RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**435-8541**
SRP Section:	**07.02- Reactor Trip System**
Application Section:	**4.3, 4.4 and 7.2**
Date of RAI Issue:	**03/08/2016**

Question No. 07.02-16

Regulatory Basis:

10 CFR 52.47, “Contents of applications; technical information” states: “The application must contain a level of design information sufficient to enable the Commission to judge the applicant's proposed means of assuring that construction conforms to the design and to reach a final conclusion on all safety questions associated with the design before the certification is granted. The information submitted for a design certification must include performance requirements and design information sufficiently detailed to permit the preparation of acceptance and inspection requirements by the NRC, and procurement specifications and construction and installation specifications by an applicant.”

The NRC staff makes its safety finding based on information provided in the DCD and any documents incorporated by reference into the DCD. It is necessary for all documents containing essential design information that is not contained in the DCD to be docketed and clearly referenced in the DCD wherever needed to support or supplement the Tier 2 design and analysis information.

Requests:

1. The applicant stated during the audit held on January 20 and 21, 2016, that the functional design of the CPCS is based on those described in topical report CEN-310-P-A, “CPC and Methodology Changes for the CPC Improvement Program.” In addition, the applicant stated that topical report CEN-312, “Overview Description of the Core Operating Limit Supervisory System (COLSS),” describes the design basis for the core operating limits supervisory system (COLSS). Since these documents contain design information the staff deems necessary to make its safety finding, please either (1) include these design details in the appropriate section in the DCD or (2) incorporate the above topical reports by reference. If the reports are to be incorporated by reference, then Tier 2, Table 1.6-2 should be updated accordingly.

2. A CPCS flow diagram was presented during the audit on January 20, 2016 (page 16 of the first presentation) which the staff believes is basic design information. Please incorporate this diagram in the DCD or in the referenced technical report.

3. The staff requests clarification on procedures to be used for making changes to the core protection calculator or core operating limits supervisory system software and to various program constants, both those adjusted once per cycle, such as Reload Data Block constants, and those addressable constants which can be changed during power operation. Specifically, are procedures used by operating C-E System 80 plants, such as CEN-39(A)-P, “CPC Protection Algorithm Software Change Procedure” and CEN-323-P-A, “Reload Data Block Constant Installation Guidelines,” considered APR1400 licensing bases? If so, please incorporate these reports by reference in the DCD, as well as the procedure for determination of addressable constants. If alternate procedures are to be used for APR1400, please provide a description and reference to the documentation. If these procedures will not be finalized until the COL Holder selects the fuel to be loaded, a COL Holder Item should be added to the DCD to ensure that the procedures are developed at least 12 months prior to fuel loading.

Response

1. Reference to topical reports CEN-310-P-A and CEN-312 will be added to DCD Tier 2, Sections 7.2 and 7.7 respectively as well as added to Table 1.6-2.

2. Technical Report APR1400-F-C-NR-14003-P, Rev. 0, “Functional Design Requirements for a Core Protection Calculator System for APR1400” will be revised to incorporate the CPCS flow diagram.

3. The Core Protection Calculator System (CPCS) was the first digital system incorporated into the protection system in the CE System 80 plants. CEN-39(A)-P, "CPC Protection Algorithm Software Change Procedure” and CEN-323-P-A, "Reload Data Block Constant Installation Guidelines" were used to change the software functional design and database of the CPCS after its installation. Most of the safety systems are digitalized with a qualified platform in the APR1400. The software to be installed into the safety platform is designed, implemented, verified and validated in accordance with APR1400-Z-J-NR-14003-P, “Software Program Manual” (SPM).

   The SPM includes the design and the testing concept described in the CEN-39(A)-P, "CPC Protection Algorithm Software Change Procedure” and the CEN-323-P-A, "Reload Data Block Constant Installation Guidelines." The planning documents for the CPCS software will be developed for the APR1400 specific plant during the construction phase of the project in accordance with the SPM. These documents will describe the specific development and V&V requirements for the CPCS software.

