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.:	**488-8617**
SRP Section:	**7.2 - Reactor Trip System**
Application Section:	**7.2**
Date of RAI Issue:	**05/18/2016**

Question No. 07.02-17

This series of request for additional information (RAI) questions are requesting design details about the Core Protection Calculator System (CPCS) for the APR1400 design certification application. New APR1400 CPCS design information was provided during the January 20, 2016 and January 21, 2016, APR1400 Final Safety Analysis Report (FSAR) Chapter 4 (Reactor) audit, as well as the May 2, 2016 and May 3, 2016, APR1400 FSAR Chapter 7 (Instrumentation and Controls) public meeting.

a) Provide design details, design descriptions, functional, and logic diagrams that explain and discuss the actuation, execution, and operation of the CPCS auxiliary trips as listed in the APR1400 FSAR, Revision 0, Tier 2, Table 7.2-4, “Reactor Protection System Design Inputs,” Sheet 2. 10 CFR Part, 50, Appendix A, General Design Criterion 20, “Protection system functions,” states in part, that the protection system shall be designed to initiate automatically the operation of appropriate systems, including the reactivity control systems. The guidance of the Standard Review Plan (SRP), Revision 5, Section 4, “Safety System Designation,” states, in part that for design basis completeness, information provided for each design basis item should be sufficient to enable the detailed design of the I&C system to be carried out. The NRC staff was not able to identify diagrams or figures that graphically describe the trip actuation output paths of the CPCS auxiliary outputs as described in the APR1400 application. At the May 3rd, 2016, APR1400 public meeting, the applicant stated that the CPCS auxiliary trips do not have separate output paths for each listed trip. The NRC staff was not able to identify design information that would describe how the CPCS auxiliary trips are performed and executed in the APR1400 FSAR or its referenced documents. At the May 3rd, 2016, public meeting, the applicant stated that the requested information was not included in the APR1400 application. Therefore, the NRC staff request the applicant to update APR1400 application to include design descriptions that would explain and describe the operation of the CPCS auxiliary trips execution. This design information should be updated in the APR1400 design certification application in the appropriate places, such as the APR1400 FSAR and

applicable technical reports such as APR1400-F-C-NR-14003-P, “Functional Design Requirements for a Core Protection Calculator System for APR1400” and APR1400-Z-J-NR-14001-P, “Safety I&C System.”

b) Provide a consistent and unambiguous definition for the CPCS maximum penalty factor (PF) value when two CPCS control element assembly calculators (CEACs) become inoperable. 10 CFR Part, 50, Appendix A, General Design Criterion 23, “Protection System Failure Modes,” states in part, that the protection system shall be designed to fail into a safe state or into a state demonstrated to be acceptable on some other defined basis. SRP Section 5.5, “System Integrity,’ states, in part, that computer-based safety systems should, upon detection of inoperable input instruments, automatically place the protective functions associated with the failed instrument(s) into a safe state (e.g., automatically place the affected channel(s) in trip) and that hardware or software failures detected by self-diagnostics should also place a protective function into a safe state. The maximum CPCS departure from nucleate boiling ratio (DNBR) and high local power density (LPD) penalty factor utilized by the CPCS when both CEACs of a division become inoperable was defined in the response to RAI # 274-8277 (ADAMS Accession Number ML15363A340; Question# 07.01-38) as “predetermined penalty factor” (PF). However, at the May 2, 2016, and May 3, 2016, public meeting, the applicant stated that several design descriptions used to define this maximum CPCS failure mode penalty factor will be replaced with the term “preselected PF” to describe the CPCS maximum penalty factor value utilized when both CEACs become inoperable. This new design information should be updated in the APR1400 design certification application in the appropriate places, such as the APR1400 FSAR and applicable technical reports such as APR1400-F-C-NR-14003-P, “Functional Design Requirements for a Core Protection Calculator System for APR1400” and APR1400-Z-J-NR-14001-P, “Safety I&C System.”

