REVISED 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.:	**540-8729**
SRP Section:	**08.02 - Offsite Power System**
Application Section:	**8.2**
Date of RAI Issue:	**02/21/2017**

Question No. 08.02-12

In Request for Additional Information (RAI) response dated November 14, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16319A389), the applicant discussed its response to RAI 08.02-11 an open phase detection (OPD) system on the primary side of the main transformer and standby auxiliary transformers (SATs). The applicant stated that the OPD system will provide an alarm in the main control room (MCR) and send trip signals to the Class 1E switchgear buses. The applicant revised COL item 8.2(7) to state that the COL applicant is to determine the specific type of OPD system and in addition added COL item 8.2(10) for the COL applicant to provide a high-impedance ground fault detection feature that provides an alarm in the MCR. The applicant stated that the OPD system combined with the conventional protective relays in the current design ensures protection for all OPCs. However, in the analysis results of simulation for open phase conditions, the applicant states that for certain scenarios, the Class 1E undervoltage relays will not operate and there is a possibility of actuation of Class 1E degraded voltage relays.

Based on the above, the staff finds that the applicant did not provide sufficient design information concerning the automatic protective features that would be provided to transfer the offsite power circuits to Class 1E buses if they are functionally degraded due to open-phase conditions. Furthermore, the staff's review of operating reactor licensees' NRC Bulletin 2012-01, "Design Vulnerability in Electric Power System," responses and interactions with the industry representatives in various public meetings revealed that undervoltage and degraded voltage detection and protection schemes cannot detect all OPCs and mitigate the consequences of OPCs under all operating electrical system configurations and plant loading conditions.

In BTP 8-9, Position B.2.c, the NRC staff position for new reactors with active design safety features, reviewed under 10 CFR Part 50 and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," the following criteria should be satisfied when evaluating OPCs:

"The design of protection features for OPCs should address the following:

(i) Power quality issues caused by OPCs such as unbalanced voltages and currents, sequence voltages and currents, phase angle shifts, and harmonic distortion that could affect redundant ESF buses. The ESF loads should not be subjected to power quality conditions specified in industry standards such as Institute of Electrical and Electronic Engineers (IEEE) Standard (Std) 308-2001, “Criteria for Class 1E Power Systems for Nuclear Power Generating Stations,” Section 4.5, “Power Quality,” with respect to the design and operation of electrical systems as indicated in Regulatory Guide (RG) 1.32 “Criteria for Power Systems for Nuclear Plants.”

(ii) Protection scheme should comply with applicable requirements including single failure criteria for ESF systems as specified in 10 CFR Part 50, Appendix A, GDC17, and 10 CFR 50.55a(h)(2) or 10 CFR 50.55a(h)(3), which require compliance with IEEE Std 279-1971 “Criteria for Protection Systems for Nuclear Power Generating Stations” or IEEE Std 603-1991, ”Standard Criteria for Safety Systems for Nuclear Power Generating Stations.” RG 1.153, “Criteria for Power, Instrumentation, and Control Portions of Safety Systems,” provides additional guidance on this topic.

If protective features are provided in a non-Class 1E system only, a failure of the non-Class 1E scheme should not preclude the onsite electrical power system from performing its safety function given a single failure in the onsite power system.

(iii) Protection scheme design should minimize misoperation, maloperation, and spurious actuation of an operable off-site power source. Additionally, the protective scheme should not separate the operable off-site power source in the range of voltage perturbations such as switching surges, load or generation variations etc., normally expected in the transmission system.

(iv) The unbalanced voltage/current conditions for ESF components expected during various operating and loading conditions should not exceed motor manufacturer’s recommendations. The International Electrotechnical Commission (IEC) Standard IEC 60034-26, National Electrical Manufacturers Association (NEMA) Standard (MG 1) Parts 14.36 and 20.24, and IEEE Std. C37.96- 2012 (Guide for AC Motor Protection), Section 5.7.2.6, “Unbalanced Protection and Phase Failures,” may be used for general guidance.

Technical Specification Surveillance Requirements and Limiting Conditions of Operation for equipment used for mitigation of OPCs should be identified and implemented consistent with the operability requirements specified in the plant TSs and in accordance with 10 CFR 50.36(c)(2) and 10 CFR 50.36(c)(3). RG 1.93 “Availability of Electric Power Sources,” provides additional guidance on this topic.”

QUESTION 1:

Describe the design features that would be provided in the event that offsite power circuit(s) is (are) functionally degraded due to open-phase conditions, and safe shutdown capability is not assured, then the safety related buses should be designed to be transferred automatically to the alternate reliable offsite power source or onsite standby power system within the time assumed in the accident analysis and without actuating any protective devices, given a concurrent design basis event. Describe how the protection features meet the criteria in BTP 8-9, B.2.c.

Specifically, explain how the failure of the non- Class 1E scheme (i.e. failure of the OPD system, which is the failure of the redundant detection subsystems) does not preclude the onsite electrical power system from performing its safety function given a single failure in the Class 1E onsite system.

