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## 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.:** 178-8184  
**SRP Section:** 08.02 – Offsite Power System  
**Application Section:** 8.2  
**Date of RAI Issue:** 08/31/2015

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### **Question No. 08.02-7**

The NRC issued Bulletin 2012-01, “Design Vulnerability in Electric Power System,” (Agencywide Documents Access and Management System (ADAMS) Accession Number ML12074A115) to all holders of operating licenses and combined licenses for nuclear power reactors requesting information about the facilities’ electric power system designs, in light of the recent operating experience that involved the loss of one of the three phases of the offsite power circuit (single-phase open circuit condition) at Byron Station, Unit 2 to verify compliance with applicable regulations.

DCD, Tier 2, Table 8.1-2 indicates that BL-2012-01, Design Vulnerability of Electric Power System is applicable to DCD section 8.2.

In order to verify that the applicants of new reactors have addressed the design vulnerability identified at Byron in accordance with the requirements specified in General Design Criterion (GDC) 17, “Electric Power Systems,” in Appendix A, “General Design Criteria for Nuclear Power Plants,” of 10 CFR 50, and the design criteria for protection systems under 10 CFR 50.55a(h)(3), please provide the following information. The staff position on this issue is provided in Branch Technical Position BTP 8-9 (ML15057A085).

- A) Describe the protection scheme design for important-to-safety buses (non-safety or safety-related) to detect and automatically respond to a single-phase open circuit condition or high impedance ground fault condition on credited offsite power circuits.
- B) If the important-to-safety buses are not powered by offsite power sources during at-power condition, explain how the surveillance tests are performed to verify that a single-phase open circuit condition or high impedance ground fault condition on an off-site power circuit is detected.
- C) Discuss how an unintended separation from the off-site power source due to a false indication of an open phase can be prevented.

- D) Based on the power system configuration of APR1400, provide a summary of analysis performed for ground-fault, and open phase condition

### **Response**

The issue of open phase conditions (OPCs) is one of the most challenging issues that is being addressed by nuclear power plant (NPP) operators and licensees of all over the world, including KHNP as the applicant of the design certification of the APR1400 and nuclear operator of a number of NPPs which are in operation and under construction.

On the basis of the recommendations in NRC BL 2012-01 and World Association of Nuclear Operators (WANO), Significant Operating Experience Report (SOER) 2015-1, Rev.1, KHNP is currently setting up a long-term plan, to properly address the OPCs for operating NPPs and new NPPs. The plan includes (1) performance of a design vulnerability evaluation of each unit, (2) provision of a guidance for diagnostic and monitoring actions (for operating units), (3) performance of detailed analyses needed to characterize and quantify the safety challenges of OPCs, and (4) the development and implementation of the final design solution against OPCs based on the analysis results.

Once the optimized design solution against OPCs is concluded after the detailed analyses, the solution will be applied to the design and operating features of the operating NPPs and new NPPs taking into account specific design configurations and parameters of each unit.

For this reason, KHNP has determined that the necessary design evaluation and analyses against the OPCs along with the final solution for the APR 1400 design certification is the scope of the COL applicant as described in DCD Tier 2, Subsection 8.2.3 and specified in (COL 8.2(7)).

As the staff position on the OPCs was consolidated by Branch Technical Position (BTP) 8-9 which has considered NRC BL 2012-01, BTP 8-9 will be added to DCD Tier 2, Subsection 8.1.3.3, 8.2.2.3, and Table 1.9-2 and 8.1-2, and replace NRC BL 2012-01 in the relevant Subsections and Tables of DCD Tier 2.

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### **Impact on DCD**

DCD Tier 2, Subsections 8.1.3.1, 8.1.3.3, 8.2.1.3, 8.2.2.3, 8.2.3, 8.2.4, and Tables 1.8-2, 1.9-2, 1.9-5, and 8.1-2 will be revised as shown in the Attachment.

### **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**

There is no impact on any Technical, Topical, or Environmental Report.

