the RCMS and the signal is no longer transmitted, the FRPS trips the reactor. It presents all safety information to the operator through dedicated safety displays in the wall panels, in the main control room (MCR), and in the emergency control center (ECC). It is a 3-channel system, each consisting of a Tricon platform responding to the events such as the AOO and DBA.

An Ethernet backbone network was established in the architecture as a non-Class 1E redundant network.

In response to the ATWS, the APS was designed the same non-Class 1E 2-channel system with 2/2 voting logic as the JRTR's APS except that the test switch is replaced with an on-line software testing routine.

The ASTS, RRS, PICS, RMS, VMS, CCTV and HVAC are the same as those of the JRTR. RA-10's seismic systems are three, one for FRPS, the others for the SRPS,

The PAM (Post-Accident Monitoring), Class 1E analog equipment, was designed for two purposes: post-accident indications and minimal control means. The JRTR's post-accident monitoring system (PAMS) is a Class 1E digital system. This brought us a COTS (Commercial-Off-The-Shelf) dedication burden of graphic user interface software. Since the number of input signals to the PAMS is not so many that the PAMS can be replaced with Class 1E analog devices. This can reduce engineering cost. It is required to provide analog control devices in response to the CMF of the digital systems. Therefore, minimal analog devices in response to the CMF are facilitated in the PAM.

RA-10's PAMS, Spec 200, provides indication that the reactor is shutdown, safety functions are being carried out, and ESFs are effective, in the MCR and ECC during and after an accident.

The supplementary control room was designed to contain minimal devices required only for the safety shutdown. However, JRTR's supplementary control room contains more devices.

3. Conclusions

Internationally competitive I&C architecture was constructed as a result of high level design of I&C for the NRR. The architecture was based on the JRTR I&C and improved for the competition. RA-10 I&C architecture was selected as competitive architecture. Through the construction of the NRR I&C architecture, it was shown to be competitive.

REFERENCES

[1] PARK, Gee-Yong, Instrumentation & Control Design, Technical Meeting of JRTR Design, KINS, Daejeon, Korea, June 13, 2011.
[2] H. Blaumann, et al., RA-10: a New Argentinian Multipurpose Research Reactor, Int'l Conference on Research Reactors, Rabat, Morocco, November 14-18, 2011.
[3] USNRC NUREG/CR-6303, "Method for Performing Diversity and Defense-in-Depth Analysis of Reactor Protection Systems", December, 1994.

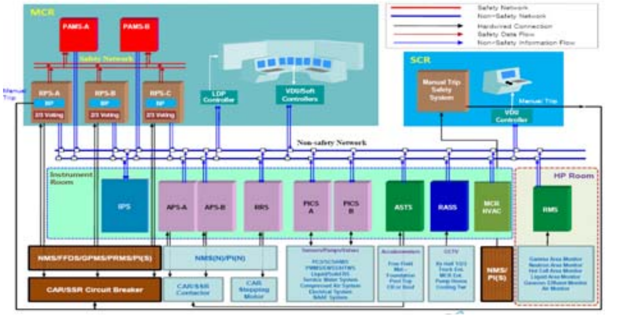

Fig. 1. JRTR I&C Architecture (Excerpted from [1])

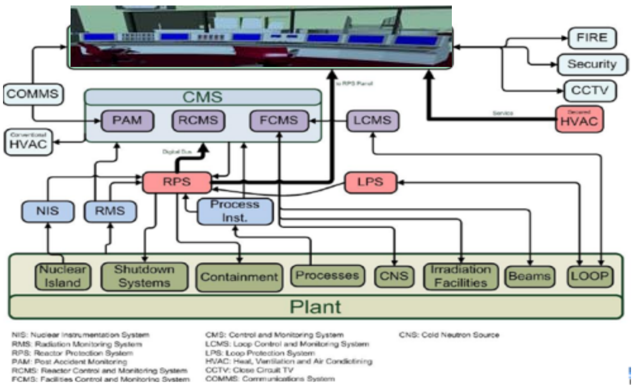

Fig. 2. RA-10 I&C Architecture (Excerpted from

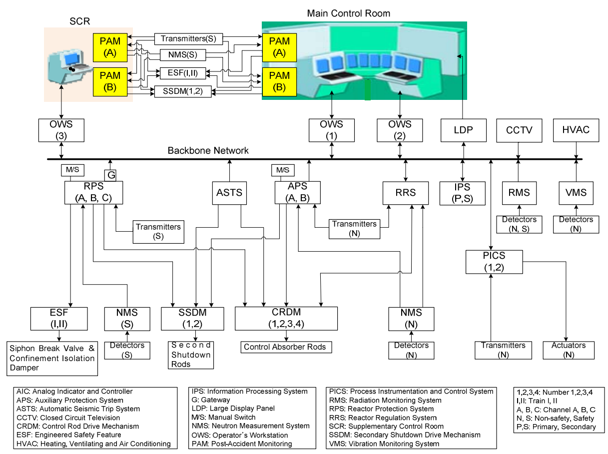

Fig. 3.NRR I&C Architecture