QUESTION 2:

IEEE Std. 603-1991 defines protective action as the initiation of a signal within the sense and command features or the operation of equipment within the execute features for the purpose of accomplishing a safety function. Furthermore, in IEEE Std. 603-1991 safety function is defined as

> "one of the processes or conditions (for example, emergency negative reactivity insertion, post-accident heat removal, emergency core cooling, post-accident radioactivity removal, and containment isolation) essential to maintain plant parameters within acceptable limits established for a design basis event. NOTE: A safety function is achieved by the completion of all required protective actions by the reactor trip system or the engineered safety features concurrent with the completion of all required protective actions by the auxiliary supporting features, or both."

In light of the above definitions, please explain how the protective actions to automatically protect the Class 1E system against OPC are in accordance with IEEE Std. 603-1991 and 10 CFR 50.55a(h)(3).

Response – (Rev. 1)

Based on clarification provided by the NRC staff on the scope and level of details of the open phase condition (OPC) protection to be provided by the DC applicant, KHNP has included general discussion of the detection and protection aspects of the OPC. KHNP will ensure that the COL applicant addresses the specific aspects of the detection and protection features of the selected open phase detection and protection (OPDP) system.

The following provides responses to the relevant portions of the above request that corresponds to the DC applicant's scope requested in the RAI. Accordingly, relevant portions of DCD Tier 2 will be revised as shown in the attachment.

Item 1.a) **Describe the design features that would be provided in the event that offsite power circuit(s) is (are) functionally degraded due to open-phase conditions, and safe shutdown capability is not assured, then the safety related buses should be designed to be transferred automatically to the alternate reliable offsite** power **source or onsite standby power system within the time assumed in the accident analysis and without actuating any protective devices, given a concurrent design basis event.**

As stated in item A in the response to RAI 453-8521, Question 08.02-11 (Reference KHNP submittal MKD/NW-16-1103L, dated November 14, 2016; ML16319A386), the APR1400 will be provided with design features to ensure that an OPC is properly detected and alarmed in the main control room (MCR) and remote shutdown room (RSR) and the degraded power source is automatically transferred to the reliable alternate offsite power source or the onsite emergency power source.

In all plant operating conditions, once an OPC is detected by OPDP system, the OPDP system sends an alarm signal to the MCR and RSR with a minimum time delay.

Depending upon electrical classification (non-Class 1E or Class 1E) of the OPDP system, (to be chosen by the COL applicant), typical protection features will be provided as follows:

Protection features with non-Class 1E OPDP system

If an OPC occurs on the high-voltage (HV) side of the MT under a loaded condition, the non-Class 1E OPDP system will provide an OPC protection signal to the unit trip protection scheme after a time delay which initiates tripping of the switchyard circuit breaker(s), generator circuit breaker, and automatic bus transfer by swapping the offsite power source from UATs to SATs. Should the SATs not be available at the time, the power source to the Class 1E medium voltage (MV) buses will be transferred to the emergency diesel generators (EDGs) by operation of the loss of voltage (LOV) relay (27P) at each Class 1E MV bus.

If an OPC occurs on the HV side of the SAT(s) under a loaded condition, the OPDP system will provide an OPC protection signal to the SAT protection scheme after a time delay which initiates tripping of the switchyard circuit breaker(s) and isolation of all the Class 1E and non-Class 1E MV switchgear buses from the offsite power source. As a result, the EDG on each bus will automatically start and accept the safety loads in a sequenced manner. The 4.16 kV Class 1E buses (trains A, B, C, and D) will be energized and supplied by their respective EDGs.

Protection features with Class 1E OPDP system

The Class 1E OPDP system is provided with preset voltage value(s) of the buses set (i) to ensure minimum required functions of the Class 1E equipment and (ii) to prevent permanent damage on the Class 1E equipment (e.g., motors, transformers, converters, etc.). When an OPC occurs on the HV side of the MT or SATs under a loaded condition, negative-sequence voltages and currents are generated on the Class 1E buses due to the open phase(s) on the upstream circuit. If the magnitude and duration of the negative-sequence voltage on a Class 1E bus exceeds the preset value(s), the Class 1E protection scheme provides a trip signal to isolate the Class 1E bus from the degraded offsite power source and initiate transfer of the Class 1E bus to the onsite emergency ac source (i.e., EDG) in the same way as the undervoltage relays (27P and 27S) actuate during a loss of voltage or a degraded voltage condition.

For both (non-Class 1E and Class 1E) protection schemes, appropriate setting of the time delay for the OPC protection will be determined by the COL applicant lest the effect of an OPC should actuate protective devices for equipment.

With the protection features of OPDP system described above, the APR1400 electric power system will retain its capability to provide power for the required safety functions for any OPC which would cause the offsite power circuit(s) to be functionally degraded, given a concurrent design basis event.

Item 1.b) Describe how the protection features meet the criteria in BTP 8-9, B.2.c. Specifically, explain how the failure of the non- Class 1E scheme (i.e. failure of the OPD system, which is the failure of the redundant detection subsystems) does not preclude the onsite electrical power system from performing its safety function given a single failure in the Class 1E onsite system.

