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Development of CPC/COLSS Simulation Model for YGN#3,4 Simulator

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Abstract

The safety and reliablity of nuclear power plant operations relies heavily on the plant operators ability to respond to various emergency situations. It has become standard industry practice to utilize simulators to improve the safety and reliability of nuclear power plants operations. The simulators built for Younggwang#3("YGN#3"), which is based on the Korean Standard Nuclear Power Plant ("KSNPP") design, has been developed precisely for this purpose. The YGN#3 simulator is the first simulator in Korea to be developed locally and is now operational on site. A particular attention was placed on the development of CPC/COLSS safety system which is unique to the YGN#3. The effort to develop CPC/COLSS simulation model has been successful and plans exist for applying this model to simulator projects in the future.

1. Introduction

The importance of operator ability to respond to emergency situation was revealed in the accident investigation of the TMI disaster in 1979. The accident report concluded that the operator mistaked during the accident contributed greatly to the disaster. The TMI disaster demonstrated the importance of operator training and the use of simulators for this very purpose. KEPCO has decided to localize this technology which has been relied soley on foreign vendors until now. The KSNPP has several features which is conceptually different from other nuclear power plants in Korea. One of these features is the CPC/COLSS(Core Protection Calculator/Core Operational Limit Supervisory System). The CPC, which is a digital computer based protection system, is designed to provide on-line calculations of Departure from Nucleate Boiling Ratio(DNBR) and Local Power Density(LPD) and to initiate reactor trip if the core conditions exceed the DNBR and LPD design limit. The COLSS is designed to assist the operator in implementing the Limiting Conditions for Operations(LCOs) in Technical Specifications for DNBR/Linear HEAT Rate(LHR) margin, Azimuthal tilt, and axial shape index(ASI) and to provide alarm when the LCOs are reached. The emphasis was placed on the development of an accurate simulation of the CPC/COLSS which is the first of it's kind to be installed in Korea. The analysis of performance and operations showed that the simulation model developed was indeed accurate simulation of the YGN#3 power plant.

2. CPC/COLSS Model Configuration of Simulator

The simulator for the YGN#3 is a full scope replica type to be used for training plant operators. The CPC/COLSS on the simulator was also designed to provide the same features as those installed in the actual plant. In order the accomplish this Hardware identical to the plant Main Control Room(MCR) was installed. The hardware installed included the same operator module such as the plasma display unit, CRT and Function Keyboards. The simulation host computer was a Silicon Graphics Challenge L and Indy Workstations operating under Real-Time UNIX OS. Table.1 shows the configuration of the actual plant and that of the simulator. Figure 1 shows the simulator H/W configuration for CPC and COLSS

Real Plant CPC/COLSS	Simulator CPC/COLSS
Process(Pipe, Pump, Core, Instrumentation...)	Process Modeling Programs
Main Control Room(MCR) (Example : CRT, PDU)	Main Control Room(MCR) (Example : CRT, PDU)
Computer Systems For Calculation, Display (3205/3280MPS)	Simulation Computer Systems (CHALLANGE L, INDY)

Table 1. The configuration of the actual plant and that of the simulator

Figure 1. The simulator H/W configuration for CPC and COLSS

3. CPC/COLSS Model Development of Simulator

3.1 Development Process

The first step in the development of the CPC/COLSS simulation model is the generation of the Software Requirement Specifications(SRS). The SRS is generated by compiling performance requirement and specifications from plant operators and plant data. The SRS defines the scope of simulation for the simulator for each specific system. The next process is the development of Detailed Design Specifications(DDS). During the DDS phase, the modeling of algorithm and system interfaces are developed. The design data used for this is the CPC/COLSS Functional Design Requirement which is provided by the vendor. After the completion of the DDS, the developed system model is put through a Stand-alone Test and Non-Integrated Systems Test. The system model is then integrated with the simulator and put through an Integration Test. Finally, after the Integration Test is completed, the software model is integrated with the H/W and tested by plant operators during the Factory Acceptance Test(FAT) and Site Acceptance Test(SAT). Figure 2 shows the development process.

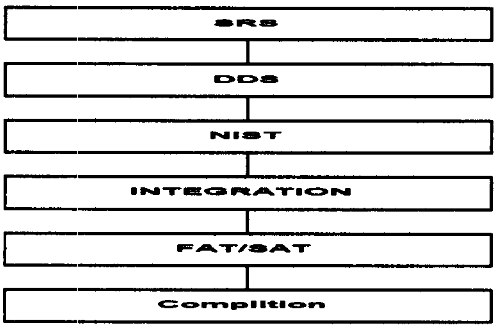

Figure 2. The development process.

