NSSS-BOP Model Integration of OPR1000 Simulator

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1. Introduction

OPR1000 simulator based on the design data of ShinKori-Unit 1, which will be used for training operators of ShinKori-Unit 1&2 and ShinWolsung-Unit 1&2, is being developed. Both real power plant and simulator for OPR1000 are under construction at the moment. OPR1000 simulator adopted RELAP5 R/T code for the modeling of NSSS (Nuclear Steam Supply System) TH (Thermal-Hydraulics) and Reactor Core, and selected 3KEYMASTER^{TM}, a commercial plant simulation tool for NSSS auxiliary systems modeling, BOP(Balance of Plant) modeling and simulator environment. NSSS and BOP Model of OPR1000 Simulator has been integrated on 3KEYMASTER^{TM}. For V&V (Verification and Validation) of the integration, a lot of tests have been carried out through GOP (General Operating Procedure), AOP (Abnormal Operating Procedure), and EOP (Emergency Operating Procedure) during FAT (Factory Acceptance Test) period.

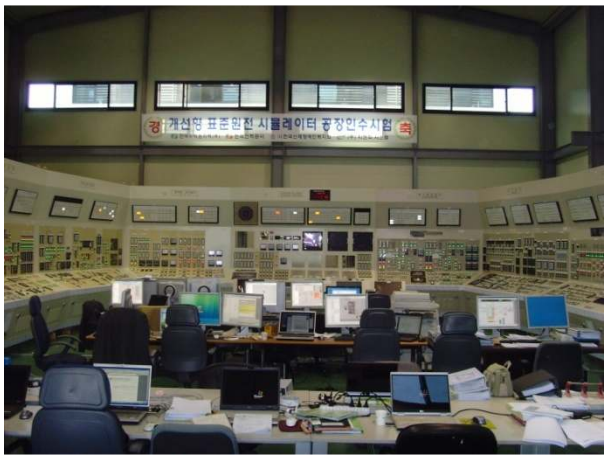

Fig. 1. Overall View of OPR1000 Simulator

2. NSSS Modeling

2.1 Reactor Core Modeling

The core model of OPR1000 simulator has been developed on RELAP5 R/T input with NNKM (Nodal Neutron Kinetics Module. The core is divided into 12 slices axially and 5 thermal-hydraulic volumes radially. The 5 volumes cover 177 radial meshes based on fuel assemblies as shown in the Fig. 2.

Each zone is subdivided into a number of regions and defines averages of volume and heat structure quantities for each region of a zone. After the control rod positions are computed, the control fraction for each axial level is computed. Once the control fractions are computed on each axial level, the neutron cross sections for each level can be computed.

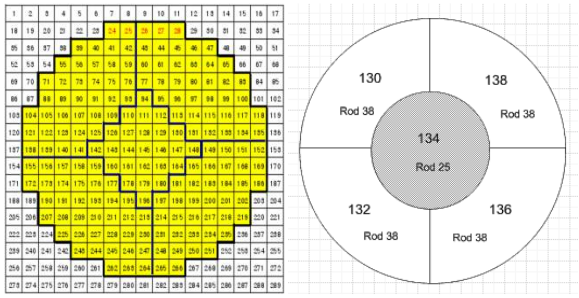

Fig. 2. Nodalization diagram of the Core for NNKM

2.2 TH Modeling

RELAP5 R/T input for TH modeling of OPR1000 has been developed from RELAP5 input deck for Ulchin Unit 3&4. The differences from RELAP5 input for Ulchin Unit 3&4 are as follows

- Boron concentration is added to hydrodynamic components
- Heat structures adjacent to core are changed according to core modeling with NNKM
- Pressurizer nodes are divided into 8 parts.
- Pressurizer heater/vent/spray/Aux. spray, Reactor head vent, over pressure protection devices (PSV, SDS), MSSVs, ADVs, TCVs, Turbine Bypass Valves and etc. are added.

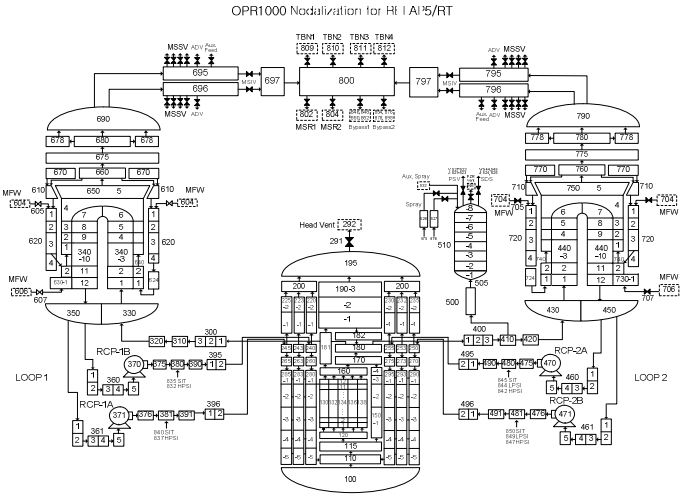

Fig. 3. RELAP5 R/T Nodalization for OPR1000

TH model covers RCS (Reactor Coolant System), Pressurizer, Steam Generator, Main Steam Line. Fig. 3 shows RELAP5 R/T TH Model Nodalization for OPR 1000 simulator.

3. BOP Modeling

BOP model of OPR1000 simulator has been developed on 3KEYMASTER™ which provides several tools for component, logic, transmitter, relay, electric, containment and hydraulic modeling. Dynamic and logic part of each system are embodied according to plant data. Fig. 4 shows an example of Main Steam System modeling among BOP models.

