

Project Experience of MMIS for Shin-Hanul units 1&2 (Component Design, Manufacturing and Testing)

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1. Introduction

Doosan is one of Korea's foremost EPC contractors for plant projects inside and outside the country. Doosan's business portfolio in this area includes castings and forgings, which are basic materials for industry; nuclear reactor vessels, steam generator, boilers, turbines, generators and other components for the power industry; sea water desalination systems, water treatment plants and other water related facilities as well as material handling equipment. Especially, Doosan is uniquely positioned in the field of nuclear power plant in the world-wide.

Doosan has secured the first step to nuclear technology field through the development of the nuclear power plant (NPP) man machine interface system (MMIS), which is one of the three major core technologies of non-independence. In the nuclear power plant, MMIS takes a function as the brain and nerve system in the human body. Korean MMIS was selected for the Shin-Hanul units 1&2 for the first time and Doosan is charge of a component design and equipment supply. At the end of successful completion of MMIS for Shin-Hanul units 1&2, Doosan will be a total provider of the MMIS from development, validation, and manufacturing to delivery in Korea [1].

2. Design

The design and development of Korean MMIS started in April 2001. The Ministry of Science & Technology launched the Korea Nuclear I&C System (KNICS) project led by the KNICS R&D Center, directed by Kim Kook-hun of the Korea Electro-technology Research Institute (KERI). Through the KNICS project from 2001 to 2008, topical reports for licensing, prototypes for Equipment Qualification (EQ) and performance testing were achieved.

In 2007, the Ministry of Knowledge Economy (MKE) launched the Nu-Tech 2012 program for 100 percent NPP technology independence. This program included an MMIS made for total MMIS integration and testing and one special topic, the Reactor Core Protection System (RCOPS). The whole scope of this program, including the implementation of 15 subsystems, simulation tests using a digital NPP simulator, and RCOPS development, was led by Doosan. Table 1 show the technical features for the

major systems of Doosan MMIS, which are based on a fully-digitalized system using Korean PLC and DCS.

Table 1. Technical Features

System	Technical Features
PPS	Coincidence processor structure (3 Rack with 3 Processor Module)
RCOPS	Improvement of CEA signal checking algorithm to avoid CEA position latching problem
ESF-CCS	Maintenance Feature : MTP/ITP in each safety system
QIAS-P	Application of redundant communication module and path
QIAS-N	Application of separated network with IPS
IPS/CPS	IPS Server and Network configuration based on DCS
PCS NPCS/DPS	Redundant power controller DC Hold Power automatic commitment
NIMS	High performance industrial computer included PCI type data acquisition device
MCR/LDP	Nuclear Steam Supply System & Balance of Plant integrated Control Design

3. Manufacturing

For the project application, Doosan has proactively prepared production facilities for NPP MMIS and KEPIC-EN certification & quality system. Finally, Doosan was contracted to supply the MMIS for Shin-Hanul units 1&2 since 2009 and believe their MMIS is the best of the existing digital I&C systems. It would be impossible without the following organizations' support: The Korean government's support through research projects; KHNP's thorough reviewing from construction to the operation and maintenance stage; KEPICO-ENC's design analysis; and Doosan and its developer groups' passion and scientific/engineering efforts.

Doosan has a nuclear I&C shop for the manufacturing of I&C equipment for NPP. Doosan nuclear I&C shop has a maximum manufacturing capacity of 40 cabinets per month and a maximum testing capacity of 300 cabinets per year. Also we have plant to move to bigger place for more manufacturing capacity and simultaneously testing for two units. Doosan MMIS manufacturing is based on PLC and DCS platform. In early 2014, Doosan was complete to manufacture the Korean MMIS for Shin-Hanul unit 1 NPPs which is consists of about 300 I&C cabinets. After the completion of an electrical testing for each

cabinet, they are delivered to the testing place in the nuclear I&C shop for the MMIS integrated testing.

3. Testing

According to the industrial code & standards and Doosan quality process, MMIS testing consists of hardware equipment qualification, software verification and validation, and system testing.

3.1. Hardware equipment qualification (EQ)

Hardware equipment qualification is to verify that the equipment can operate normally with no more than 40 years when used for a lifecycle of nuclear power plant. Design must be safety function in postulated service environments. (Environment, EMC, Seismic, etc.)

Doosan performs the EQ based on type test and analysis methods. Major EQ test is composed of an environment test, EMC test, and Seismic test. Each system's prototype is successfully performed and then Doosan finalized the HW component design. Figure 1 shows a typical EQ process for MMIS of Shin-Hanul unit 1.

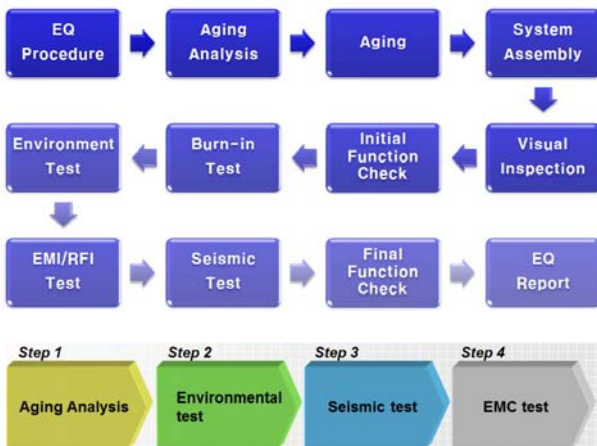


Figure 1. Typical EQ Process

3.2. Software verification and validation (V&V)

Software verification and validation (V&V) is a software-engineering discipline that helps to build quality into software. V&V is a collection of analysis and testing activities across the full lifecycle and complements the efforts of other quality-engineering functions. V&V comprehensively analyzes and tests software to determine that it correctly performs its intended functions, to ensure that it performs no unintended functions, and to measure its quality and reliability [2].

