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.:	**453-8521**
SRP Section:	**08.02 - Offsite Power System**
Application Section:	**8.2**
Date of RAI Issue:	**03/28/2016**

Question No. 08.02-11

By letter dated December 23, 2015, the applicant provided a response to RAI 8184, Question 08.02-7. In the response, the applicant stated 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 item 8.2(7).

10 CFR Part 52.47(a)(3) states that the application must include:

"(i) The principal design criteria for the facility. Appendix A to 10 CFR part 50, general design criteria (GDC), establishes minimum requirements for the principal design criteria for water cooled nuclear power plants similar in design and location to plants for which construction permits have previously been issued by the Commission and provides guidance to applicants in establishing principal design criteria for other types of nuclear power units;

(ii) The design bases and the relation of the design bases to the principal design criteria;"

In order to verify 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), the DCD should contain a description of how the design conforms the above regulations in regards to the design vulnerability described in BL 2012-01. The description in the DCD should have sufficient detail that the COL applicant can implement the design to detect, alarm and mitigate open phase conditions in accordance with 10 CFR Part 52.47(a)(3)(i) and 52.47(a)(3)(ii). Additionally, the staff position on this issue is provided in Branch Technical Position BTP 8-9 (ML15057A085).

Please provide the following information:

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 offsite 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

E) Please provide ITAAC to confirm that OPC conditions are detected, alarmed and mitigated against.

Response

KHNP has performed a design vulnerability study of the APR1400 electric power system for the various open phase condition (OPC) scenarios, which are identified in NRC Bulletin 2012-01 and Branch Technical Position (BTP) 8-9. The study evaluates the impacts of an open phase fault with and without high-impedance ground fault conditions on the APR1400 design. The result of the analysis is described in item D of this response.

KHNP has also completed a review of the applicable industry OPC solutions based on several examples used in U.S. NPPs to identify the optimal solution for the APR1400. Among the reviewed designs, three different types of open phase detection (OPD) solutions were found to be applicable to the APR1400 electric power system. Further detailed information is described in item A of this response.

This response supersedes the previous submitted response to RAI 178-8184, Question 08.02-7 and provides KHNP's comprehensive approach to resolving the OPC issue identified in NRC Bulletin 2012-01 and BTP 8-9. Detailed markups are provided for DCD Tier 1, Section 2.6 (ITAAC) and Tier 2, Table 1.8-2 and Section 8.2 as shown in the attachment.

The following provides responses corresponding to items the staff specifically requested in the RAI.

Item A) The APR1400 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.

KHNP's design vulnerability study for the OPC scenarios identified that only the relay protection on the low side of the grid interconnection transformer (i.e., MT and SATs) could allow an open phase condition on the primary side of a transformer to go unnoticed for some period particularly at lower or no load conditions. Voltages and currents on the secondary side are greatly dependent on the winding configuration and also on the transformer's core construction as described in the EPRI Interim Report (Rev. 0), "Interim Report: EPRI Open-Phase Detection Method."

In some cases, the OPCs will cause a further degraded condition such as a large motor trip due to excessive negative sequence current; unless the conditions are properly detected, alarmed, and mitigated against.

In order to ensure that an OPC is properly detected and alarmed in the main control room (MCR) and the degraded power source is automatically transferred to the reliable standby power source, an additional detection and protection system for OPC (namely, OPD system) is being included on the primary-side of power transformers (MT and SATs), in addition to the protective relays which have already been incorporated into the APR1400 design.

Following is the summary of design features of the conventional protective relays which have been incorporated into the current design and which have limited ability to detect and mitigate against an OPC. Also discussed is the OPD system, which is combined with the current system and ensures protection for all OPCs.

The behaviors of conventional protective relays and those of the OPD system, along with the effects and consequences on the main electrical equipment of an OPC or high-impedance ground fault, are discussed in detail in item D of this response.

<u>Conventional protective relays in the APR1400 design</u>

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OPD system

Three OPD systems currently being implemented in NPP fleets in the U.S. are considered to be applicable to the APR1400 electric power system. The general design features of the three industry solutions for OPC are described below.

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Each of the OPD systems listed above applies different technologies and algorithms for the detection of an OPC. However, all of the potential solutions have sufficient capability to detect OPCs with the following characteristics at a minimum.