## APR1400 DCD TIER 2

Table 1.8-2 (10 of 29)

Item No.	Description
COL 8.2(1)	The COL applicant is to identify the circuits from the transmission network to the onsite electrical distribution system that are supplied by two physically independent circuits.
COL 8.2(2)	The COL applicant is to provide information on the location of rights-of-way, transmission towers, voltage level, and length of each transmission line from the site to the first major substation that connects the line to the transmission network.
COL 8.2(3)	The COL applicant is to describe the switchyard voltage related to the transmission system provider/operator (TSP/TSO) and the formal agreement between the nuclear power plant and the TSP/TSO. The COL applicant is to describe the capability and the analysis tool of the TSP. The COL applicant is also to describe the protocols for the plant to remain cognizant of grid vulnerabilities.
COL 8.2(4)	The COL applicant is to describe and provide layout drawings of the circuits connecting the onsite distribution system to the preferred power supply.
COL 8.2(5)	The COL applicant is to describe site-specific information for the protective devices, ac power, and dc power that control the switchyard equipment.
COL 8.2(6)	The COL applicant is to provide an FMEA for switchyard components. In addition, the COL applicant is to provide the results of grid stability analyses to demonstrate that the offsite power system does not degrade the normal and alternate preferred power sources to a level where the preferred power sources do not have the capacity or capability to support the onsite Class 1E electrical distribution system in performing its intended safety function.
COL 8.2(7)	<del>The COL applicant is to design the offsite power system to detect, alarm, and automatically clear a single phase open circuit condition.</del>
COL 8.2(8)	The COL applicant is to describe how testing is performed on the offsite power system components.
COL 8.2(9)	The COL applicant is to provide the required number of immediate access circuits from the transmission network.

The COL applicant is to conduct an evaluation of each preferred and alternate offsite power source alignment during all plant operating modes and also conduct a design vulnerability study on the physical arrangements of the field equipment.

The COL applicant is also to perform sufficient analyses needed to characterize and quantify the safety challenges of open phase conditions (OPCs) including a high impedance ground fault condition.

Based on the analysis results, the COL applicant is to develop a design to detect, alarm, and protect against an OPC, which properly addresses and meets the requirements of B.1 and B.2 of Branch Technical Position (BTP) 8-9.

**APR1400 DCD TIER 2**

Table 1.9-2 (18 of 33)

SRP Section/Title	Revision / Issue Date	Conformance or Summary Description of Deviation	DCD Tier 2 Section
BTP 8-5 – Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems	Rev. 3 03/2007	The APR1400 conforms with this BTP.	8.1.3.3, 8.3.1.2.2, 8.3.2.2.2 Table 8.1-2
BTP 8-6 – Adequacy of Station Electric Distribution System Voltages	Rev. 3 03/2007	The APR1400 conforms with this BTP with the exception of B.1. The Class 1E distribution system is separated from the offsite power system by the secondary undervoltage relay regardless of the occurrence of an SIAS.	8.1.3.3, 8.2.2.3, 8.3.1.1.2.3, 8.3.1.1.3.12, Table 8.1-2
BTP 8-7 – Criteria for Alarms and Indications Associated with Diesel-Generator Unit Bypassed and Inoperable Status	Rev. 3 03/2007	The APR1400 conforms with this BTP.	8.1.3.3, 8.3.1.1.3 Table 8.1-2
BTP 8-8 – Onsite (Emergency Diesel Generators) and Offsite Power Sources Allowed Outage Time Extensions	02/2012	Not applicable	N/A
9.1.1 – Criticality Safety of Fresh and Spent Fuel Storage and Handling	Rev. 3 03/2007	The APR1400 conforms with this SRP.	9.1.1
9.1.2 – New and Spent Fuel Storage	Rev. 4 03/2007	The APR1400 conforms with this SRP.	9.1.2
9.1.3 – Spent Fuel Pool Cooling and Cleanup System	Rev. 2 03/2007	The APR1400 conforms with this SRP.	9.1.3
9.1.4 – Light Load Handling System and Refueling Cavity	Rev. 4 07/2014	The APR1400 conformance with acceptance criteria 5 is not applicable for the APR1400 design certification. (APR1400 is a single unit.)	9.1.4
9.1.5 – Overhead Heavy Load Handling Systems	Rev. 1 03/2007	The APR1400 conformance with exceptions. Criterion 5 is not applicable for the APR1400 design certification. (APR1400 is a single unit.)	9.1.5
<b>BTP 8-9 – Open Phase Conditions in Electric Power System</b>	<b>Rev. 0 07/2015</b>	<b>The APR1400 conforms with this BTP</b>	<b>8.1.3.1, 8.1.3.3, 8.2.1.3, 8.2.2.3, Table 8.1-2</b>

