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.:	**539-8730**
SRP Section:	**08.01 – Electric Power – Introduction**
Application Section:	**8.1**
Date of RAI Issue:	**02/21/2017**

Question No. 08.01-21

Compliance with 10 CFR Part 50, GDC 17 requires that onsite and offsite electrical power be provided to support functioning of systems, structures, and components (SSCs) important to safety. Standard Review Plan (SRP) 8.2 and 8.3 explains that the GDC 17 requirements for the interface between the onsite and offsite electric power system in evolutionary advance light water reactor (ALWRs) designs are documented in SECY-91-078. In SECY-91-078, "Chapter 11 of the Electric Power Research Institute's (EPRI's) Requirements Document and Additional Evolutionary Light Water Reactor (LWR) Certification Issues," the staff concluded that feeding the safety buses from the offsite power sources through non-safety buses or from a common transformer winding with non-safety loads increases the difficulty in properly regulating voltage at the safety buses, subjects the safety loads to transients caused by the non-safety loads, and adds additional failure points between the offsite power sources and safety loads.

The APR1400 design includes non-safety and safety buses being fed from a common 4.16kV transformer winding of the unit auxiliary transformers (UATs) and standby auxiliary transformer (SATs). The staff's concerns related to the APR1400 design where the non-safety and safety buses are being fed from a common transformer winding are (1) voltage regulation at the safety buses, (2) transients from the non-safety loads or system impacting the safety loads or system, and (3) the creation of a failure point between the offsite power and the safety buses.

The applicant's response to RAI 8426, Question 08.01-14, to address the staff's concerns associated with the non-safety and safety buses being fed from a common transformer winding is discussed below.

1. The on-load tap changers (OLTCs) at the primary side of the UATs and SATs ensure that the voltage regulation at the medium voltage (MV) safety buses is maintained in an acceptable range, and voltage regulation study was performed.

2. There is a potential for transients at the safety buses caused by accident or operating occurrences on the non-safety buses such as (a) large motor starting, (b) motor reacceleration during a bus transfer condition, or a (c) short circuit.

   a. A large motor starting study has been performed and the results of the study demonstrate that voltage variation at the safety buses is maintained within acceptable limits during the non-safety large motor starting condition.

   b. The transient effect of re-acceleration of non-safety motors during a bus transfer is assessed by the fast bus transfer study and the result of the study concludes that the re-acceleration of non-safety motors do not hinder the re-acceleration of the safety motors.

   c. During a short circuit on the non-safety bus, the design allows the safety bus to remain connected, or to be transferred to the alternate power supply.

3. The UAT (or SAT) relays are able to detect an electric fault at a connection point between safety or non-safety buses. Power is then transferred to the alternate PPS or to the EDG power source, to eliminate the failure point between the offsite power source and the safety buses.

The applicant also explained that a failure mode effects analysis (FMEA) was performed and demonstrates that the APR1400 offsite power system retains its ability to feed the safety loads of both divisions through both (normal and alternate) PPS upon a single failure on the non-safety bus.

The staff finds the response acceptable and requests that the applicant incorporate in the DCD, its justification to support that the APR1400 design is in compliance with GDC 17, and in conformance with SECY-91-078, such that

1. Voltage regulation at the medium voltage (MV) safety buses is maintained in an acceptable range,

2. Potential transients caused by accident or operating occurrences on the non-safety buses such as (a) large motor starting, (b) motor re-acceleration during a bus transfer condition, or a (c) short circuit will not impact the safety buses, and

3. Power is transferred to the alternate PPS or to the EDG power source, to eliminate the failure point between the offsite power source and the safety buses, when there is a fault at the connection point between the safety and non-safety at the common 4.16kV transformer winding.

The staff requests that the applicant explain how (e.g. COL Item, ITAAC) they will verify that transients on the non-safety buses will not impact the safety buses as described in the APR1400 design.