(i) Power quality issues caused by OPCs such as unbalanced voltages and currents, sequence voltages and currents, phase angle shifts, and harmonic distortion that could affect redundant ESF buses. The ESF loads should not be subjected to power quality conditions specified in industry standards such as Institute of Electrical and Electronic Engineers (IEEE) Standard (Std) 308-2001, "Criteria for Class 1E Power Systems for Nuclear Power Generating Stations," Section 4.5, "Power Quality," with respect to the design and operation of electrical systems as indicated in Regulatory Guide (RG) 1.32 "Criteria for Power Systems for Nuclear Plants."

According to a review of unbalanced load flow (ULF) due to an OPC in the APR1400, major power quality issues caused by OPCs on ESF loads are unbalanced voltage/current condition and degraded voltage condition on the Class 1E buses. The result of the review is addressed in item D of the response to RAI 8521, Question 08.02-11.

With the OPDP system in place, the voltage unbalance on the Class 1E buses due to an OPC will be resolved by detection of the OPC and transfer of the degraded offsite power source to the alternate offsite power source or the emergency onsite power source. The OPC clearing time is much less than the time the negative-sequence voltage/current may cause thermal damage on ESF motors. For further details, refer to the descriptions in item 1.e of this response.

A degraded voltage condition is another aspect of degradation of power quality due to an OPC.

The APR1400 study of ULF due to OPCs indicates that in some cases, OPCs accompany a degraded voltage condition along with voltage unbalance on the Class 1E buses. However, by actuation of the OPDP system upon detection of an OPC, the degraded voltage condition will be resolved much earlier than the time delays (e.g., 1st level for alarm: 60 sec.; 2nd level for trip: 4 min.) of the degraded voltage relays (DVR, 27S) elapse. This means that operation of the DVRs will not occur under an OPC and, therefore, a degraded voltage condition caused by an OPC is not of concern.

In summary, the Class 1E system will be properly protected by actuation of the OPDP system and no specific concerns of power quality are expected on the Class 1E system of the APR1400 due to OPCs.

Item 1.c) Protection scheme should comply with applicable requirements including single failure criteria for ESF systems as specified in 10 CFR Part 50, Appendix A, GDC17, and 10 CFR 50.55a(h)(2) or 10 CFR 50.55a(h)(3), which require compliance with IEEE Std 279-1971 "Criteria for Protection Systems for Nuclear Power Generating Stations" or IEEE Std 603-1991, "Standard Criteria for Safety Systems for Nuclear Power Generating Stations." RG 1.153, "Criteria for Power, Instrumentation, and Control Portions of Safety Systems," provides additional guidance on this topic.

If protective features are provided in a non-Class 1E system only, a failure of the non-Class 1E scheme should not preclude the onsite electrical power system from performing its safety function given a single failure in the onsite power system.

As depicted in Figure 1, the APR1400 overall design features to address an OPC will encompass non-Class 1E and Class 1E systems. Considering the application of IEEE Std. 603-1991, only the Class 1E portion of the design features is subject to the applicable requirements, including the single failure criteria for ESF (Class 1E) systems. Compliance with the requirements for the Class 1E system is addressed in DCD Tier 2, Subsections 8.3.1.1.2 and 8.3.1.2.2. If the COL applicant chooses an OPDP system bounded only for the Class 1E system, the OPDP system as a whole should comply with applicable requirements, including single failure criteria for ESF (Class 1E) systems.

If a failure occurs in the non-Class 1E part of OPC detection and protection features (including a failure of redundant detection features), the failure does not preclude the onsite electric power system from performing its safety function given a single failure in the onsite power system based on the following.

- The worst case single failure in the non-Class 1E portion of the detection and protection features is spurious operation of the detection and protection feature. This condition causes unwanted separation of the offsite power source formerly supplying safety loads. As a result, the Class 1E buses will lose electric power unless the offsite power is transferred to the alternate offsite source. And the loss of voltage condition will automatically initiate operation of the emergency power source for safety loads and maintain the ability of supplying electric power to ESF loads.

- There is no physical or functional interface or interdependency between a failure in the non-Class 1E features and protective actions of the Class 1E features. No single point vulnerability exists between the non-Class 1E and Class 1E features owing to proper physical separation in accordance with IEEE Std. 384-1992 as endorsed by RGs 1.32 and 1.75.

- The Class 1E protection scheme is redundant and independent, so the safety function of the Class 1E system is not compromised given a single failure in the onsite power system.

- Therefore, a failure in the non-Class 1E portion of the OPC detection and protection features does not preclude the onsite electric power system from performing its safety function given a single failure in the onsite power system.

As the specific features of the APR1400 OPC detection and protection are deferred to the COL application stage, compliance with the applicable requirements is to be addressed by the COL applicant.

