Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2011

Performance Test Results of Safety I&C Systems of SMART MMIS

Yong Suk Suh[a], Jong Yong Keum[a], Kwang Il Jeong[a], Joon Ku Lee[a], Sang Seok Lee[a], Kwan Woong Kim[a]
[a]*SMART Tech. Validation Div., KAERI, 150-1 Dukjin-dong, Yuseong-gu, Daejon, Korea, 305-353*
[*]*Corresponding author: yssuh@kaeri.re.kr*

1. Introduction

KAERI has developed SMART (System-integrated Modular Advanced ReacTor), a 330MWt integral pressurized light water reactor that integrates four reactor coolant pumps, one pressurizer, eight steam generators, and one reactor core into a reactor vessel, since 1997 and submitted a SSAR (Standard design Safety Analysis Report) to Korea institute of nuclear safety (KINS) at the end of 2010 for the purpose of achieving the standard design approval (SDA) by the end of 2011 [1].

SMART MMIS has been designed with fully digitalized systems. Non-safety instrumentation and control (I&C) systems are designed based on the commercial distributed control systems. The safety I&C systems are designed using a new platform that was developed and validated by KAERI [2]. Safety I&C systems are modularized using the platform. In the protection systems (PSs), datalinks are used to transmit data in a one-way direction in order to meet the independency requirement. In the engineered safety features-component control system (ESF-CCS), network switch devices (NSDs) are used to connect the group and loop controllers. The NSD was also newly developed and validated by KAERI [3].

After validating the platform and NSD, a test facility was developed using the platform and NSDs to validate the performance of safety I&C systems. This paper presents the development and test results from the test facility.

2. Development of the Test Facility

The safety I&C systems of SMART MMIS consists of the following systems:

- Safety process instrumentation system (SPIS)
- Safety neutron instrumentation system (SNIS)
- Reactor protection system (RPS)
- SMART core protection system (SCOPS)
- ESF-CCS
- Inadequate core cooling monitoring system (ICCMS)

The above systems consist of four channels except the ICCMS consists of two channels. The RPS one channel consists of bi-stable module (BSM) and coincidence module (CCM). The ESF-CCS one channel consists of group controllers (GCs) and loop controllers (LCs). In order to validate the feasibility of the systems, developing a test facility to check out the performance of the systems is determined. The test facility consists of two channels of PSs and one channel of ESF-CCS. The PS consists of SPIS, SNIS, RPS, and SCOPS. The block diagram of the test facility is shown in Fig. 1.

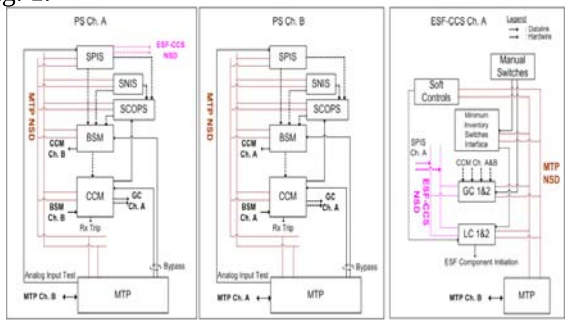

Fig. 1. Block Diagram of the Test Facility

Based on the Fig. 1 and using the platforms and NSDs, cabinet configuration of the test facility is shown in Fig. 2.

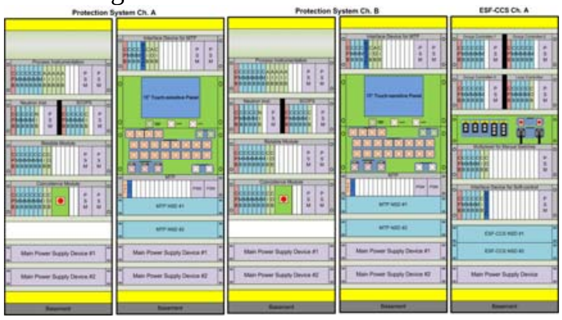

Fig. 2. Cabinet Configuration of the Test Facility

The cabinet in Fig. 2 was installed in KAERI as shown in Fig. 3.

Fig. 3. Performance Testing Environment

In Fig. 3, a stimulator, which is not shown in Fig. 3, was installed in the back of the facility to generate live input signals to the facility. An oscilloscope is used to measure and log response time generated from the facility. The SNIS and SCOPS were excluded from the test since software development was incomplete. The facility has not been used for nuclear power plants since it was newly developed. The hardware and software were developed in accordance with digital system development phases consisting of a plan, requirement, design, implement, and testing phase. It was internally reviewed but not independently. Testing was performed under ambient environment.

3. Performance Test Results

Testing block diagram is shown in Fig. 4. Fig. 4 does not cover full scope of Fig. 1 but minimal scope to test a low pressurizer pressure reactor trip event. The event is also used to test the performance of ESF-CCS.