3.2 CPC/COLSS model program structure and process flow

3.2.1 CPC/COLSS commonly used software

The computerized systems such as CPC/COLSS developed commonly used software collectively so that changes can be easily made and implemented throughout the simulator. The main task of common S/W development are Data Gathering Task, Communication Manager, Scanning Task, Timer Task.

3.2.2 CPC/COLSS display task and program module

The display task recieves information such as symbols(Pump, valves..), Value(Temperature, Pressure, level...), TEXT(Point ID, description...) from Current Value Table(CVT) and displays this data on the PDU and CRT in the MCR. The display task also recieves operator input and processes the input command.

3.2.3 CPC program module

The plant CPC is design to perform rapid and accurate calculations to maintain certain plant safety parameters to within specified safety limits. In order to comply with this design requirement, the calucation algorithm was installed on the simulation host computer. The CPC program module is set in a top-down configuration with segment modules placed in a hierarchial sequence. The structure allows for the independent compiling of the modules. Figure 3 shows the configuration of the CPC model program.

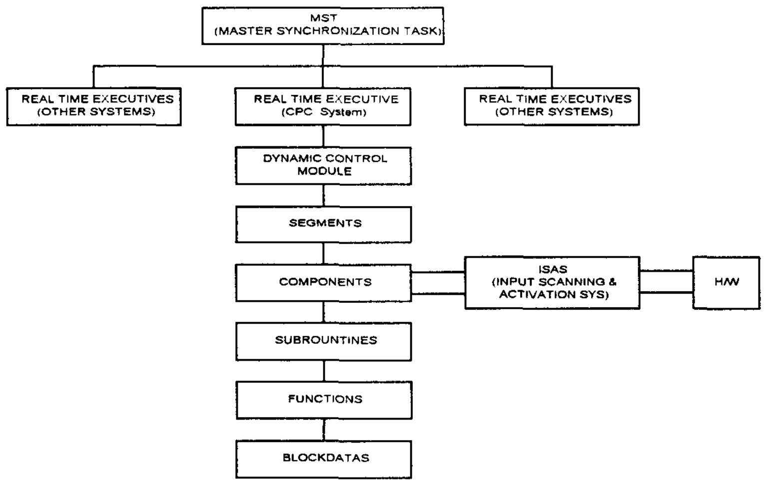

Figure 3. The configuration of the CPC model program.

3.2.3.1 Control Module

The control module has the highest place in the program heirarchy. The control module calls submodules (segments, component, subroutines...) for simulation and sets the calculation cycle rate for the various submodules.

3.2.3.2 Segment Module

The segment module is comprised of mathmatical equations which models the CPC based on the FDR(Functional Design Requironments). The segment module calls on subroutines and component modules for calculating the following functions.

- Coolant Mass Flow Program(FLOW)
- DNBR and Power Density Update Program(UPDATE)
- Power Distribution Program(POWER)
- Static DNBR and Power Density Program(STATIC)
- Trip Sequence Subroutine(TRIPSEQ)
- CEA Penalty Factor Calculation Program(CEAC)

3.2.3.3 Component

The component module simulate the control logics of various components in the acutal power plant. The component modules are a type of a subroutine with component level malfunction feature included in them.

3.2.3.4 Subroutine

The Subroutines used for repeated functions. The Subroutines maybe called by control modules, segments, components, and other subroutines.

3.2.3.5 Functions

The Functions maybe called by control modules, segments, components, and other functions. They are used to calculate and return one value.

3.2.3.6 Block Data

The Block Data is used to store constants which are not actually stroed in the CPC/COLSS program itself. These include constants such as Reload Data Block and Addressable constants.

3.2.4 COLSS Program module

COLSS program being a mounted program is installed separately on a W/S instead of the simulation host computer itself. The COLSS program consists of 5 modules with 20 calculation algorithm written in C programming language.

3.2.5 CPC/COLSS execution flow

The CPC algroithm is executed by the simulation host computer and the variables calculated is displayed on the operator displays. The interface with other systems are executed by accessing data from the global memory and sending the information via a Send Server of the communication manager to the recieve servers on the WorkStations. These data are read by the scan task and updated to the shared memory(CVT). Finaly the display task scans the data in the CVT and displays it on the operator display. The COLSS algorithm calculates the various variables from the data stored in the workstation CVT. The scan task accesss the CVT and sends the information to the operator display terminal. Figure 4 shows the execution & data flow of the CPC/COLSS model program.