   The following documents are required by SPM for the CPCS to be developed and will include the detailed requirements of both CEN-39(A)-P, "CPC Protection Algorithm Software Change Procedure” and CEN-323-P-A, "Reload Data Block Constant

Installation Guidelines."

- Software Development Plan for CPCS
- Software Test Plan for CPCS
- Software Verification and Validation Plan for CPCS
- Software Configuration Management Plan for CPCS
- Software Management Plan for CPCS
- Software Quality Assurance Plan for CPCS
- Software Operation and Maintenance Plan for CPCS

All documents will be generated in the conceptual phase of the software lifecycle according to DCD Tier 1, Table 2.5.1-5, Item 11.

The RDB constants are calculated and verified every reload cycle. Then, the RDB constants will be sent to plant to be installed in accordance with the “Software Program Manual” which will be developed for the specific plant.

The CPCS addressable constants will also be established for the plant every cycle. Some addressable constants will be determined and verified by the measured data taken during startup testing. The final CPCS addressable constants determined as a result of startup testing will be installed in the CPCS by the established procedure which will be included in Software Operation and Maintenance Plan for CPCS. The CPCS startup test requirements will be developed by the COL applicant.

Impact on DCD

DCD Tier 2 Sections 7.2, 7.7, and Tables 1.6-2, 1.8-2 will be revised as shown in the attachment.

Impact on PRA

There is no impact on PRA.

Impact on Technical Specifications

There is no impact on Technical Specifications

Impact on Technical/Topical/Environmental Report

Technical Report APR1400-F-C-NR-14003-NP, Rev. 0, “Functional Design Requirements for a Core Protection Calculator System for APR1400” will be revised as shown in the attachment.

e. Core protection calculators

One CPC per channel is provided. The DNBR and LPD are calculated in each CPC using the input signals described below. The DNBR and the LPD are compared with trip setpoints for initiation of the low DNBR trip and the high LPD trip. A trip signal from a CPC in each channel is hardwired to the BP in the respective PPS channel. The CPC also provides pre-trip output signals.

Two independent CEACs are provided in each channel of the CPCS to calculate individual CEA deviations from the position of the other CEAs in their subgroup. RSPT signals of all core quadrants are transmitted to the CEAC through CPPs of each channel, and the specified CEA position signals used in the CPC of the corresponding channel are provided from the CPPs to the CPC through the CEAC. CPP channels A and B provide the position signals of RSPT1 to CEAC1 through CPPs in the other channels, and CPP channels C and D provide the position signals of RSPT2 to CEAC2 through CPPs in the other channels.

The data communications between CPPs and CEACs of the other channels use isolated one-way SDL communication.

Each CPC receives the following inputs:

1) Core cold leg and hot leg temperature

2) Pressurizer pressure

3) RCP speed

4) Ex-core neutron flux power

5) Selected CEA position

6) Penalty factors for CEA deviations within a subgroup from each CEAC

The following calculations are performed in the CPC or CEACs and are described further in the Functional Design Requirements for a Core Protection Calculator System for the APR1400 (Reference 1):

which includes the CPCS Improvement Program (Reference 30)

1) CEA deviations

26. APR1400-Z-J-NR-14001-P, “Safety I&C System,” KHNP, November 2014.

27. IEEE Std. 352-1987, “IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems,” Institute of Electrical and Electronics Engineers, 1987.

28. IEEE Std. 379-2000, “IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems,” Institute of Electrical and Electronics Engineers, 2000.

29. APR1400-F-C-NR-14001-P, "CPC Setpoint Analysis Methodology for APR1400," KHNP, July 2014.
30. CEN-310-P-A, "CPC and Methodology Changes for the CPC Improvement Program," Combustion Engineering, Inc., April 1986.

Note: Reference 29 will be added in the Response to RAI 328-8422 Question 04.04-7.

parameter display system (SPDS) set forth in NUREG-0696 and NUREG-0737, Supplement No.1 (Reference 14).