Add

## APR1400 DCD TIER 2

Table 1.9-5

Generic Communications Applicability to APR1400

GC No.	Title	Comment	DCD Tier 2 Section
GL 2008-01	Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems.	The APR1400 conforms with this Generic Letter.	6.2.2, 6.3.2.5.2
BL 2007-01	Security Officer Attentiveness	Not applicable (COL)	N/A
BL 2011-01	Mitigation Strategies	Not applicable	N/A
<del>BL 2012-01</del>	<del>Design Vulnerability in Electric Power System</del>	<del>Not applicable (COL)</del>	<del>N/A</del>

Delete

## APR1400 DCD TIER 2

The APR1400 has the non-Class 1E 125 Vdc and 250 Vdc power systems to supply non-Class 1E dc loads. These systems provide power to non-Class 1E 120 Vac I&C loads through inverters.

The onsite power systems are described in Section 8.3.

### 8.1.3 Design Bases

#### 8.1.3.1 Offsite Power System

The design bases for the offsite power system are as follows:

- a. The two or more transmission lines from the transmission network are connected to the switchyard. The offsite power circuits to the switchyard are designed to be independent and physically separate to provide reasonable assurance of availability under normal and postulated accident conditions.
- b. Each of the two preferred power circuits between the switchyard and onsite power system has sufficient capacity and is available to supply power to the plant safety-related systems within a few seconds following a loss-of-coolant accident (LOCA) to provide reasonable assurance that core cooling, containment integrity, and other vital safety functions are maintained.
- c. The MT rating is selected to transfer the power generated by the APR1400 to an offsite power system and permit the offsite power source to supply power to the onsite loads.
- d. The two UATs and two SATs are sized to provide the full load requirements of the main buses in their respective load groups.
- e. The protection is provided to detect, alarm, protect against an open phase condition (OPC) ~~and automatically clear a single phase open circuit condition~~ at the primary sides of the MT or SAT.

,and automatically transfer the Class 1E switchgear buses to the alternate reliable offsite power source or onsite standby power system.

Add

**APR1400 DCD TIER 2**

- NRC RG 1.212, “Sizing of Large Lead-Acid Storage Batteries,” November 2008.
- NRC RG 1.218, “Condition-Monitoring Techniques for Electric Cables Used in Nuclear Power Plants,” April 2012.

Branch Technical Positions

- BTP 8-1, “Requirements for Motor-Operated Valves in the ECCS Accumulator Lines,” Rev. 3, March 2007.
- BTP 8-2, “Use of Diesel Generator Sets for Peaking,” Rev. 3, March 2007.
- BTP 8-3, “Stability of Offsite Power Systems,” Rev. 3, March 2007.
- BTP 8-4, “Application of Single Failure Criterion to Manually Controlled Electrically Operated Valves,” Rev. 3, March 2007.
- BTP 8-5, “Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems,” Rev. 3, March 2007.
- BTP 8-6, “Adequacy of Station Electric Distribution System Voltages,” Rev. 3, March 2007.
- BTP 8-7, “Criteria for Alarms and Indications Associated with Diesel Generator Unit Bypassed and Inoperable Status,” Rev. 3, March 2007.
- BTP 8-8, “Onsite (Emergency Diesel Generators) and Offsite Power Sources Allowed Outage Time Extensions,” February 2012.