c) Identify in the APR1400 FSAR, Chapter 15 safety analysis, where the time delay that the core protection calculator (CPC) will utilize before reverting to the “predetermined penalty factor” (PFmax), as discussed in the response to RAI 274-8277 (ADAMS Accession Number ML15363A340; Question 07.01-37). 10 CFR 52.47(a)(2), “Contents of Applications; Technical Information,” states, in part, that the description shall be sufficient to permit understanding of the system designs and their relationship to the safety evaluations. SRP Section 4, “Safety System Designation,” states in part, that the information provided in the design basis should be analyzed to demonstrate its consistency with the plant safety analysis and the information provided for the design basis items should be technically accurate. At the January 21, 2016 audit and the May 2, 2016, and May 3, 2016, public meeting, the applicant stated that the CPC time delay is not considered in the APR1400 FSAR Chapter 15 safety analysis, as was originally stated in the response to RAI 274-8277 (ADAMS Accession Number ML15363A340; Question 07.01-37). Verify that the APR1400 FSAR, Tier 2, Chapter 15 safety analysis includes this time delay as stated in the response to RAI 274-8277, Question 07.01-37 and ensure consistency regarding this time delay in the APR1400 application.

Response

a) The auxiliary trips which are generated by CPCS are indicated in the following locations:

- DCD Tier 2, Table 7.2-4 CPC Auxiliary Trips
- DCD Tier 2, Table 7.2-7 Failure Mode and Effects Analysis for the Plant Protection System, Items 2-1, 2-2, and 2-5
- Functional Design Requirements for a Core Protection Calculator System for APR1400 TeR, APR1400-F-C-NR-14003-P, Section 4.5.4, Auxiliary Trips
- Safety I&C System TeR, APR1400-Z-J-NR-14001-P, Section 4.3.1.1, Auxiliary Trips

The functions and design details are provided in the FDR for a CPCS TeR. The examples of the CPCS auxiliary trips are described in the DCD Tier 2, Table 7.2-7 Failure Mode and Effects Analysis for the Plant Protection System, Items 2-1, 2-2, and 2-5.

The logic diagram for actuation, execution and operation of CPCS auxiliary trips are included in in the DCD Tier 2, Figure 7.2-7. For example, the range checks for process inputs are done in the FLOW CALCULATION, CALCULATION OF Delta-T POWER, and CORRECTION FOR SHAPE ANNEALING AND CEA SHADOWING FACTORS modules in Figure 7.2-7. The triggers of auxiliary trip from these modules are provided to both DNBR COMPARATOR and LOCAL POWER DENSITY COMPARATOR modules to generate DNBR and LPD trips simultaneously.

To provide a clearer description for CPCS auxiliary trips, In the DCD Tier 2, Table 7.2-4, the following note (9) will be added:

″(9) Any CPC auxiliary trip sets both the DNBR and LPD trip contact outputs.”

In addition, the following sentences will be added in the Safety I&C System technical report, Section 4.3.1.1:

″An auxiliary trip is initiated in response to any one of the following conditions by setting both the DNBR and LPD trip contact outputs.”

b) The TeR “Functional Design Requirements for a CPCS for APR1400”, APR1400-F-C-NR-14003-P, and the DCD Tier 2, Table 7.2-7 use terminology which is not consistent. To provide consistency, DCD Tier 2, Table 7.2-7 will be revised as follows:

- The term of “pre-assigned PF” in the DCD Tier 2, Table 7.2-7 will be replaced with "pre-selected PF”.

The following definition will be added in Table 7.2-7:

- Pre-selected PF: Penalty factor which is selected to initiate plant trip for two CEAC fail condition.

c) When sensing that both CEAC1 and CEAC2 are inoperable, the affected channel CPC processor will automatically generate the DNBR and LPD trips after the defined time delay.

