Test Facilities for SMART MMIS

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1. Introduction

The System-integrated Modular Advanced ReacTor (SMART) project managed by KAERI is to submit a standard safety analysis report (SSAR) of SMART to the Korean nuclear regulatory body by the end of 2010 and aims to get a design certificate at the end of 2011. For this, the SMART Man-Machine Interface System (MMIS) has been developed with the following design goals:

- One-man-operation capabilities in the main control room during plant normal operating condition.
- Network-based, hard real-time, and modular I&C systems

In order to completely generate the SSAR, two projects are now underway: a standard design (SD) and a technology validation (TV). The SD produces requirements of system design and interfaces, system specifications and related backup documents. The TV constructs test facilities and produces test reports so that the contents of the SD are validated through the performance of the TV. The SD produces design parameters and gives them to the TV. The TV validates the parameters through the test facilities and gives test results back to the SD. These processes iteratively proceed until generating a complete set of data for the SSAR.

The TV of the MMIS establishes two test facilities: full scope dynamic mockup (FSDM) and digital safety systems platform (DSSP). This paper is to introduce an outline of the development of the FSDM and DSSP.

2. Development of the FSDM

The purpose of the FSDM development is to validate the feasibility of SMART operations in the main control room. HFE-V&V (human factors engineering - verification and validation) will be performed to satisfy requirements of the integrated system validation described in NUREG-0711. The FSDM encompasses a large display panel, soft-controls, alarm and information displays, and hard-wired switches. The typical configuration of the FSDM is shown in Fig. 1.

The FSDM, a test bed for the integrated system validation of SMART control room design, should comply with all the requirements from ANSI/ANS 3.5-1998 (Nuclear power plant simulators for use in operator training). Since SMART is a new plant, however, a phase-approach is applied to develop it. In the phase of standard design certification, it is supposed to be a partial mockup which has a limited plant dynamic engine and MMIs. In the construction phase, it will be completed to one that fully meets all requirements from ANSI/ANS 3.5-1998 to get an operation permit.

Fig. 1. A typical configuration of the FSDM

3. Development of the DSSP

The purpose of the DSSP development is to validate requirements of safety and performance of the MMIS digital safety systems. The safety requirements are derived from the IEEE Std 603 and 7-4.3.2. The performance requirements are derived from the safety analysis of the SMART. The maximum loop time of SMART MMIS safety systems is 60% of the response time required by the analysis. The design features of the MMIS validated through the DSSP are summarized as follows:

- Hard real-time using high speed digital signal processors
- Predefined tasks scheduling with fixed priorities
- ANSI C programs
- Network based system interfaces

The DSSP is incrementally developed as follows:

- A unit control sub-rack
- Two channels of protection system
- One channel of safety grade control system

The unit control sub-rack is a basic module that is capable of providing a control function. It typically consists of a central processing board (CPB), communication boards (CMBs), input/output boards (IOBs), and power supply boards (PSBs) as shown in Fig. 2. The DSSP consists of a set of the sub-racks.

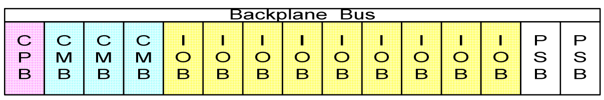

Fig. 2. A typical configuration of unit control sub-rack

Parameters that are assessed through the unit control sub-rack are as follows:

- Response time a CPB to/from IOBs in a sub-rack
- Response time a CPB to/from a CPB between sub-racks via a CMB
- Deterministic tasks scheduling
- Diagnosis
- Accuracy