Bulletin

- ~~• BL 2012-01, “Design Vulnerability in Electric Power System,” July 2012.~~

Delete

- BTP 8-9, "Open Phase Conditions in Electric Power System," Rev. 0, July 2015.

Add

APR1400 DCD TIER 2

Table 8.1-2 (5 of 8)

Criteria		DCD Section				Remarks
		8.2	8.3.1	8.3.2	8.4	
4. Branch Technical Position		Guidance				
BTP 8-1	Requirements on Motor-Operated Valves in the ECCS Accumulator Lines		G			
BTP 8-2	Use of Diesel-Generator Sets for Peaking		G			
BTP 8-3	Stability of Offsite Power Systems	G				
BTP 8-4	Application of the Single Failure Criterion to Manually Controlled Electrically Operated Valves		G			
BTP 8-5	Supplemental Guidance for Bypass and Inoperable Status Indication for Engineered Safety Features Systems		G	G		
BTP 8-6	Adequacy of Station Electric Distribution System Voltages	G	G			
BTP 8-7	Criteria for Alarms and Indications Associated with Diesel-Generator Unit Bypassed and Inoperable Status		G			
BTP 8-8	Onsite (Emergency Diesel Generators) and Offsite Power Sources Allowed Outage Time Extensions					Not applicable

(G) Guidance provided in the subject document is applied to the noted section.

Add

BTP 8-9	Open Phase Conditions in Electric Power System	G				
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APR1400 DCD TIER 2

~~Table 8.1-2 (8 of 8)~~

Criteria		<del>DCD Section</del>				Remarks
		8.2	8.3.1	8.3.2	8.4	
<del>7. NRC Bulletin</del>		<del>Requirements</del>				
<del>BL 2012-01</del>	<del>Design Vulnerability in Electric Power System</del>	A				

~~(A) Requirements and criteria provided in the subject document are applied to the noted section.~~

Delete

**APR1400 DCD TIER 2**

closed and the MG is connected to the transmission system through the MT and also supplies power to the UATs. The alternate preferred circuit is connected to the high-voltage side of the SATs. In case the power supply is unavailable from the UATs, the power supply is maintained because the onsite non-safety-related and safety-related bus connections are transferred automatically from the UATs to the SATs. When the normal preferred power supply is restored, the transfer from the SATs to the UATs is accomplished manually. The UATs and SATs are three-winding transformers connected to the onsite non-safety-related and safety-related buses through their low-voltage side windings. Both non-safety-related and safety-related buses are normally supplied from the UATs.

The IPB is used to connect the MG to the GCB. The IPB provides the electrical connection among the GCB, the MT, and the two UATs. The MT is composed of three single-phase transformers that are connected to the two UATs through the IPB.

The GCB is used as a means of providing immediate access of the onsite ac power systems to the offsite power system by isolating the MG from the MT and the UATs and allowing backfeeding of offsite power to the onsite ac power system. The GCB is capable of

The COL applicant is to conduct an evaluation of each preferred and alternate offsite power source alignment during all plant operating modes and also conduct a design vulnerability study on the physical arrangements of the field equipment.

The COL applicant is also to perform sufficient analyses needed to characterize and quantify the safety challenges of open phase conditions (OPCs) including a high impedance ground fault condition.

Based on the analysis results, the COL applicant is to develop a design to detect, alarm, and protect against an OPC, which properly addresses and meets the requirements of B.1 and B.2 of Branch Technical Position (BTP) 8-9 (Reference 7) (COL 8.2(7)).

~~The COL applicant is to design the offsite power system to detect, alarm, and automatically clear a single phase open circuit condition at the primary sides of MT or SATs in accordance with NRC BL 2012-01 (COL 8.2(7)) (Reference 7).~~

The COL applicant is to describe how testing is performed on the offsite power system components (COL 8.2(8)). The ratings of the MG, GCB, MT, UATs, SATs, and IPB are shown in Table 8.2-1.