The time delay is considered before applying the maximum PF (PFMAXD & PFMAXL) when both CEACs are failed. This time delay is not considered in the DCD Tier 2 Chapter 15 Safety analysis because there is no design basis event in the DCD Tier 2 Chapter 15 that assumes the occurrence of CEA misoperation concurrent with the both CEAC failures. Furthermore, in the safety analysis, the probability of CEA misoperation during the time delay is very low and the resulting consequence of fuel failure and radiological dose is bounded by other postulated accidents in the DCD Chapter 15.

Impact on DCD

Table 7.2-4 and 7.2-7 of DCD Tier 2 will be revised, as indicated in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

The Safety I&C System technical report "APR1400-Z-J-NR-14001" will be revised, as indicated in the attachment.

(9)

Table 7.2-4 (2 of 2)

Type	Nominal Value at Full Power	Nominal Trip Setpoint	Setpoint Type (1)	Nominal Margin to Trip
CPC Auxiliary Trips				
Cold leg temperature, °C (°F)	291 (555)	262.2 (504) to 310.6 (591)	Fixed	+19.6 (36) –28.8 (51)
Primary pressure, kg/cm^{2}A (psia)	158.2 (2,250)	127.3 (1,810) to 168.0 (2,389)	Fixed	+9.8 (139.4) –30.9 (440)
Hot pin ASI	0.0	–0.5 to +0.5	Fixed	+0.5; –0.5
One pin radial peak	1.6	1.28 to 7.0	Fixed	+5.4; +0.32
Hot leg temperature, °C (°F)	324 (615)	Thot > Tsat-11.1 °C (20 °F)	Fixed	10 (18)
Asymmetric steam generator transient, °C (°F)	0 (0)	8.33(15)	Fixed	8.33 (15)
Pump speed, %	100	95.0	Fixed	5.0
Variable overpower	100 % Power	110 % Power	Variable	10 % Power
Increasing rate	0	6 % / min		6 % / min
Decreasing rate	0	90 % / min		90 % / min
Band (2)	NA	15 % band		NA
Low pressure, kg/cm^{2}A (psia) and DNBR	158 (2,250) and 2.0	141.7 (2,015) and 1.45	Fixed	16.3 (235) and 0.55

(1) Type of setpoint generation

(2) % band is percent above measured ex-core power level.

(3) Calculated value of DNBR provides reasonable assurance of a trip conservatively considering all sensor and processing time delays and inaccuracies. Calculated DNBR is less than or equal to actual core DNBR.

(4) Setpoint can be manually decreased to a fixed increment below existing pressure as pressure is reduced during controlled plant cooldown and is automatically increased as pressure is increased maintaining a fixed increment. This fixed increment is 28 kg/cm^2 (400 psi) for pressurizer pressure and 14 kg/cm^2 (200 psi) for steam generator pressure.

(5) Trip setpoint has a minimum value of 7 kg/cm^{2}A (100 psia).

(6) Percentage of the distance between steam generator upper and lower level wide range instrument nozzle

(7) Percentage of the distance between steam generator upper and lower level narrow range instrument nozzle

(8) For the low reactor coolant flow (LRCF) reactor trip setpoint, the process used to calculate the trip setpoint and generate a trip by comparing it with the input value occurs simultaneously. That is, the digital data from which the trip setpoint is created is the same as that used to establish the trip. Therefore, no uncertainty factor exists that would affect the trip setpoint, and the nominal trip setpoint for LRCF is identical to the allowable value in Technical Specifications (Chapter 16), Table 3.3.1-1.

(9) Both the DNBR and LPD trips are initiated in the CPCS for any condition of the CPC auxiliary trips.

4.3 Core Protection Calculator System

4.3.1 Functions

The CPCS generates low DNBR and high LPD trip signals. The CPCS monitors pertinent reactor core conditions and calculates DNBR and LPD values from monitored process parameters in each of four redundant core protection calculators (CPCs).

The CPCS provides DNBR and LPD pre-trip and trip signals when either the calculated DNBR or LPD approaches or exceeds its respective setpoint or when certain auxiliary conditions are met. The CPCS channel pre-trip and trip outputs are used by the PPS logic where 2-out-of-4 voting is performed to generate a reactor trip signal.