SPADES+ monitors the status of the critical safety functions during normal, abnormal, and emergency operating conditions and provides alarms when any of the critical safety functions is not being maintained.

SPADES+ provides the capability to display the status of the following critical safety functions:

a) Core reactivity control

b) Maintenance of vital auxiliaries

c) Reactor coolant system inventory control

d) Reactor coolant system pressure control

e) Core heat removal

f) Reactor coolant system heat removal

g) Containment isolation

h) Containment temperature and pressure control

i) Containment combustible gas control (radioactive emissions control)

SPADES+ provides the capability to display the success path status for each critical safety function and initiates an alarm when the function becomes inoperable.

2) Core operating limit supervisory system

The COLSS consists of process instrumentation and algorithms used to continually monitor the limiting conditions for operation (LCO). A description of COLSS algorithms and a discussion of the treatment of COLSS input information are provided in the Functional Design Requirements for a Core Operating Limit Supervisory System for APR1400 Technical Report (Reference 5). The COLSS continuously calculates departure from nucleate

and Overview Description of the Core Operating Limit Supervisory System (Reference 15)

3. Regulatory Guide 1.47, “Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems,” Rev. 1, U.S. Nuclear Regulatory Commission, February 2010.

4. APR1400-E-I-NR-14012-P, ″Style Guide,″ KHNP, December 2014.

5. APR1400-F-C-NR-14002-P, “Functional Design Requirements for a Core Operating Limit Supervisory System for APR1400,” KHNP, August 2014.

6. Regulatory Guide 1.133, “Loose-Part Detection Program for the Primary System of Light-Water-Cooled Reactors,” Rev. 1, U.S. Nuclear Regulatory Commission, May 1981.

7. APR1400-Z-J-NR-14003-P, “Software Program Manual,” KHNP, November 2014.

8. APR1400-Z-J-NR-14002-P, “Diversity and Defense-in-Depth,” KHNP, November 2014.

9. APR1400-Z-A-NR-14019-P, “CCF Coping Analysis”, KHNP, November 2014.

10. APR1400-Z-J-NR-14012-P, “Control System CCF Analysis,” KHNP, November 2014.

11. 10 CFR 50.150, “Aircraft Impact Assessment,” U.S. Nuclear Regulatory Commission.

12. IEEE Std. 383-2003, “IEEE Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations,” Institute of Electrical and Electronics Engineers, 2003.

13. NUREG-0696, “Functional Criteria for Emergency Response Facilities,” U.S. Nuclear Regulatory Commission, 1981.

14. NUREG-0737, Supplement No. 1, “Clarification of TMI Action Plan Requirements: Requirements for Emergency Response Capability,” U.S. Nuclear Regulatory Commission, 1983.

15. CEN-312-P, "Overview Description of the Core Operating Limit Supervisory System," Rev. 01-P, November 1986.

Table 1.6-2 (2 of 2)

Report Number [1]	Title	DCD Tier 2 Section
APR1400-F-A-NR-14002-P APR1400-F-A-NR-14002-NP	The Effect of Thermal Conductivity Degradation on APR1400 Design and Safety Analyses	15.4 15.6
APR1400-F-A-NR-14003-P APR1400-F-A-NR-14003-NP	Post-LOCA Long Term Cooling Evaluation Model	15.6
APR1400-H-N-NR-14012-P APR1400-H-N-NR-14012-NP	Mechanical Analysis for New and Spent Fuel Storage Racks	9.1.2
APR1400-K-I-NR-14005-P APR1400-K-I-NR-14005-NP	Staffing and Qualifications Implementation Plan	18.5
APR1400-K-I-NR-14009-P APR1400-K-I-NR-14009-NP	Design Implementation Plan	18.11
APR1400-Z-A-NR-14006-P APR1400-Z-A-NR-14006-NP	Non-LOCA Safety Analysis Methodology	15.0.2
APR1400-Z-A-NR-14007-P APR1400-Z-A-NR-14007-NP	LOCA Mass and Energy Release Methodology	6.2.1.3
APR1400-Z-J-NR-14001-P APR1400-Z-J-NR-14001-NP	Safety I&C System	7.1, 7.2, 7.3, 7.4, 7.5, 7.8, 7.9
APR1400-Z-J-NR-14003-P APR1400-Z-J-NR-14003-NP	Software Program Manual	7.1.4, 7.2.2.2, 7.3.1
APR1400-Z-J-NR-14004-P APR1400-Z-J-NR-14004-NP	Uncertainty Methodology and Application for Instrumentation	7.2.2.7, 7.3.2.7
APR1400-Z-J-NR-14005-P APR1400-Z-J-NR-14005-NP	Setpoint Methodology for Plant Protection System	7.2.2.7, 7.3.2.7
APR1400-Z-M-NR-14008-P APR1400-Z-M-NR-14008-NP	Pressure-Temperature Limits Methodology for RCS Heatup and Cooldown	5.2, 5.3