**APR1400 DCD TIER 2**NRC Regulatory Guide 1.204

NRC RG 1.204 (Reference 21) is related to the guidelines for lightning protection of nuclear power plants.

The lightning protection of the APR1400 is described in Subsection 8.3.1.1.8. The APR1400 is designed to meet the requirements related to the lightning protection of nuclear power plants in IEEE Std. 665 (Reference 22), IEEE Std. 666 (Reference 23), IEEE Std. 1050 (Reference 24), and IEEE Std. C62.23 (Reference 25).

8.2.2.3 Conformance with NUREG-0800Standard Review Plan, Section 8.2, Appendix A

The APR1400 has a GCB that is designed and tested in accordance with the SRP Section 8.2, Appendix A. The GCB is designed to perform its intended function during steady-state operation, power system transients, and major faults.

BTP 8-3, "Stability of Offsite Power Systems"

The COL applicant is to analyze the stability of the offsite power systems, as described in GDC 17 (COL 8.2(6)).

BTP 8-6, "Adequacy of Station Electric Distribution System Voltages"

BTP 8-6 (Reference 26) is related to adverse effects on the Class 1E loads that are caused by sustained low grid voltage conditions when the Class 1E buses are connected to offsite power. The APR1400 provides a second level of undervoltage protection with time delays to protect the Class 1E equipment from sustained undervoltages. Conformance with BTP 8-6 is addressed in Subsection 8.3.1.1.3.12.

BTP 8-9, "Open Phase Conditions in Electric Power System"

BTP 8-9 (Reference 7) is related to detect, alarm, and protect against an open phase condition which occurs in the offsite electric power system. Conformance with BTP 8-9 is addressed in Subsection 8.2.1.3.

Add

## APR1400 DCD TIER 2

- COL 8.2(7) ~~The COL applicant is to design the offsite power system to detect, alarm, and automatically clear a single phase open circuit condition.~~
- COL 8.2(8) The COL applicant is to describe how testing is performed on the offsite power system components.
- COL 8.2(9) The COL applicant is to provide the required number of immediate access circuits from the transmission network.

The COL applicant is to conduct an evaluation of each preferred and alternate offsite power source alignment during all plant operating modes and also conduct a design vulnerability study on the physical arrangements of the field equipment.

The COL applicant is also to perform sufficient analyses needed to characterize and quantify the safety challenges of open phase conditions (OPCs) including a high impedance ground fault condition.

Based on the analysis results, the COL applicant is to develop a design to detect, alarm, and protect against an OPC, which properly addresses and meets the requirements of B.1 and B.2 of Branch Technical Position (BTP) 8-9.

3. 10 CFR Part 50, Appendix A, General Design Criterion 5, "Sharing of Structures, Systems, and Components," U.S. Nuclear Regulatory Commission.
4. 10 CFR Part 50, Appendix A, General Design Criterion 17, "Electric Power Systems," U.S. Nuclear Regulatory Commission.
5. 10 CFR Part 50, Appendix A, General Design Criterion 18, "Inspection and Testing of Electric Power Systems," U.S. Nuclear Regulatory Commission.
6. NUREG-0800, Standard Review Plan, Section 8.2, Appendix A, "Guidelines for Generator Circuit Breakers/Load Break Switches," Rev. 5, U.S. Nuclear Regulatory Commission, May 2010.
- ~~7. BL 2012-01, "Design Vulnerability in Electric Power System," U.S. Nuclear Regulatory Commission, July 27, 2012.~~
8. IEEE Std. 765-2006, "IEEE Standard for Preferred Power Supply (PPS) for Nuclear Power Generating Stations (NPGS)," Institute of Electrical and Electronics Engineers, 2006.

7. NUREG-0800, Standard Review Plan, BTP 8-9, "Open Phase Conditions in Electric Power System," Rev. 0, U.S. Nuclear Regulatory Commission, July 2015.