Response

The specific electrical system design features of the APR1400, provided in response to RAI 8426, Question 08.01-14 (Reference KHNP submittal MKD/NW-16-1174L, dated Jan. 4, 2017; ML17004A024), will be reflected in the relevant subsections of the DCD Tier 2 as shown in the attachment to support that the APR1400 is in compliance with GDC 17 and SECY-91-078. DCD Tier 2, Subsection 8.3.1.3.9 is being added to specifically describe the bus transfer study.

In addition, DCD Tier 1, Subsection 2.6.1.1, Table 2.6.1-3, and Tier 2, Subsection 14.3.2.6 will be revised such that the COL applicant will verify through ITAAC that transients or failures occurring in the non-Class 1E buses will not cause failure of the Class 1E loads.

In DCD Tier 1, Table 2.6.1-3, ITAAC Item 26 is being added for the COL applicant to verify that the Class 1E loads will not fail due to transients on non-Class 1E electrical equipment during non-Class 1E large motor starting or re-acceleration by performing transient analyses (i.e., motor starting, bus transfer analysis) using the actual equipment data of the site.

The existing ITAAC Item 20 will be used to verify that the Class 1E buses remain unaffected by a short-circuit fault on the non-Class 1E buses or circuits by proper coordination of overcurrent protection for the Class 1E power system. The existing ITAAC Item 8 of Table 2.6.1-3 in DCD Tier 1 will be used to verify that the medium voltage Class 1E buses can be automatically transferred satisfactorily to the alternate preferred offsite power supply should the normal preferred offsite power supply not be available.

Impact on DCD

DCD Tier 1, Subsection 2.6.1.1 and Table 2.6.1-3, and DCD Tier 2, Subsections 8.2.1.3, 8.3.1.1, 8.3.1.1.2.3, and 14.3.2.6 will be revised as shown in the attachment. DCD Tier 2, Subsection 8.3.1.3.9 will be added as shown in the attachment.

Impact on PRA

PRA impact screening assessment reveals that the double-incoming circuit breakers of the non-Class 1E switchgear do not impact the PRA result and, therefore, are not incorporated into the PRA model. Instead, the relevant information will be included in the PRA notebook (Auxiliary Power System).

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.

21. The post-fire safe shutdown circuit analysis provides assurance that one success path of shutdown SSCs remains free of fire damage.

22. The Class 1E cables are sized considering derating due to ambient temperature, cable grouping, and other derating effects as applicable.

23. Monitoring of primary side of the MT and SATs to detect the following open phase conditions (OPCs) is provided by the transformer dedicated open phase detection (OPD) system over the full range of transformer loading from no load to full load:

    - loss of one phase with and without a high-impedance ground fault condition; and

    - loss of two phases without a high-impedance ground fault condition.

24. Upon detection of an OPC with or without a high-impedance ground fault, the transformer dedicated OPD system sends an alarm in the main control room.

25. In case an OPC with or without a high-impedance ground fault on the primary side of the MT or SATs occurs while the transformer(s) is (are) under loading condition, the Class 1E medium voltage switchgear buses are automatically separated from the degraded offsite power source. If the condition occurs on the primary side of MT, the Class 1E medium voltage switchgear buses are automatically transferred to the alternate offsite power source (from the SATs) after the buses are disconnected from the normal offsite power source (from the UATs).

26. Transients due to failures or incidental operation of the non-Class 1E electrical equipment will not cause failure of the Class 1E loads.

2.6.1.2 Inspection, Test, Analyses, and Acceptance Criteria

Table 2.6.1-3 specifies the inspections, tests, analyses, and associated acceptance criteria for the ac electrical power distribution system.