4.3.1.1 Trip Functions

DNBR Trip

The low DNBR trip is provided to trip the reactor when the calculated DNBR approaches a preset value. The calculation of DNBR is performed by the CPCS based on core average power, reactor coolant pressure, reactor inlet temperature, reactor coolant flow, and the core power distribution. The CPCS calculation includes allowances for sensor and processing time delays and inaccuracies such that a trip is generated by the CPCS before violation of the DNBR safety limit in the limiting coolant channel of the core during incidents of moderate frequency or infrequent incidents.

LPD Trip

The high LPD trip is provided to trip the reactor when the calculated core peak LPD reaches a preset value. The preset value is less than that value which would cause fuel center-line melting. The calculation of LPD is based on the core average power and core power distribution and includes a compensation to account for the thermal capacity of the fuel. The calculated trip assures a core peak LPD below the safety limit for peak linear heat rate.

An auxiliary trip is initiated in response to any one of the following conditions by setting both the DNBR and LPD trip contact outputs.

Auxiliary Trips

The CPCS is also designed to meet additional design bases via auxiliary trip functions. ~~These auxiliary trip functions are:~~

- Variable overpower trip provides protection for sudden power increases. The trip signal is generated when the calculated reactor power increases greater than the setpoint. The setpoint is a variable that changes based on the calculated reactor power within pre-defined rate limits. If the reactor power increases rapidly and exceeds the rate limited variable setpoint, the trip signal is generated.

- Asymmetric SG transient trip provides protection for instantaneous closure of the main steam isolation valves to a single SG. The temperature difference of two cold leg temperatures is monitored. If the difference is greater than the pre-defined setpoints, the trip signal is generated.

- Range trips on several parameters assure that the core conditions are within the analyzed operating space. If the input values or certain calculated variables exceed the pre-defined ranges, the range trip signal is generated.

- Pump trip precludes operation with fewer than two RCPs running.

Table 7.2-7 (26 of 68)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	last good Effect on PPS	Remarks and Other Effects
2-12	CEAC 1 processor module (PM) processor section	a) OFF; processor off	Loss of module power; software execution stops	• CEAC 1 watchdog timer timeout, CEAC 1 fail indication on OM/MTP. • Channel trouble indication / annunciation. • CEAC 1 fail flag to CPC in the same channel.	• CEAC 1 fail indication on OM/MTP • Channel trouble indication / annunciation CEAC 1 processor fault lamp on, green run lamp out	Two redundant CEACs in each channel.	• Affected CPC uses the ~~last valid~~ PF from the failed CEAC or the current PF from the operable CEAC, whichever is larger. • If the other CEAC is failed/declared inoperable/or in test, a large ~~pre-assigned~~ PF is assumed in that CPC.	Operation with a single failed CEAC in one or more channels addressed in LCO 3.3.3.
		b) ON; processor running, CEAC fails to detect proper CEA position, or otherwise fails to produce desired results.	Erroneous inputs, unrecognized hardware or software malfunction;	• Possible inconsistency in CEA position with respect to other CEAC/pulse count. • Failure to properly indicate CEA motion.	• Cross channel comparison of CEA position	CEACs in each channel.	• Affected CPC uses the higher of the PFs from the two CEACs in the affected channel. • CEAC 1 is the preferred source of Target CEA position to the CPC. • If target CEA position is improper, could get improper channel response to a valid subgroup deviation or groups out of sequence. • If so, only one CPC channel is affected. • RPS logic is converted to a 2-out-of-2 coincidence logic.	To restore the PPS logic to 2-out-of-3 coincidence, the bypassed channel is returned to operation and the failed channels are bypassed. Note that on line diagnostics identify problems in CEAC module and generate CEAC failure.

