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Development of the Kori-1 Simulator for the MCR modernization.

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1. Introduction

Kori Unit 1 is the first commercial nuclear power reactor, pressurized water reactor that came into commercial service in April 1978 and is licensed for continued operation till 2017.
The Main Control Board (MCB) was designed and was not applied the Human Factor Engineering (HFE) program during the construction phase but was performed the D-CRDR (Detailed-Control Room Design Review) as a post-TMI action. So Korea Hydro-Nuclear Power, Ltd. (KHNP) has selected the hybrid type MCR by considering the existing equipment conditions and the operability of the plant as follows.

Operator console upgrade,
Plant Computer System (PCS) upgrade,
PAS (Plant alarm System) upgrade,
Remote Shutdown Panel (RSP) upgrade,
Electrical control panel upgrade, and
Interior improvement including lighting system.

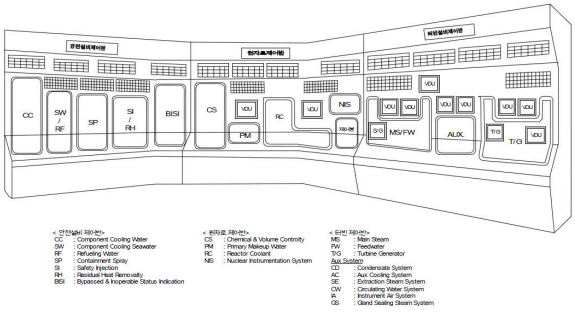

Fig. 1 Upgraded MCR of Kori-1

KINS will conduct the safety review of the new control room in Kori-1 as the same review level of construction permit (CP), operating license (OL) process.[1]
KHNP Central research Institute (CRI) developed a Kori-1 Full Scope Simulator (FSS) to have HFE Verification and Validation Test and operator training for the new modernized I&C of the MCR.
This paper describes the several features and the results of the Kori-1 FSS.

1. Thermal Hydraulic and Neutronics Modeling

The NSSS thermal hydraulics model for the Kori-1 Simulator was developed by using the RELAP5 RT code, the real-time version of RELAP5 developed by Idaho National Laboratory(INL).[2]
It could be configured from RELAP5/MOD3.2 by choosing the correct set of conditional coding and the base RELAP5 nodalization was shown in Figure 2.

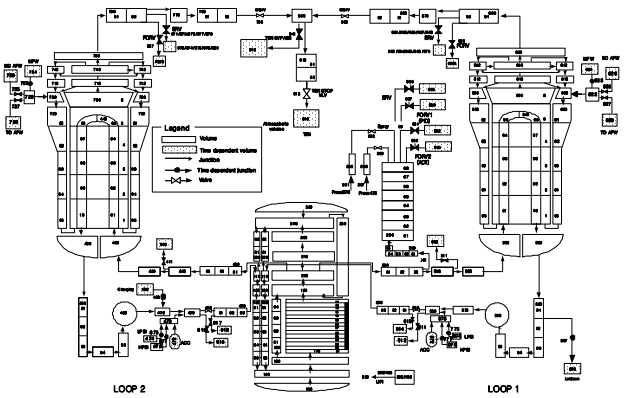

Fig. 2 Nodalization of Kori-1 TH model

The NESTLE is a true two-energy group neutronics code that computes the neutron flux and power for each node at every time step.

2. Balance of the Plant Modeling

The Balance of the Plant(BOP) Modeling was developed by using the WSC(Western Services Corporation)'s 3KEYMASTER™ which is the comprehensive suite of high-fidelity, efficient, object-oriented graphical modeling tools for the flow networks, the electrical networks, the logic and control, the relay and other component libraries.
The turbine control system was modeled by using the virtual stimulated solution, NetSim™ which is a tool that provides a powerful simulation environment for Woodward's pictures-to-code GAP™ (Graphical Application Programmer) software.

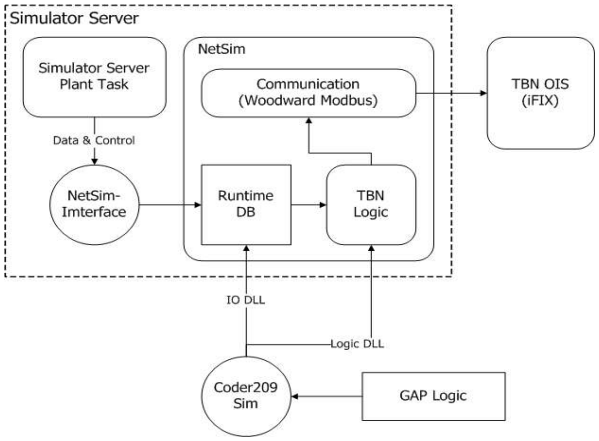

Fig. 3 Configuration of the NetSim™

The Figure 3, 4 shows the configuration of the NetSim™ and the simulator server and the Human-Machine Interface (HMI) Display.