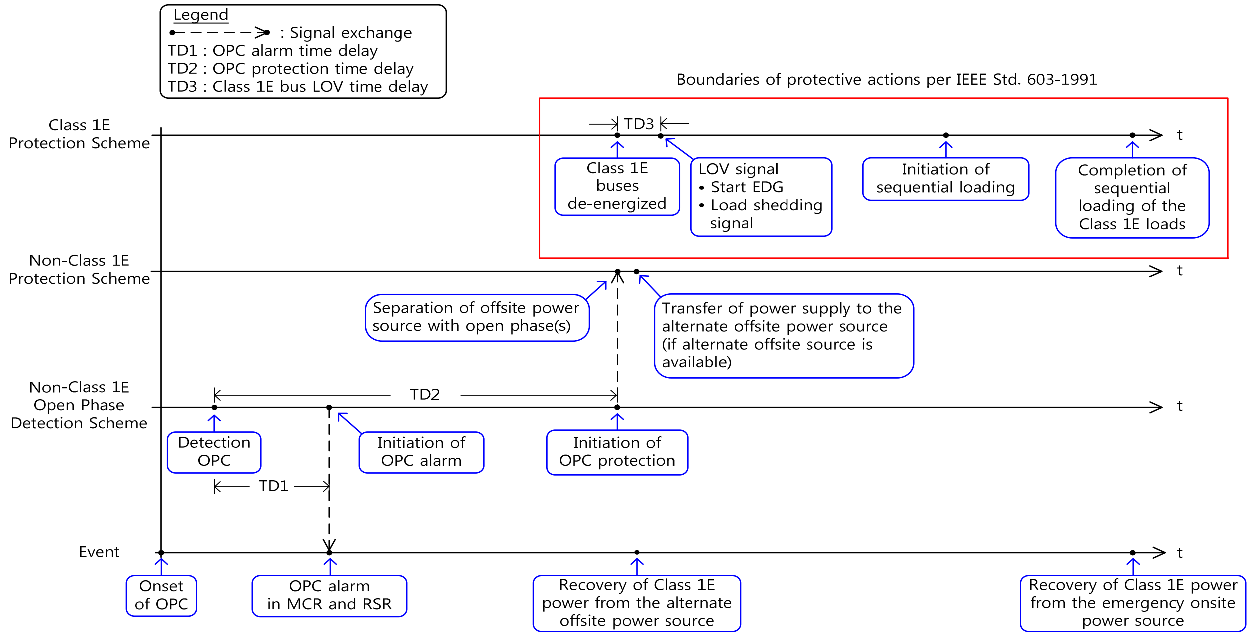

Figure 1 – Typical OPC Detection and Protection Sequence Diagram (with non-Class 1E detection features)

Item 1.d) Protection scheme design should minimize misoperation, maloperation, and spurious actuation of an operable off-site power source. Additionally, the protective scheme should not separate the operable off-site power source in the range of voltage perturbations such as switching surges, load or generation variations etc., normally expected in the transmission system.

As described in DCD Tier 2, Subsection 8.2.1.3, in order to minimize misoperation, maloperation, and spurious actuation of the OPDP system, the OPDP system is comprised of redundant detection subsystems or devices with voting logic (e.g., 2-out-of-2, 2-out-of-3, or 2-out-of-4). A failure of any one of the constituent components does not cause an unintended separation from the operable offsite power circuit. In addition, the OPC protection scheme will be provided with a sufficient time delay for initiation of the protection function (separation of the degraded offsite power source), so that temporary voltage perturbations in the offsite power source will not be falsely processed in the protection features.

Item 1.e) The unbalanced voltage/current conditions for ESF components expected during various operating and loading conditions should not exceed motor manufacturer's recommendations. The International Electrotechnical Commission (IEC) Standard IEC 60034-26, National Electrical Manufacturers Association (NEMA) Standard (MG 1) Parts 14.36 and 20.24, and IEEE Std. C37.96- 2012 (Guide for AC Motor Protection), Section 5.7.2.6, "Unbalanced Protection and Phase Failures," may be used for general guidance.

According to the APR1400 study of ULF due to OPCs, the worst case voltage unbalance under a single-phase condition is encountered in a single-phase open condition with a high-impedance ground fault on the line side of an SAT while the SATs are heavily loaded. The highest level of voltage unbalance was estimated to be 7.62% of negative-sequence voltage at the 4.16kV Class 1E bus (Train C).

Two-phase open conditions cause a more severe voltage unbalance condition on the buses. However, the conditions are cleared by operation of the conventional protective relays (e.g., loss of voltage relays, tripping of switchyard circuit breakers) with a less time delay than the OPC protection.

The time to reach the motor thermal limit due to 45.6% of negative-sequence current, which corresponds to 7.6% of negative-sequence voltage, is 192 seconds. This is determined using negative-sequence current limit characteristics with a typical value (I_2^2 t = 40) derived from an unbalanced short circuit capability model of synchronous machines based on the guidance of NEMA Std. MG-1 and IEEE Std. C37.96-2012.