(1) P – denotes document is proprietary.

NP – denotes document is non-proprietary.

CEN-310-P-A	CPC and Methodology Changes for the CPC Improvement Program	7.2
CEN-312-P	Overview Description of the Core Operating Limit Supervisory System	7.7

3.2 Program Structure

The CPC design bases require that the system calculate conservative, but relatively accurate, values of DNBR and peak linear heat rate. However, the algorithms required to achieve sufficiently detailed calculations cannot be executed rapidly enough to provide protection for those design basis events with the most rapid approach to the specified acceptable fuel design limits. In order to achieve a system time response sufficient to accommodate the limiting design basis events, additional dynamic calculations of DNBR and peak linear heat rate are required. The dynamic calculations must provide conservative estimates of DNBR and peak linear heat rate based on changes in the process variables between successive detailed calculations of DNBR and peak linear heat rate. The detailed calculations of DNBR and peak linear heat rate must also be separated into different programs. The grouping of detailed calculations must be such that the execution interval of each program reflects the time interval over which the dynamic adjustments to the parameters, calculated in that program, are valid.

The resultant protection software shall consist of six interdependent programs:

1) Coolant Mass Flow Program (FLOW),

2) DNBR and Power Density Update Program (UPDATE),

3) Power Distribution Program (POWER),

4) Static DNBR and Power Density Program (STATIC),

5) Trip Sequence Program (TRIPSEQ),

6) CEAC Penalty Factor Program.

Figure 3.2 shows the functional block diagram of CPCS.

The five programs are executed in the CPC Processor Subrack. The last program is executed in the CEAC Processor Subrack.

The FLOW program shall compute the primary coolant mass flow rate and DNBR margin. The DNBR margin is transmitted to the Information Processing System (IPS).

The UPDATE program shall perform the following major computations:

1) Calibrated neutron flux power,

2) Total thermal power,

3) Core average heat flux,

4) Hot pin heat flux distribution,

5) DNBR and quality margin at the node of minimum DNBR, updated for changes in input parameters,

6) Peak local power density,

7) Asymmetric Steam Generator Transient (ASGT) trip,

8) Variable Overpower Trip (VOPT),

9) Low Pressure and Low DNBR Trip (LPLDT).

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Figure 3.2 Functional Block Diagram of CPCS

Table 1.8-2 (9 of 29)