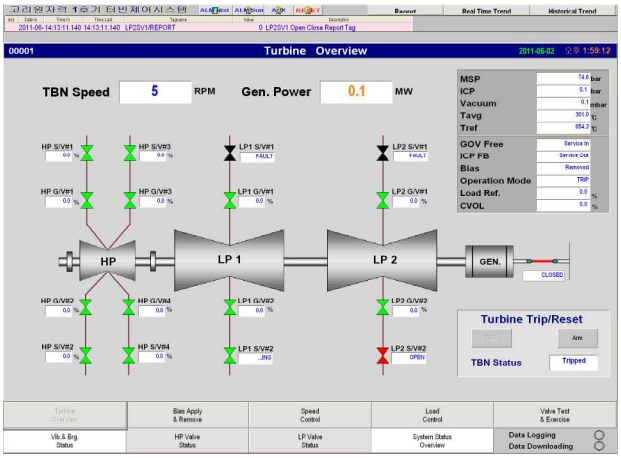

Fig. 4 Sample Display of the NetSim™

3. Sever Accident Modeling

Though Kori-1 Nuclear Power Plant (NPP) was licensed for the continued operation, there are still some of issues for the Public Acceptance (PA) after the Fukushima nuclear disaster in March 2011.
So it is important to have training for the mitigation of the severe accident not to have core damage. Because the RELAP5-RT code could not simulate the severe accident phenomena, KHNP CRI has developed the Real Time Severe Accident Model (RSAM5) which was based on the Modular Accident Analysis Program (MAAP5) with the co-development of Fauske & Associates, LLC (FAI). The MAAP5 parameter file was developed from the existing MAAP4 parameter file, Kori 1 FSAR, existing Kori 1 RELAP input data, and reference replacement steam generator data.
Figure 5. shows the configuration of the RSAM5.

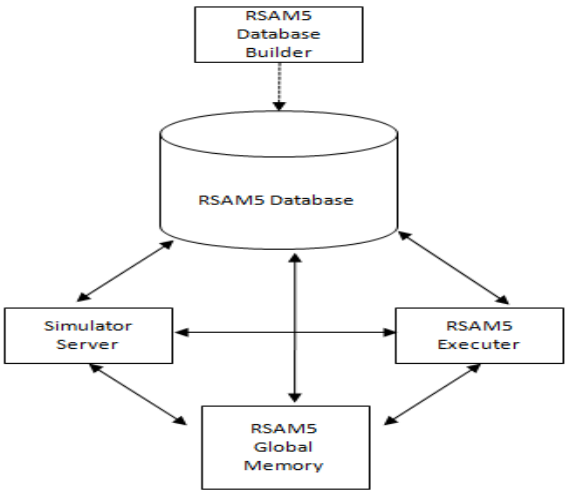

Fig. 5 Overall Configuration of the RSAM5

The RSAM is interface with the simulator environment (3KEYMASTER™) and could simulate the most of the physical phenomena inside the reactor vessel, the reactor coolant system (RCS), and the containment during severe accidents.[3]

4. Conclusions

KHNP Central research Institute (CRI) developed a Kori-1 Full Scope Simulator (FSS) to have HFE Verification and Validation Test and operator training for the new modernized I&C of the MCR.

Fig. 6 View of Kori-1 Simulator

It has deployed the state-of the-art simulation technologies such as the RELAP5-RT, best estimated thermal-hydraulic modeling, virtual stimulated technology for the turbine control system, and the real-time severe accident codes, RSAM5.
KHNP will use the simulator as follows;

- HFE V&V test for the MCR upgrade,
- Operator training including the normal operation, transient and Design Basis Accident (DBA) and beyond DBA (Severe Accident),
- Severe Accident Management Guideline (SAMG) V&V
- Emergency Drill etc.

REFERENCES

[1] Dhong Hoon Lee et al., "Regulatory Approaches on Human Factors Engineering of Main Control Room Modernization: A Case of Kori-1 Nuclear Power Plant in Korea", Proceedings of the IEEE 8th Conference of Human Factors and power Plants, IEEE, CA 2007.
[2] George L. Mesina et al., "Streamlining of the RELAP5-3D Code", Proceedings of the NURETH 12th Conference, IEEE, PA 2007.
[3] Fauske & Associates, LLC, 2011, "*MAAP5: Modular Accident Analysis Program for LWR Power Plants, Transmittal Document for MAAP5 Code Revision MAAP5.0.1. FAI11-1161*", November.