It is also within the scope of the COL applicant to determine appropriate setpoints of the OPDP system for alarm and protection (i.e., alarm and actuation thresholds, time delays) such that the motor manufacturer's recommendation for ESF components would not be exceeded owing to timely actuation of the APR1400 OPDP system in case of an OPC.

Item 1.f) Technical Specification Surveillance Requirements and Limiting Conditions of Operation for equipment used for mitigation of OPCs should be identified and implemented consistent with the operability requirements specified in the plant TSs and in accordance with 10 CFR 50.36(c)(2) and 10 CFR 50.36(c)(3). RG 1.93 "Availability of Electric Power Sources" provides additional guidance on this topic."

The existing Surveillance Requirements (SRs) and Limiting Condition of Operations (LCOs) for equipment used for mitigation of OPCs in the APR1400 Generic Technical Specifications (GTS) are mostly consistent with operability requirements of electric power system. Depending upon the type of OPC detection and protection scheme to be employed by the COL applicant, provided in a non-Class 1E system or a Class 1E system, the COL applicant will be required to amend relevant part of the existing SRs or LCOs of the APR1400 GTS as necessary and provide site-specific Technical Specifications as addressed in DCD Tier 2, Chapter 16, Subsection 16.1.1.4, taking into account the latest status of any issued industry agreed upon specification(s) dealing with OPCs.

Item 2) IEEE Std. 603-1991 defines protective action as the initiation of a signal within the sense and command features or the operation of equipment within the execute features for the purpose of accomplishing a safety function. Furthermore, in IEEE Std. 603-1991 safety function is defined as "one of the processes or conditions (for example, emergency negative reactivity insertion, post-accident heat removal, emergency core cooling, post-accident radioactivity removal, and containment isolation) essential to maintain plant parameters within acceptable limits established for a design basis event. NOTE: A safety function is achieved by the completion of all required protective actions by the reactor trip system or the engineered safety features concurrent with the completion of all required protective actions by the auxiliary supporting features, or both."

In light of the above definitions, please explain how the protective actions to automatically protect the Class 1E system against OPC are in accordance with IEEE Std. 603-1991 and 10 CFR 50.55a(h)(3).

As acknowledged in BTP 8-9, B.2.c.(ii), the OPC detection and protection features can be provided (by the COL applicant) in a Class 1E system, a non-Class 1E system, or combination of both. The following provides a detailed explanation on how the OPC detection and protection functions are related to, and satisfy, the requirements in IEEE Std. 603-1991 and 10 CFR 50.55a(h)(3) in the cases of (i) the OPC detection and protection features provided in a non-Class 1E system and (ii) the features in a Class 1E system.

<u>Non-Class 1E OPC detection and protection features</u>

As noted in IEEE Std. 603-1991, a safety function is achieved by (i) all required protective actions by the protection system (i.e., the reactor trip system and/or engineered safety features) concurrent with (ii) all required protective actions by the auxiliary supporting features. The definitions of protection system and auxiliary supporting features in IEEE Std. 603-1991 are as follows:

- ***protection system:*** *That part of the sense and command features involved in generating those signals used primarily for the reactor trip system and engineered safety features.*
- ***auxiliary supporting features:*** Systems *or components that provide services (such as cooling, lubrication, and energy supply) required for the safety systems to accomplish their safety functions.*

As identified and discussed in Figure 3, Section 5.12.2, and Appendix A, Section A5 of IEEE Std. 603-1991, electric protective relaying (Class 1E) is not classified into auxiliary supporting features, but other auxiliary features which are not directly relied on for safety systems to accomplish safety functions.

As depicted in Figure 1 of this response, the full range of the APR1400 OPC detection and protection features encompasses non-Class 1E and Class 1E systems. Actions of the non-Class 1E open phase detection and protection schemes are considered to be analogous to protective relaying like other offsite component protection features (e.g., transformer protection, line protection, etc.) since those protective functions are designed for the same functional objective; to isolate failed equipment and to allow the necessary power supply to support the onsite power system.

When an OPC occurs and the degraded offsite power source is isolated by actions of the non-Class 1E OPC detection and protection features, actions of the Class 1E protection scheme to recover the Class 1E power system are automatically initiated, (unless the Class 1E power system is readily recovered by the alternate offsite power source). The Class 1E protection features, within the boundaries of the safety system, constitute auxiliary supporting features and, therefore, shall be designed in accordance with all the requirements of IEEE Std. 603-1991. Compliance with the requirements for the Class 1E system is addressed in DCD Tier 2, Subsections 8.3.1.1.2 and 8.3.1.2.2.

The non-Class 1E OPC detection and protection features are not within the applicability of IEEE 603-1991 and, therefore, are not part of either the auxiliary supporting features or other auxiliary features defined in IEEE 603-1991.

Also, the origins of the protective actions for safety functions defined in IEEE Std. 603-1991 pertain to the reactor trip system and ESF or auxiliary support features. Initiation of signals from the non-Class 1E OPC detection and protection scheme does not constitute protective actions for a safety function.