Table 2.6.1-3 (8 of 8)

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
25. In case an OPC with or without a high-impedance ground fault on the primary side of the MT or SATs occurs while the transformer(s) is (are) under loading condition, the Class 1E medium voltage switchgear buses are automatically separated from the degraded offsite power source. If the condition occurs on the primary side of MT, the Class 1E medium voltage switchgear buses are automatically transferred to the alternate offsite power source (from the SATs) after the buses are disconnected from the normal offsite power source (from the UATs).	25. Tests will be performed using simulated signals to verify that as-built Class 1E medium voltage switchgear buses are automatically separated from the degraded offsite power source and, in case of an OPC on the primary side of the MT, transferred to the alternate offsite power source (from the SATs).	25. Each as-built Class 1E medium voltage switchgear buses are automatically disconnected and, in case of an OPC on the primary side of the MT, transferred to the alternate offsite power source (from the SATs).
Add 26. Transients due to failures or incidental operation of the non-Class 1E electrical equipment will not result in failure of the Class 1E loads.	26.a Analyses will be performed to verify that the voltage variation at the Class 1E buses is maintained within acceptable limits during the non-Class 1E large motor starting condition.	26.a A report exists and concludes that the voltage variation at the Class 1E buses is maintained within acceptable limits during the non-Class 1E large motor starting condition.
	26.b Analyses will be performed to verify that the transient effect of re-acceleration of the non-Class 1E motors do not hinder the re-acceleration of the Class 1E motors during a bus transfer.	26.b A report exists and concludes that the transient effect of re-acceleration of the non-Class 1E motors do not hinder the re-acceleration of the Class 1E motors during a bus transfer.

b. When the normal preferred power supply is not available, the alternate preferred power supply maintains its availability.

c. The switchyard buses where the preferred power source circuits are connected are arranged as follows:

 1) Any incoming or outgoing transmission line for one preferred power source circuit can be switched without affecting the other preferred power source circuit.

 2) When a switchyard circuit breaker is isolated under maintenance condition, there is no disruption of service to either preferred power sources circuit.

8.2.1.3 Offsite Power System Components and Circuits

The offsite power system components consist of the MG, IPB, GCB, MT, two UATs, and two SATs. The MG is connected to the transmission network when the generator reaches rated speed and output voltage, and paralleling to the transmission network is accomplished automatically or manually by using the synchroscope and synchronizer. In the event that the MG is not in service, this system is used to supply power from the transmission network to the station auxiliaries.

The APR1400 design includes two offsite circuits to each independent safety train that is supplied directly from an offsite power source with no intervening non-safety buses, thereby permitting the offsite source to supply power to safety buses ~~regardless of failure of non-safety buses.~~ upon a failure or presence of transients on non-Class 1E electrical equipment. Discussion on the impact of faults or transients of non-Class 1E electrical equipment on the Class 1E loads is described in Subsection 8.3.1.1.2.3. This design feature complies with GDC 17 and the staff's position in SECY-91-078 (Reference 29). The preferred power supply system has provisions to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the MG or loss of power from the onsite electric power sources. Two physically independent circuits connect the switchyard to the APR1400.

Each preferred power source has the capacity and capability to permit functioning of structures, systems, and components important to safety and all other auxiliary systems under normal, abnormal, and accident conditions. The normal preferred power circuit is connected to the high-voltage side of the MT. During power operation mode, the GCB is closed and the MG is connected to the transmission system through the MT and also supplies power to the UATs. The alternate preferred power circuit is connected to the feed incoming breaker and to provide a permissive for closing of the alternate feed incoming breaker to preclude unintended bus transfer. In case the fast transfer is not successful, residual transfer is performed automatically. The fast and residual transfer on each bus are permitted only when the alternate preferred power source from the SATs is available and the protection relay for the bus is not tripped.

~~The COL applicant is to provide a bus transfer study of the onsite power system. Based on the bus transfer study, the COL applicant is also to provide final relay selection and settings for the bus transfer (COL 8.3(2)).~~

The onsite ac power system consists of the 13.8 kV and 4.16 kV switchgears, 480V load centers, and 480V motor control centers (MCCs). The configuration of the onsite ac power system and offsite power system is shown in Figure 8.1-1.

8.3.1.1.1 Non-Class 1E Onsite AC Power System

There are two 3-winding UATs and two 3-winding SATs in the APR1400, and each transformer provides 13.8 kV and 4.16 kV power. During normal plant operation, two non-Class 1E 13.8 kV switchgears, one non-Class 1E 4.16 kV switchgear, and one PNS 4.16 kV switchgear are powered from a UAT in each division. One non-Class 1E AAC 4.16 kV switchgear can be aligned to either of PNS 4.16 kV switchgears.