Doosan V&V team performed whole V&V activities for safety-critical software based on a document evaluation and traceability analysis and three phased software tests: module test, unit test, and software integration test. After the completion of software V&V,

Doosan finalized the SW component design and qualification. Figure 2 shows a typical V&V process for MMIS of Shin-Hanul unit 1.

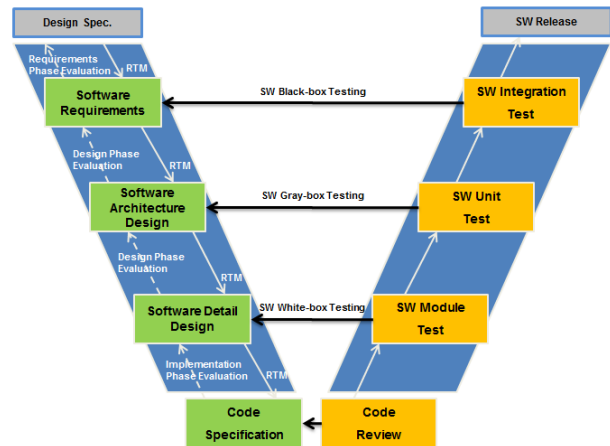


Figure 2. Typical V&V Process

3.3. System Testing

After hardware and software qualification through the EQ and V&V, I&C cabinets were fully assembled as an MMIS for Shin-Hanul unit 1. In I&C shop, as an acceptance test for customer, three steps' system testing was performed such as integrated system test (IST), MMIS-integrated system test (MMIS-IST), and factory acceptance test (FAT).

Figure 3 shows scope of MMIS testing for Shin-Hanul unit 1. IST is to verify the functionality for the level of each system. MMIS-IST(S) stands for MMIS-IST test for safety related systems and MMIS-IST(NS) stands for MMIS-IST for non-safety related systems. Additionally, MMIS-IST(I) which stands for integration is performed to verify the integrated performance between safety and non-safety related systems.

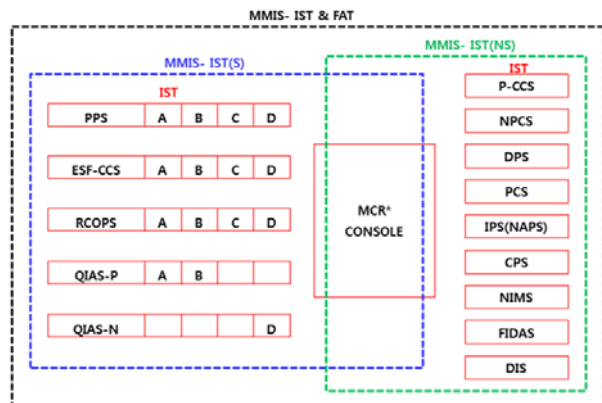


Figure 3. Scope of MMIS Testing

MMIS-IST is to verify the interface and the network performance among whole assembled MMIS systems. At the end of the factory acceptance testing, Doosan recently completed the delivery to the Shin-Hanul site in July 2015.

4. Proven Technology

Doosan MMIS improved reliability by combined operations both four and three redundant systems for the first time in the world, and achieved the excellent installation and maintenance. In addition, Doosan MMIS has a high reliable and fully duplicated system for each control and information function respectively, and it fully satisfies an international standard through the separation of safety and non-safety system in NPP

Even after the Shin-Hanul units 1&2 contracts, all the parties involved as well as Doosan's top management were very careful to ensure the success of Doosan's MMIS project. They asked international experts to examine it after the Korean experts' review and audit. At this time, the IAEA provided the Independent Engineering Reviews on I&C Systems (IERICS) program for effectively examining and reviewing Doosan MMIS. During the IERICs program in 2010, the IAEA and related experts from six countries reviewed Doosan MMIS to see whether it coincided with the IAEA's safety guidelines. Finally, Doosan MMIS received eight good practices certified including the integrated system test, a thorough third party review, and two out of three logic adopted in the BOP system design.

In 2014, Doosan MMIS was fully verified through six-time examination and audit from KINS which is Korean Regulatory Body. KINS provided some essential improvements for quality of Doosan MMIS and Doosan has successfully responded to the opinion of the KINS.

5. Conclusions

Man Machine Interface System (MMIS) is equivalent to the brain and nerve system of a nuclear power plant. It monitors and controls the operating conditions to prevent accidents proactively. Doosan achieved a complete development of MMIS which is core part of nuclear technology that was relied on oversea's companies in the past by an accomplishment of R&D in cooperation with domestic utility, KHNP and research institutions.

Doosan's MMIS is very user-friendly, easy to understand, transparent to audits, and guarantees maximum reliability, availability, maintainability, and safety. Doosan proved safety and reliability through test and inspection of integrated function of nuclear safety & non-safety control system. Doosan MMIS was evaluated a one of the best system through IAEA IERIC's review via safety guide from IAEA specialist's group in 2010. Doosan also achieved the improvements of quality through the KINS audits in 2014.

Now Doosan is looking forward to succeeding projects not only from domestic utilities, but also foreign utilities to maximize customers' safety and

profits through proven MMIS technology. Doosan is carrying out Shin-Hanul units 1&2 MMIS and several upgrading project for Kori units 1&2 CRCS, Ulchin units 1&2 DRCS & DRPI and Yonggwang units 3&4 CEDMCS and so on. Doosan will make the highest quality of service for the clients as total provider of the world nuclear power plant equipment who produces safe and reliable nuclear I&C system based on global-top technology.

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