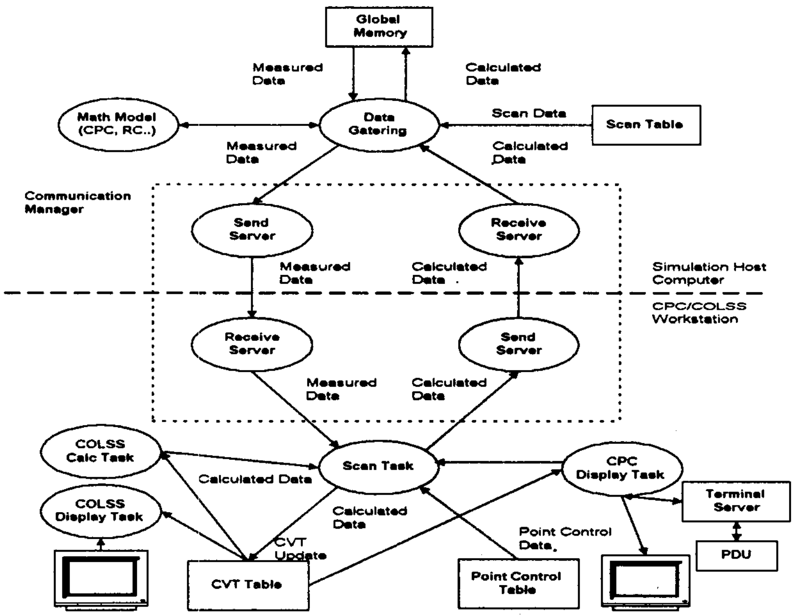

Figure 4. The execution & data flow of the CPC/COLSS model program.

4. Test and Validation

The validation of YGN#3 simulator CPC/COLSS was performed by comparing the on-line calculated variables(DNBR, LPD...) from the actual plant to those calculated by the simulator model. The data used for validation was from the data gathered during YGN#3 Test operation.

4.1 CPC simulation model and analysis result

The operations test of the plant is performed at 0%, 20%, 50%, 80%, and at 100% full power plant operations. The calculated values for the CPC DNBR, LPD... are compared to those calculated from an identical algorithm off-line called the CEDIPS. The calculated values for these parameters from the simulator were compared in an identical procedure to that of the actual power plant.

The system requirement is that the two values differ no more than 2% of each other. The values of constants used for the two calculations are from the actual plant database. Table 3 shows the comparision between the two calculators for 20%, 50%, 80% and 100% power. The difference between the simulator and the CEDIPS came within 1.7%, well within the 2% requirement.

Power Level	Parameters	Plant CPC	Simulator CPC	Error(%)
20%	LPD(w/cm)	218.56	218.30	0.12
	DNBR	6.2196	6.29828	1.25
50%	LPD(w/cm)	367.17	366.72	0.12
	DNBR	3.0614	3.0112	1.67
80%	LPD(w/cm)	415.93	414.33	0.39
	DNBR	2.4919	2.45055	1.68
100%	LPD(w/cm)	489.82	489.75	0.014
	DNBR	1.9566	1.92634	1.57

$$*ERROR = \frac{(CPC - Model)}{Model} * 100(\%)$$

Table 3. The comparision between the two calculators for 20%, 50%, 80% and 100% power

4.2 COLSS simulation model and analysis result.

The COLSS operations test is performed by operating the COLSS independently using a Test Case provided by the vendor. Afterwards the Detailed Print from the plant is compared to the results from the COLSS inspection program called the COLSS Fortran. The simulator COLSS was also tested using the identical procedure. Table 4 is the compilation of Detailed printout results.

Parameters	Simulator COLSS	Plant COLSS
RCS FLOW RATE	359376.33	359376.40
REL MASS FLOW RATE	1.088643	1.09361
BDELT	98.641586	98.6391
BSCAL	99.868037	99.7502
TBN POWER	98.703	98.703
PLANT POWER	99.700	99.684
ASI	0.01334401	0.012884
INTEGRAL RADIAL INTRAD	1.4643201	1.461660
WEIGHTED AVERAGE TILT	0.00446275	0.00411252
MAX3DPK	1.70240371	1.7107590
DNBRS	112.353228	112.57370
KWFPS	132.626653	132.14280

Table 4. The compilation of Detailed printout results.

5. Conclusion

The analysis of the simulator CPC/COLSS output was verified to be within the design performance limit of YGN#3 and demonstrates the accuracy of the simulation model developed for the YGN#3 simulator. The success in developing the simulation model of a safety system unique to YGN#3 should contribute to the improvement in plant operartion there. Furthermore the author believes that the model developed can be applied to future simulator projects such as the North Korea simulator project.

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