The AAC GTG is automatically started by a starting signal from an undervoltage relay and supplies power to two PNS buses (division I and division II) manually during a LOOP. The loads that are not safety-related, but require operation during a LOOP, are connected to these buses manually. The AAC source is provided with diverse starting mechanisms compared to the Class 1E EDG. The AAC source is selected to minimize common-mode failures with the Class 1E EDG. The AAC source rating is adequate to meet the load requirements shown in Tables 8.3.1-4 and 8.3.1-5 during an SBO or LOOP conditions.

Two independent circuit breakers (referred to as double incoming circuit breakers), connected in series, are used as a set of incoming breakers for all non-Class 1E 13.8 kV and 4.16 kV switchgear incomers, thereby significantly reducing the probability of failure of the non-Class 1E incoming breakers in case of bus fault. Of the two independent circuit breakers, only one breaker is used for switching operation and protection and the other only for protection as shown in Figure 8.3.1-1.

preferred power sources and connected to its dedicated Class 1E EDG by the load sequencer.

The four independent Class 1E buses of the onsite power system and the connection between the onsite and offsite power systems are provided with physical separation and electrical isolation. The arrangement is shown in Figure 8.3.1-1.

Following a LOOP, the associated Class 1E EDGs are started and the safety buses are isolated from offsite sources and fed solely from the associated EDG. The four load sequencers (one for each Class 1E bus) used for bus load shedding and load sequencing are independent from one another. The Class 1E 4.16 kV bus degraded voltage relay scheme is designed to meet the requirements of Branch Technical Position (BTP) 8-6 (Reference 8). The protective relay scheme is described in detail in Subsection 8.3.1.1.3.11.

Non-Class 1E loads are connected to the Class 1E bus by Class 1E isolation devices. The isolation devices meet Regulatory Position (1) of RG 1.75. Periodic testing of the isolation devices (e.g., visual inspection of fuses and fuse holders, circuit breaker operability tests, etc.) is performed during every refueling outage to demonstrate that the overall coordination scheme under multiple faults of non-safety related loads remains within the limits specified in the design criteria. Pressurizer heater backup groups are provided power from the Class 1E 4.16 kV bus in accordance with 10 CFR 50.34 (Reference 9). Emergency ac lighting is powered from the Class 1E 480V MCC buses. Emergency lighting is described in Subsection 9.5.3.

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The physical separation between the redundant equipment, including cables and raceways, is designed in accordance with IEEE Std. 384 as endorsed by NRC RG 1.75. The design criteria for the cable designs are described in Subsection 8.3.1.1.10. The identification of onsite power system components, including cables and raceways, is described in Subsection 8.3.1.1.10.

8.3.1.1.2.4 System Capacity and Capability

The Class 1E onsite power system has four independent trains. Each train is connected to one EDG. The selected two EDGs (trains A and C or trains B and D) are sufficient to meet the emergency load requirements for a safe shutdown during a LOOP concurrent with LOCA conditions.

designed in accordance with the human factors engineering design criteria and implementation methods as described in Chapter 18.

Testing of the onsite ac power system is described in Subsection 8.3.1.1.6.

Load sequence testing for LOOP or combined LOOP and LOCA is performed during the plant shutdown condition. EDG testing capability is described in Subsection 8.3.1.1.3.7.

8.3.1.3.8 Grounding

The grounding system complies with the guidelines in IEEE Std. 665 and IEEE Std. 1050, as endorsed by RG 1.204. The grounding system consists of station grounding, system grounding, equipment grounding, safety grounding, and instrumentation grounding.