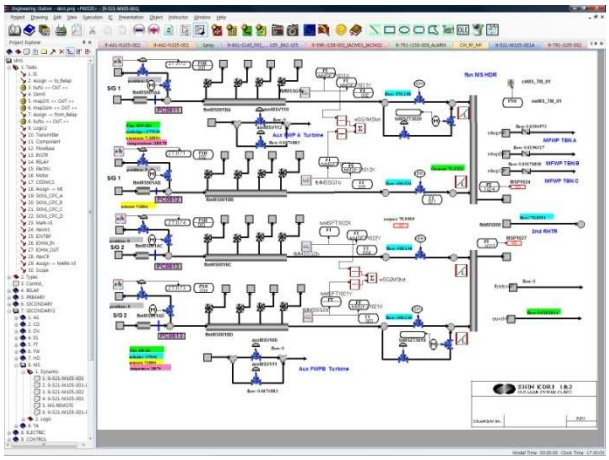

Fig. 4. Example of BOP modeling (Main Steam System)

4. Model Integration of OPR1000 Simulator

4.1 Interface File for Integration

First, two list files of variables for I/O interface between NSSS and BOP model should be made as shown in Fig. 5. Unit conversions between interface variables of two models are carried out through these files.

```
# | BOP | | RELAP5 || | | |
# | Variable | BOP | Variable || RELAP5 | | Conversion Factors |
# Index | Name | Units | Name || Units | Description | Multiplier | Adder
# ------| ---- | ----- | ---- || ----- | ----------- | ---------- | -----
0|||time     |0| sec  | relap5 time      |1|0.00E+00
1|||rkotpow  |0| MW   | Total Power      |1.00E-06|0.00E+00
2|||rkogapow |0| MW   | Decay Power      |1.00E-06|0.00E+00
3|||rkofipow |0| MW   | Fission Power    |1.00E-06|0.00E+00
4|||rkoxerea |0| pcm  | Xenon Worth      |1|0.00E+00
5|||rkosmrea |0| pcm  | Samarium Worth   |1|0.00E+00
6|||rkoreac  |0| pcm  | Net reactivity   |1|0.00E+00
7|||cntrlvar |1510| MPa  | PZR Pressure           |1.00E-06|0.00E+00
8|||cntrlvar |1690| MPa  | SG1 dome Pressure      |1.00E-06|0.00E+00
9|||cntrlvar |1790| MPa  | SG2 dome Pressure      |1.00E-06|0.00E+00
```

Fig. 5. Example of an I/O interface variable file

Second, assign files should be made as shown in Fig. 6. The file decides what interface variables on list file are connected.

```
//bufss[5]
//bufss[6]
bufss[7]   pPZR.input
bufss[7]   fbbRC_PZR.pressure
bufss[7]   fbbCV102.pressure
bufss[7]   fbbRG01_RC01_F6.pressure
```

Fig. 6. Example of an assign file

4.2 Integration Method

For real-time interface between NSSS and BOP model, null transient output and property files on standalone RELAP5 environment are needed for transplanting NSSS model to 3KEYMASTER™ simulation environment. The property file consists of kinetics constants and cross sections.

Next, select IC (Initial Condition) from standalone BOP model in 3KEYMASTER™ and rename null transient output file from NSSS model as the same IC number with BOP model. Then reset the IC number and run the integrated simulator model. After testing it out and satisfied with the result, snap it as a new IC.

5. Test for V&V

For V&V of the integration, several tests have been performed during FAT. Fig.7 illustrates the result of main steam line break transient test. At the time of malfunction insertion, break flow increases abruptly and decreases while the pressurizer pressure decreases because of heat loss by steam outflow and recovers according to PPCS (Pressurizer Pressure Control System).

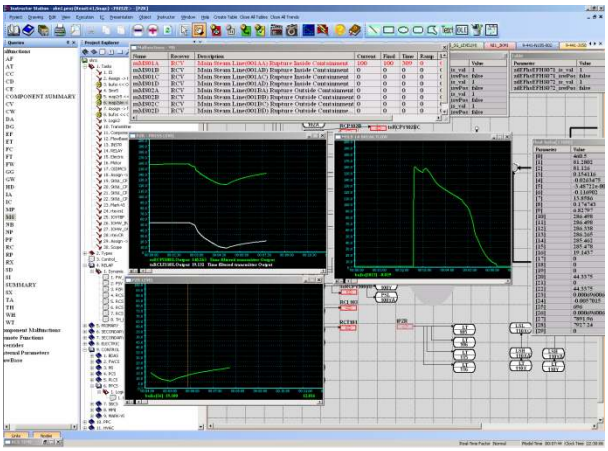

Fig. 7. Example of Transient Test (MSLB)

6. Conclusions

NSSS and BOP model of OPR1000 simulator has been integrated on 3KEYMASTER™. For V&V of model integration, several tests have been performed during FAT. The simulator S/W model is connected with H/W panels that an instructor can evaluate trainees who take action on certain situation the instructor provides. OPR1000 simulator will be tested for better performance during SAT (Site Acceptance Test) period.

REFERENCES

[1] J. H. Hong, M. S. Lee, S. H. Lee, J. K. Suh and D. H. Hwang, “Development of Neutronics Model for Shinkori Unit 1 Simulator”, Transactions of the Korean Nuclear Society Spring Meeting, Gyoungju, Korea, May 29-30, 2008, p. 871-872.

[2] D. H. Hwang, M. S. Lee, J. H. Hong, S. H. Lee, J. K. Suh, “Interface between Core/TH Model and Simulator for OPR1000, Transactions of the Korean Nuclear Society Spring Meeting, Jeju, Korea, May. 22, 2009.