The development of the unit control sub-rack complies with IEEE Std 603 and 7-4.3.2. Two channels of protection systems are developed with a set of the sub-racks. Channel A of the protection systems is shown in Fig. 3. In Fig. 3., protection system channel B is not shown but it is identical to the channel A that contains the process instrumentation, neutron instrumentation, SMART core protection, plant protection, interface and test processor (ITP), and maintenance and test panel (MTP). The DSSP does not contain complete sets of SMART MMIS safety systems, but critical parts of them. SMART core protection is developed as one sub-rack. This is possible because four channels of control rod position sensors are installed in the SMART, high performance of the CPB, and implementation with ANSI C. The MTP is not safety grade, but safety related so that safety grade ITP is necessary to interface to the safety grade sub-racks of protection system. The MTP is shared by each safety system. A unique communication protocol is developed for the DSSP. There are two types of communications: a one-way datalink and a network via a switch. The datalink is used to communicate between channels and between echelons of defense-in-depth systems. The network is used to communicate between sub-racks inside same channel.

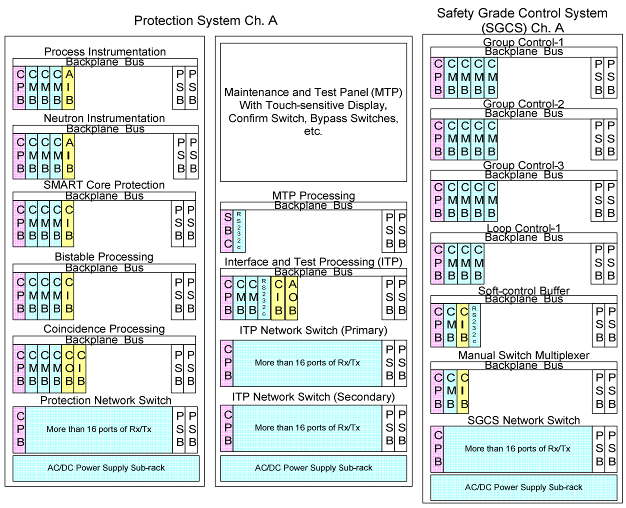

Fig. 3. A typical configuration of protection system and safety grade control system

Parameters that are assessed through the two channels of protection system are as follows:

- Response time from the instrumentation sub-racks to the coincidence processing sub-rack in each channel
- Response time between channels
- A CPB to/from a CPB between sub-racks via a CMB

One channel of safety grade control system is developed with a set of the sub-racks as shown in Fig. 3. It contains triple group controls (GC), one loop control (LC), and one soft-control buffer. Only one LC is developed among 10 LCs that the SMART MMIS expects to have in a channel out of four channels. The soft-control, which is safety related, is installed in a safety consol of the FSDM and interfaces to the LC via the soft-control buffer triple that is safety grade.

Parameters that are assessed through the two channels of protection system are as follows:

- Response time from the instrumentation sub-racks to the LCs
- Response time from soft-control to the LCs

4. Discussion

In Korea, the FSDM had been developed through Korea Next Generation Reactor (KNGR) project [1] and the DSSP had been developed through Korea Next Instrumentation and Control System (KNICS) project [2]. These two projects are not related. However, the FSDM and DSSP in this paper is being cooperatively developed to ensure that the SMART MMIS design features comply with safety and performance criteria. The design of I&C safety systems of MMIS usually considers features of a platform. For example, RTP Co.'s platform consists of sub-racks based on the triple modular redundancy and Westinghouse Co.'s platform consists of boards in which a process section and a communication section are included. These features impact on the design constraints. So, it is necessary to ascertain which the prototypes impacts on the SMART MMIS design. In other words, we need to check if the SMART MMIS design be constrained by the prototypes.

5. Conclusions

In order to generate the SSAR of SMART MMIS by the end of 2010, the SD and TV need to work cooperatively to design and validate the MMIS design through two test facilities: the FSDM and DSSP. The test results from the FSDM and DSSP will be used for generating the SSAR of SMART MMIS.

REFERENCES

[1] IAEA-TECDOC-1245, "Performance of operating and a advanced light water reactor design ", IAEA, Oct. 2001.

[2] K. C. Kwon, M. S. Lee, "Technical Review on the Localized Digital Instrumentation and Control Systems", Vol. 41, No. 4, 2009-05, Page 447-454.