The station grounding consisting of interconnected bare copper conductors is provided to protect personnel and equipment from the hazard voltages. System grounding is intended to provide grounds of neutral points of MG, UATs, SATs, load center transformers, EDG, and AAC GTG. Equipment grounding is provided for the ground fault return path via the raceway system. Safety grounding is for protecting personnel from injury and property from damage. Instrumentation grounding is intended to establish the signal reference and minimize degradation of instrumentation signals by grounding signal cable shields, instrumentation applications, and signal return conductors. Guidelines for the design of the grounding system are described in Subsection 8.3.1.1.8. The COL applicant is to provide the analysis for the station and switchyard grounding system with underlying assumptions, based on the site-specific parameters including soil resistivity and site layout (COL 8.3(12)).

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8.3.2 DC Power System

8.3.2.1 System Description

The onsite dc power system includes the dc power sources and their distribution systems and auxiliary supporting systems that are provided to supply motive or control power to the safety-related and non-safety-related equipment. Batteries and battery chargers serve as the power sources for the dc power system, and inverters convert dc power to ac power for I&C power, as required. These three components, when combined, provide an uninterruptible power supply (UPS) that furnishes a continuous and reliable source of 120 Vac power. Under normal conditions, the dc distribution systems are designed to

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The Class 1E and non-Class 1E onsite power system is designed such that the Class 1E loads will not fail upon a failure or presence of transients on non-Class 1E electrical equipment. In the event of a fault on non-Class 1E buses, the faulted bus is securely isolated by protective devices while the other Class 1E and non-Class 1E buses remain connected to the offsite power source by proper coordination of protective devices. In case of a fault at UAT or SAT winding or its connection to the Class 1E and non-Class 1E buses, the faulted non-Class 1E equipment or circuit is properly isolated by protective devices and the power supply to Class 1E buses is automatically transferred to the SATs or EDGs. The operational occurrences and incidental conditions of the non-Class 1E power system, such as voltage regulation, large motor starting, re-acceleration of motors during bus transfer, and short circuit conditions, are evaluated by the electrical power system studies as described in Subsection 8.3.1.3 to demonstrate that the Class 1E onsite ac power system retains its intended function during the operational and incidental conditions caused or affected by the non-Class 1E offsite and onsite power systems. This design feature properly satisfies GDC 17 and the staff position in SECY-91-078 (Reference 29).

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8.3.1.3.9 <u>Bus Transfer Study</u>

Analysis is performed to check if a fast bus transfer is expected on each bus upon a fault on the normal offsite power source and to demonstrate the bus transfer (fast transfer or residual voltage transfer) will be performed successfully at each bus without failure of motor re-acceleration in the Class 1E and non-Class 1E power system. The COL applicant is to provide a bus transfer study of the onsite power system. Based on the bus transfer study, the COL applicant is also to provide final relay selection and settings for the bus transfer (COL 8.3(2)).

1) To verify that Class 1E equipment is seismic Category I and that equipment located in a harsh environment is qualified.

b. Redundancy and independence

1) To verify the Class 1E divisional assignments and independence of electric power by both inspections and tests

2) To verify by analysis that the transients or failures occurring in the non-Class 1E electrical equipment will not cause failure of the Class 1E loads.

c. Capacity and capability

1) To verify adequate sizing of the electrical system equipment and its ability to respond to postulated events (e.g., automatically in the times needed to support the accident analyses)

2) To verify by analysis the ability of the as-built electrical system and installed equipment (e.g., diesel generators, transformers, switchgear, direct current systems, and batteries) to power the loads, including tests to demonstrate the operation of equipment

3) To verify the initiation of the Class 1E equipment necessary to mitigate postulated events for which the equipment is credited (e.g., loss-of-coolant accident [LOCA], loss of offsite power [LOOP], and degraded voltage conditions)

4) To verify by analysis how the as-built electrical power system responds to a LOCA, LOOP, combinations of LOCA and LOOP (including LOCA with delayed LOOP as well as LOOP with delayed LOCA), and degraded voltage, including tests to demonstrate the actuation of the electrical equipment in response to postulated events

d. Electrical protection features

1) To analyze the ability of the as-built electrical system equipment to withstand and clear electrical faults.

2) To analyze the protection feature coordination and verify its ability to limit the loss of equipment attributable to postulated faults.

e. Displays, controls, and alarms