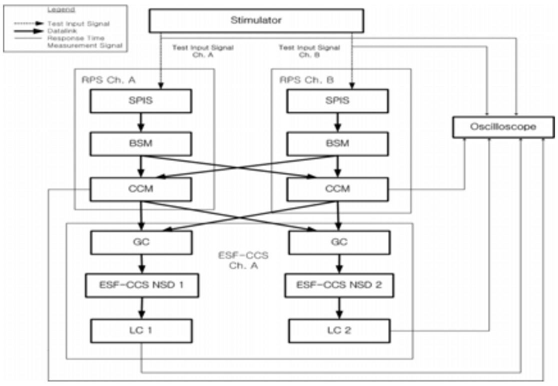

Fig. 4. Block Diagram of the Performance Test

The testing was performed in two phases as follows:

- Testing each sub-rack's performance
- Testing performance of RPS and ESF-CCS

The performance of SPIS, BSM, CCM, GC, LC1 and LC2 sub-racks was first measured. Two types of measurements were performed: software and hardware. Software measurement was done with internal timer and hardware was done with oscilloscope. Software and hardware measurements per sub-rack were performed 50 times, respectively. Test result of each sub-rack is shown in Table 1. In Table 1, the SD means standard deviation, the measurement unit is millisecond.

The performance of RPS and ESF-CCS was next measured. The stimulator generates test input signals related to the low pressurizer pressure trip event and sends them to analog input boards of the SPIS. The CCM generates a reactor trip signal when the low pressurizer pressure trip condition is maintaining for three consecutive cycles. The one cycle is 25 ms. The CCM is designed to perform two-out-of-four voting logic. However, one-out-of-two voting logic was performed in Fig. 4. When the CCM outputs the trip signal, it also sends ESF actuation signals (ESFAS) such as SIAS and CIAS to the GCs. The GC is designed to perform two-out-of-four voting logic. However, one-out-of-two voting logic was performed in Fig. 4. As soon as the GC determines to actuate the ESF components, it sends the decision to the LCs. The LC outputs ESF initiation signals as shown in Table 2. Each sub-rack in Fig. 4 is independently running every 25ms. Response times from the SPIS input to CCM output and from the the SPIS input to the LCs output was measured through 50 tests using an oscilloscope.

Table 1. Test Results of Sub-racks

Sub-rack	Software Measurement				Hardware Measurement			
	Mean	SD	Min	Max	Mean	SD	Min	Max
SPIS	1.75	0.001	1.75	1.751	1.752	0.012	1.733	1.8
BSM	2.978	0.002	2.975	2.981	2.8931	0.005	2.957	3.004
CCM	4.379	0.005	4.37	4.399	4.3847	0.005	4.377	4.403
GC	2.673	0.002	2.67	2.678	2.6756	0.008	2.65	2.69
LC1	58.3	0.161	58.259	59.394	58.422	0.15	58.3	59.4
LC2	47.35	0.024	47.3	47.41	47.414	0.04	47.4	47.6

Table 2. ESF initiation Signals and Components

ESFAS	Component	State
SIAS (Safety Injection Actuation Signal)	SI-V214	OPEN
	SI-P1	START
	CC-V101A	CLOSE
	CC-V102A	CLOSE
	VC-AH02A	START
CIAS (Containment Isolation Actuation Signal)	CC-V161	CLOSE
	CC-V162	CLOSE
	VQ-V0011A	CLOSE
	VQ-V0011B	CLOSE
	VQ-V0031A	CLOSE
	VQ-V0031B	CLOSE

Performance test result of RPS and ESF-CCS is shown in Table 3. Acceptance criteria of RPS and ESF-CCS response time is 250 ms and 350 ms, respectively. Maximal response time in Table 3 satisfied the acceptance criteria.

Table 3. Test Results of RPS and ESF-CCS

Target	Hardware Measurement			
	Mean	SD	Min	Max
RPS CCM Ch. A	94.61	16	67	131
RPS CCM Ch. B	113.1	9.534	86.8	137
ESF-CCS LC1	220.9	18.26	176	261
ESF-CCS LC2	257.4	23	220	291

4. Conclusions

In order to validate the feasibility of SMART MMIS safety systems, a test facility consisting of PS two channels and ESF-CCS one channel was developed. The performance of the RPS and ESF-CCS was measured through 50 tests by generating a low pressurizer pressure trip event. The tests resulted in that the maximal response time of RPS and ESF-CCS is 137 ms and 291 ms, respectively. The test results satisfied the performance acceptance criteria of RPS and ESF-CCS.

REFERENCES

[1] LEE, W., HWANG, D., CHUNG, Y., PARK, J., SUH, Y., LEE, S., ZEE, S., KIM, H.: Technology Validation Program for Standard Design Approval of SMART, Proceedings of 25th KAIF/KNS Annual Conference, 2010.

[2] SUH, Y., KEUM, J., JEONG, K., LEE, J., CHO, G., LEE, S., KIM, K.: Test Results of a Platform for Safety I&C Systems of SMART MMIS, Transactions of the Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, October 27-28, 2011.

[3] JEONG, K., SUH, Y., KEUM, J., LEE, J., CHO, G., LEE, S., KIM, K.: Test Results of a Network Switch Device for SMART MMIS, Transactions of the Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, October 27-28, 2011.