~~pre-determined (2)~~
pre-selected(2)

~~(2) Pre-determined PF : Penalty Factor which is determined based on the reactivity worth for each CEA.~~

(2) Pre-selected PF : Penalty factor which is selected to initiate plant trip for two CEACs fail condition

Table 7.2-7 (27 of 68)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect on PPS	Remarks and Other Effects
2-13	CEAC 2 processor module (PM) processor section	a) OFF; processor off	Loss of module power; software execution stops	• CEAC 2 watchdog timer timeout, CEAC 2 fail indication on OM/MTP. • Channel trouble annunciation. • CEAC 2 Fail flag to CPC in the same channel.	• CEAC 2 Fail indication on OM/MTP • Channel Trouble annunciation CEAC 2 processor fault lamp on, green run lamp out	Two redundant CEACs in each channel.	• Affected CPC uses the ~~last valid~~ PF from the failed CEAC or the current PF from the operable CEAC, whichever is larger. • If other CEAC is failed/declared inoperable/or in test, a large ~~pre-assigned~~ PF is assumed in that CPC.	Operation with a single failed CEAC in one or more channels addressed in LCO 3.3.3.
		b) ON; processor running, CEAC fails to detect proper CEA position, or otherwise fails to produce desired results.	Unrecognized hardware or software malfunction	Possible inconsistency in CEA position with respect to other CEAC/pulse count. Failure to properly indicate CEA motion.	Cross channel comparison of CEA position	Two redundant CEACs in each channel.	• Affected CPC uses the higher of the PFs from the two CEACs in the affected channel. • CEAC 2 is the alternate source of Target CEA position to the CPC. • Therefore, Target CEA position errors are not passed on to CPC unless CEAC 1 is also inoperable.	• Operation with a single failed CEAC in one or more channels addressed in LCO 3.3.3. • After on-line diagnostic function is performed and the problem within CEAC module is identified, CEAC fail condition is generated.

last good

~~pre-determined~~

pre-selected

Table 7.2-7 (31 of 68)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect on PPS	Remarks and Other Effects
2-16	One CEAC to CPC high speed link in a CPC channel	Loss of one SDL	Mechanical failure, loss of fiber-optic modem power, damage to link	• SDL diagnostics indicate SDL failure, channel trouble indication on OM/MTP, trouble annunciation • CPC uses ~~last valid~~ PF from inoperable CEAC versus current PF from operable CEAC. • Target CEA position sent to CPC over remaining link	• Channel trouble indicated on OM/MTP in affected channel(s) • Diagnostics identify nature of failure.	• Redundant CEAC to CPC SDL provides PFs and Target CEA position input. • One channel has one inoperable CEAC. • All others channels fully operable.	• One channel has one inoperable CEAC. • Other channels fully operable. • RPS remains in 2-out-of-3 coincidence logic.	Operation with one failed CEAC in one or more channels addressed by LCO 3.3.3.
2-17	Both CEAC to CPC high speed links in a CPC channel	Loss of both SDL	Mechanical failure, loss of fiber-optic modem power, damage to link	• SDL diagnostics indicate SDL failure, channel trouble indication on OM/MTP, trouble annunciation • Both CEACs fail. CPC uses ~~pre-assigned~~ PF on loss of both CEACs. • Likely channel trip if at high power levels • If SDL failure also causes loss of target CEA position transmission, CPC Fail and DNBR/LPD channel trip occurs.	• [illegible] OM/MTP in affected channel(s) • Diagnostics identify nature of failure • Channel trip (DNBR/LPD trip/pre-trip/CWP) likely	• On loss of both CEACs, CPC channel uses ~~pre-assigned~~ penalty. • Trip likely at high power levels. • Loss of Target CEA position input causes aux trip (DNBR/LPD) • Three channel redundancy in PPS	• One channel has two inoperable CEACs. Likely channel trip. • RPS is converted to 1-out-of-2 coincidence logic.	To restore the PPS logic to 2-out-of-3 coincidence logic, the bypassed channel is returned to operation and the failed channels are bypassed.

last good

~~pre-determined~~

pre-selected

~~pre-determined~~

pre-selected