Therefore, the non-Class 1E OPC detection and protection features would be considered as a support system, which is a risk-reducing contributor for safety functions similar to other protection features for offsite power system equipment.

Class 1E OPC detection and protection features

If the COL applicant elects to provide the OPC detection and protection features in a Class 1E system, the features will measure electrical parameters (e.g., current and voltage) from the Class 1E buses, diagnose the presence of an open phase(s) on the upstream network, and initiate alarm(s) and protection signal(s) if the power quality at the Class 1E buses is degraded below the minimum required level for safety functions. The functions of these features are similar to, and commensurate with, the functions of the undervoltage relays (27P and 27S). Like the undervoltage relays, they would be considered as auxiliary supporting features.

In this case, the function of the Class 1E OPC detection and protection features is part of the ‘required protective actions by auxiliary supporting features’ which complements a safety function concurrent with all required protective actions by the reactor trip system or ESF.

Being an auxiliary support feature credited for performing a safety function, the Class 1E OPC detection and protection features will have to meet all requirements of IEEE Std. 603.

Impact on DCD

DCD Tier 1, Subsection 2.6.1.1 and Table 2.6.1-3, Tier 2, Table 1.8-2, Subsections 8.2.1.2, 8.2.1.3, and 8.2.3 will be revised as shown in the attachment.

To correct editorial error and inconsistency in the DCD mark-up provided in the previous response, KHNP is providing a complete set of revised markup as the attachment of this response.

Impact on PRA

There is no impact on the PRA at this stage. The impact on the PRA will be assessed by the COL applicant according to the site-specific offsite power system design and the OPDP system chosen for the site.

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. The open phase detection and protection (OPDP) system is capable of detecting ~~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~~ OPDP system sends an alarm in the ~~main control room~~ MCR and RSR.

25. In case an OPC with or without a high-impedance ground fault on the primary side of the MT or SATs occurs and safe shutdown capability is not assured due to the OPC 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~~ and transferred to the alternate offsite power source ~~(from the SATs) after the buses are disconnected from the normal offsite power source (from the UATs).~~ or the onsite standby source as designed.

2.6.1.2 <u>Inspection, Test, Analyses, and Acceptance Criteria</u>

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 (7 of 8)

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
21. The post-fire safe shutdown circuit analysis provides assurance that one success path of shutdown SSCs remains free of fire damage.	21. Analysis of post-fire safe shutdown circuit and supporting breaker coordination will be performed.	21. A report exists and concludes that 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.	22.a An analysis will be performed to verify the Class 1E cables are sized considering derating due to ambient temperature, cable grouping, and other derating effects as applicable.	22.a A report exists and concludes that the Class 1E cables are sized considering due to ambient temperature, cable grouping, and other derating effects as applicable.
	22.b An inspection will be performed to verify that the as -built cable sizes bound the minimum sizes determined by the analysis.	22.b The as-built cable sizes bound the minimum sizes determined by the analysis.
23. ~~Monitoring of primary side of the MT and SATs to detect~~ The open phase detection and protection (OPDP) system is capable of detecting 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.	23. Analyses will be performed to verify that the ~~open phase detection (OPD)~~ OPDP system is capable of detecting the open phase conditions over the full range of transformer loading from no load to full load.	23. A report exists and concludes that the ~~open phase detection (OPD)~~ OPDP system is capable of detecting the open phase conditions over the full range of transformer loading from no load to full load with sufficient details (e.g., relay setpoints, time delays, etc.).
24. Upon detection of an OPC with or without a high-impedance ground fault, the ~~transformer dedicated OPD~~ OPDP system sends an alarm in the ~~main control room~~ MCR and RSR.	24. Tests will be performed on the as-built ~~OPD~~ OPDP system using simulated signals to verify that the as-built ~~OPD~~ OPDP system provides an alarm in the ~~main control room~~ MCR and RSR.	24. Using simulated signals, the ~~OPD~~ OPDP system provides an alarm in the ~~main control room~~ MCR and RSR.

Table 2.6.1-3 (8 of 8)

Upon a simulated OPC, each

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).

and safe shutdown capability is not assured due to the OPC

and

or the onsite standby source as designed.

or the onsite standby source as designed.

or the onsite standby source as designed.

Table 1.8-2 (13 of 38)

Item No.	Description
COL 6.8(6)	The COL applicant is responsible for the establishment and implementation of the Maintenance Rule program in accordance with 10 CFR 50.65.
COL 7.1(1)	The COL applicant is to provide the software installation plan, the software training plan, and the software operation and maintenance plan for the safety I&C systems, as described in the Software Program Manual Technical Report.
COL 7.2(1)	The COL applicant is to provide site-specific CPCS startup test requirement
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 7.5(3)	The COL applicant is to provide the bases document accounting for measurement uncertainties for the EOP action points.
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 the site-specific design for the switchyard equipment, including breaker arrangement, electrical schematics of breaker control system, protective devices and their settings, and auxiliary power supplies (ac and dc) for control and protection.
COL 8.2(6)	The COL applicant is to provide a high-impedance ground fault detection feature that provides an alarm in the MCR and RSR upon detection of a high-impedance ground fault at the primary side of MT or SATs.
COL 8.2(7)	The COL applicant is to provide an FMEA of the switchyard components to assess the possibility of simultaneous failure of both circuits as a result of single events. 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.