Item No.	Description
COL 6.1(1)	The COL applicant is to identify the implementation milestones for the coatings program.
COL 6.2(1)	The COL applicant is to identify the implementation milestone for the CILRT program.
COL 6.3(1)	The COL applicant is to prepare operational procedures and maintenance programs as related to leak detection and contamination control.
COL 6.3(2)	The COL applicant is to maintain complete documentation of system design, construction, design modifications, field changes, and operations.
COL 6.4(1)	The COL applicant is to provide automatic and manual operating procedures for the control room HVAC system, which are required in the event of a postulated toxic gas release.
COL 6.4(2)	The COL applicant is to provide the details of specific toxic chemicals of mobile and stationary sources and evaluate the MCR habitability based on the recommendations in NRC RG 1.78 to meet the requirements of TMI Action Plan Item III.D.3.4 and GDC 19.
COL 6.4(3)	The COL applicant is to identify and develop toxic gas detection requirements to protect the operators and provide reasonable assurance of the MCR habitability. The number, locations, sensitivity, range, type, and design of the toxic gas detectors are to be developed by the COL applicant.
COL 6.5(1)	The COL applicant is to provide the operational procedures and maintenance program as related to leak detection and contamination control.
COL 6.5(2)	The COL applicant is to maintain the complete documentation of system design, construction, design modifications, field changes, and operations.
COL 6.6(1)	The COL applicant is to identify the implementation milestones for ASME Section Xl inservice inspection program for ASME Code Section III Class 2 and 3 components.
COL 6.6(2)	The COL applicant is to identify the implementation milestone for the augmented inservice inspection program.
COL 6.8(1)	The COL applicant is to provide the operational procedures and maintenance program for leak detection and contamination control.
COL 6.8(2)	The COL applicant is to provide the preparation of cleanliness, housekeeping, and foreign materials exclusion program.
COL 6.8(3)	The COL applicant is to maintain the complete documentation of system design, construction, design modifications, field changes, and operations.
COL 6.8(4)	The COL applicant is responsible for the establishment and implementation of the Maintenance Rule program in accordance with 10 CFR 50.65.
COL 7.5(1)	The COL applicant is to provide a description of the site-specific AMI variables such as wind speed, and atmosphere stability temperature difference.
COL 7.5(2)	The COL applicant is to provide a description of the site-specific EOF.

COL 7.2(1) The COL applicant is to provide site-specific CPCS startup test requirement

The outputs to the IPS are as follows:

1) DNBR margin

2) LPD margin

3) Calibrated neutron flux power

4) CPC measurement factor and calculation results values

5) Trip-buffer and snapshot reports

The outputs to the QIAS-N are as follows:

1) DNBR margin

2) LPD margin

3) Axial shape index

4) DNBR

5) Compensated LPD

6) Cold leg temperature

7) Hot leg temperature

The CPCS consists of four channels, and each channel is installed in an independent cabinet. The operator can monitor all calculators, including inputs and calculated outputs from the OMs. The operator can change CPC addressable constants according to administrative procedures.

7.2.1.2 Reactor Protection System Logic

a. Bistable logic

The bistable logic compares input signals from the process measurement instrumentation to fixed or variable setpoints. The bistable logic initiates a channel trip when any monitored parameter exceeds the trip setpoint, as shown in

The COL applicant is to provide site-specific CPCS startup test requirement (COL 7.2(1)).

7.2.3.3 Test and Inspection

The RPS complies with the test requirements of IEEE Std. 338. Test intervals and their bases are included in the Technical Specifications (Chapter 16).

Periodic testing complies with NRC RG 1.22 and NRC RG 1.118.

7.2.3.4 Restrictive Setpoints

Restrictive setpoints are not used for the RPS.

7.2.3.5 Conformance to General Design Criteria

Conformance with the applicable GDC is described in Reference 26, and cross references to relevant information are provided in Table 7.1-1.

7.2.3.6 Conformance with IEEE Std. 603

Conformance with IEEE Std. 603 is described in Reference 26.

7.2.3.7 Conformance to IEEE Std. 7-4.3.2

Conformance to IEEE Std. 7-4.3.2 is described in Reference 26.

7.2.4 Combined License Information

~~No combined license (COL) information is required with regard to Section 7.2.~~

7.2.5 References

1. APR1400-F-C-NR-14003-P, "Functional Design Requirements for a Core Protection Calculator System for the APR1400," KHNP, August 2014.

2. Regulatory Guide 1.62, "Manual Initiation of Protection Action," Rev. 1, U.S. Nuclear Regulatory Commission, June 2010.

COL 7.2(1) The COL applicant is to provide site-specific CPCS startup test requirement.