Table 1.8-2 (14 of 38)

Item No.	Description
COL 8.2(8)	The COL applicant is to determine the specific type of ~~OPD system on the primary side of the MT and SATs,~~ [the OPDP system] which properly address and meet the requirements of B.1. and B.2. of Branch Technical Position (BTP) 8-9, taking into account the site specific design configuration, installation condition, (field) performance testing and qualification status, and operation experiences of the ~~OPD~~ [OPDP] system. The COL applicant is also to provide the ~~detail features of OPD~~ [detailed design of the OPDP] system selected for the APR1400 site. The COL applicant is to perform a field simulation on the site specific design of the offsite power system to ensure that the settings of the ~~OPD~~ [OPDP] system are adequate and appropriate for the site.
COL 8.2(9)	The COL applicant is to describe how testing is performed on the offsite power system components and identify the potential effects that must be considered during testing.
COL 8.2(10)	The COL applicant is to provide the required number of immediate access circuits from the transmission network.
COL 8.3(1)	The COL applicant is to provide and to design a mobile GTG and its support equipment.
COL 8.3(2)	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(3)	The COL applicant is to establish procedures to monitor and maintain EDG reliability during plant operations to verify the selected reliability level target is being achieved as intended in RG 1.155.
COL 8.3(4)	The COL applicant is to describe and provide detailed ground grid and lightning protection.
COL 8.3(5)	The COL applicant is to conduct periodic inspection and testing of the protection devices for the EPA conductors. All circuit breakers for the EPA conductors shall be inspected and tested in 60 months, low voltage circuit breaker overcurrent protection devices for the EPA conductors shall be inspected and tested once per 18 months for 10 % of each type of circuit breakers, and overcurrent relay for medium voltage circuit breakers for the EPA conductors shall be inspected and tested once per 18 months.
COL 8.3(6)	The COL applicant is to provide testing, inspection, and monitoring programs for detecting insulation degradation of underground and inaccessible power cables within the scope of 10 CFR 50.65.
COL 8.3(7)	The COL applicant is to establish Administrative Program(s), including application of dedicated cable and raceway management database tool as necessary, which is (are) developed on the basis of the cable and raceway numbering system to efficiently manage cable routing and cable termination and verify that the cable design fulfills the acceptance criteria (i.e., separation, filling criteria, and ampacity).
COL 8.3(8)	The COL applicant is to provide the detailed design of the cathodic protection system as applicable to the site conditions.
COL 8.3(9)	The COL applicant is to provide protective device coordination.
COL 8.3(10)	The COL applicant is to provide the analysis and underlying assumptions used to demonstrate adequacy for insulation coordination of surge and lightning protection.

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(3)).

8.2.1.2 Switchyard

The plant switchyard design is site-specific and not within the scope of the APR1400 design. 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(4)). The layout drawings are to include switchyard arrangement (breakers and bus arrangements), transmission lines, switchyard control systems, power supplies, and cable routing. The COL applicant is to describe the site-specific design for the switchyard equipment, including breaker arrangement, electrical schematics of breaker control system, protective devices and their settings, and auxiliary power supplies (ac and dc) for control and protection (COL 8.2(5)).

The COL applicant is to provide a high-impedance ground fault detection feature that provides an alarm in the MCR upon detection of a high-impedance ground fault at the primary side of MT or SATs (COL 8.2(6)).

and RSR

At least two physically independent transmission lines connect the offsite transmission network to the high-voltage switchyard of the plant. Two physically independent transmission tie lines supply offsite electric power from the switchyard to the APR1400 for plant maintenance, startup, shutdown, and postulated accident conditions. The interface requirement is that the TSP/TSO maintains operating frequency within 5 percent and operating voltage within 10 percent on nominal value bases at the interface boundary between the transmission network and the switchyard.

The COL applicant is to provide a failure modes and effects analysis (FMEA) of the switchyard in accordance with the following items:

a. The two preferred power circuits from the transmission network are linked to the onsite power system by passing through the switchyard. Because a switchyard can be common to both offsite circuits, the COL applicant is to provide an FMEA of the switchyard components to assess the possibility of simultaneous failure of both circuits as a result of single events (COL 8.2(7)).

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. This design feature satisfactorily addresses SECY-91-078. 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 protection schemes including overcurrent, differential current, sudden pressure and ground fault protection for the MT, UATs, and SATs are provided in accordance with the recommendations in IEEE Std. 666 (Reference 23). The protective relay list of the MT, UATs, and SATs is shown in Table 8.2-2.

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 interrupting normal load current and maximum fault current during transient and various fault conditions. The APR1400 is designed to follow the guidance in Appendix A of Standard Review Plan (SRP) Section 8.2 (Reference 6). After the MT is connected to the transmission network by closing the switchyard breakers with the GCB open, the UATs supply plant startup power to auxiliary and service loads of the APR1400. As part of the normal turbine-generator shutdown process, the GCB is opened to separate the MG from the switchyard when the MG output has been reduced to almost no-load condition. After the MG is disconnected from the switchyard by opening the GCB, the MT remains connected to the network system and backfeeds plant shutdown power to the APR1400 through the UATs during plant shutdown.

and RSR

~~An open phase detection (OPD) system is provided on each primary (high-voltage) side of the MT and SATs~~ to detect, alarm in the MCR, and mitigate against open phase conditions (OPCs) with and without a high-impedance ground fault during all plant operation.

The APR1400 electric power system is provided with the open phase detection and protection (OPDP) system

In case ~~of~~ OPCs with or without a high-impedance ground fault [occur] on the primary side of MT or SATs [and safe shutdown capability is not assured due to the OPCs] while the transformer(s) is(are) under loading condition, the Class 1E and non-Class 1E medium voltage (MV) switchgear buses are automatically separated from the degraded offsite power source after a time delay~~. If the condition occurs on the primary side of MT, the Class 1E and non-Class 1E switchgear buses are transferred to the alternate offsite power source (from the SATs) after the buses are disconnected from the normal offsite power source (from the UATs).~~ [, and transferred to the alternate offsite power source or the onsite standby source as designed.]

During all plant operation, ~~each OPD~~ [OPDP] system provides continuous monitoring [of OPCs,] ~~and~~ self-diagnostics [of its system if practicable,] for the surveillance functions to ensure that the ~~OPD~~ [OPDP] system maintains the capability of providing the detection and protection for the OPCs. In order to prevent an unintended separation from the normal or alternate offsite power source by misoperation, maloperation, or spurious actuation of the ~~OPD~~ [OPDP] system, ~~each OPD system consists of~~ [the OPDP system is comprised of] redundant detection ~~subsystem~~ [subsystems or devices] such that a failure in any one of the constituent system [(or device)] ~~will not cause~~ a spurious trip and offsite power supply to all safety related equipment remains unaffected. This redundant ~~protection~~ [detection] feature of the ~~OPD~~ [OPDP] system is made up of ~~a 2-out-of-2 logic scheme (minimum), or a 2-out-of-3 logic scheme (if applicable)~~ [a voting logic scheme (e.g., 2-out-of-2, 2-out-of-3, or 2-out-of-4)] of the constituent system~~.~~ [(or device).]

~~Each OPD~~ [The OPDP] system shall have sufficient capacity and capability to properly address and meet the requirements of B.1. and B.2. of Branch Technical Position (BTP) 8-9 (Reference 7).

The COL applicant is to determine the specific type of ~~OPD system on the primary side of the MT and SATs,~~ [the OPDP system] which properly address and meet the requirements of B.1. and B.2. of Branch Technical Position (BTP) 8-9, taking into account the site specific design configuration, installation condition,(field) performance testing and qualification status, and operation experiences of the ~~OPD~~ [OPDP] system. The COL applicant is also to provide the ~~detail features of OPD~~ [detailed design of the OPDP] system selected for the APR1400 site.

The COL applicant is to perform a field simulation on the site specific design of the offsite power system to ensure that the settings of the ~~OPD~~ [OPDP] system are adequate and appropriate for the site (COL 8.2(8)).

The COL applicant is to describe how testing is performed on the offsite power system components and identify the potential effects that must be considered during testing (COL 8.2(9)). The ratings of the MG, GCB, MT, UATs, SATs, and IPB are shown in Table 8.2-1.

COL 8.2(6) The COL applicant is to provide a high-impedance ground fault detection feature that provides an alarm in the MCR [and RSR] upon detection of a high-impedance ground fault at the primary side of MT or SATs.

COL 8.2(7) The COL applicant is to provide an FMEA of the switchyard components to assess the possibility of simultaneous failure of both circuits as a result of single events. 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(8) The COL applicant is to determine the specific type of ~~OPD system on the primary side of the MT and SATs,~~ [the OPDP system] which properly address and meet the requirements of B.1. and B.2. of Branch Technical Position (BTP) 8-9, taking into account the site specific design configuration, installation condition, (field) performance testing and qualification status, and operation experiences of the ~~OPD~~ [OPDP] system. The COL applicant is also to provide the ~~detail features of OPD~~ [detailed design of the OPDP] system selected for the APR1400 site.

The COL applicant is to perform a field simulation on the site specific design of the offsite power system to ensure that the settings of the ~~OPD~~ [OPDP] system are adequate and appropriate for the site.

COL 8.2(9) The COL applicant is to describe how testing is performed on the offsite power system components and identify the potential effects that must be considered during testing.

COL 8.2(10) The COL applicant is to provide the required number of immediate access circuits from the transmission network.

8.2.4 <u>References</u>

1. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena," U.S. Nuclear Regulatory Commission.