- The OPD system is capable of detecting open phase fault with and without high-impedance ground fault over the full range of transformer loading from no load to full load;
- Each OPD system consists of redundant detection subsystems with voting logic (e.g., 2-out-of-2 or 2-out-of-3) such that any failure in any one of the constituent systems will not cause a spurious trip of the sound offsite power supply;
- The OPD system provides continuous monitoring and self-diagnostics to a remote end (e.g., MCR);
- The OPD system is a non-Class 1E system similar to other offsite power protective devices. Electrical interfaces of the OPD system with the Class 1E protection and control circuits should consider separation requirements in accordance with RG 1.75 and IEEE Std. 384.

KHNP considers that selection of a specific type of OPD system is within the scope of COL applicant rather than definitively selecting one solution out of the three technically acceptable solutions listed above. It is also possible that an enhanced system design could be available to the COL applicant at the time of the detailed plant design and construction that would be better suited.

Therefore, the COL applicant is to determine the specific type of OPD system to be used on the primary side of the MT and SATs that properly addresses and meets the requirements of Sections B.1. and B.2. of BTP 8-9. The selection will take into account the site specific design configuration, installation condition, (field) performance testing and qualification status, and operating experience of the OPD system. The COL applicant is also to provide the detail features of OPD system selected for the APR1400 site (refer to COL 8.2(7)).

In order to determine the optimal OPD system and to ensure that the alarm and protection setpoints of the OPD system are adequate and appropriate for a given site, site specific field simulation will be required based on the site specific design of the offsite power equipment. 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 system are adequate and appropriate for the site (refer to COL 8.2(7)).

Once an OPC is detected by the OPD system, the OPD system sends an alarm signal to the MCR, and trip signals to the Class 1E and non-Class 1E medium voltage (MV) switchgear buses after an appropriate time delay. If an OPC occurs at the primary side of the MT under loading condition, the Class 1E and non-Class 1E MV switchgear buses will be automatically transferred from the UATs to the SATs.

In case of a high-impedance ground fault at the primary side of MT or SATs that does not accompany a loss of phase, as identified in item D of this response, the fault is not within the detection range of the conventional transformer ground fault detection relays. Therefore, even though the fault may not cause a direct impact on the Class 1E and non-Class 1E electric power systems, a specific type of dedicated high-impedance ground detection device is required as part of electrical protection coming in from the switchyard.

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, (refer to COL 8.2(10)).

KHNP will revise 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 to describe the OPD system technical features and protection scheme such that the COL applicant can implement an acceptable solution into the design.

Item B) Explanation of how the surveillance tests are performed to verify that a single-phase open circuit condition or high-impedance ground fault condition on an offsite power circuit is detected if the important-to-safety buses are not powered by offsite power sources during at power condition.

During at power conditions (normal operating condition), all 4.16 kV Class 1E switchgear buses are energized and fed from the UATs. The SATs are also energized, but are under a no load condition. To ensure that a single-phase open circuit condition or high-impedance ground fault condition on the normal and alternate offsite power circuits is automatically detected and alarmed in the MCR, the OPD system provides continuous monitoring and self-diagnostics of the system for the OPCs. The high-impedance grounding condition will also be alarmed in the MCR by a dedicated high-impedance ground detection relay.

Therefore, there is not a need for a surveillance to be imposed.

Item C) Prevention of an unintended separation from the off-site power source due to a false indication of an open phase.

In order to prevent an unintended separation from the normal or alternate offsite power source by misoperation, maloperation, or spurious actuation of the OPD system when there is no occurrence of an OPC, each OPD system discussed in item A consists of redundant detection subsystem. A failure in any one of the constituent components will not cause a spurious trip and offsite power supply to all safety related equipment will remain unaffected. This redundant protection feature of the OPD system is made up of a 2-out-of-2 logic scheme (minimum), or 2-out-of-3 logic scheme (if practicable) of the constituent system.

Item D) A summary of the analysis performed for ground-fault and open phase condition based on the power system configuration of the APR1400

<u>Overview of the analysis for open phase conditions</u>

In a balanced three-phase system, only positive sequence current and voltage exist. However, in case the phase becomes unbalanced due to an abnormal condition such as a loss of phase(s) or ground-fault, a significant amount of negative and zero sequence voltage and current is generated.

Since the effect of the voltage and current unbalanced conditions depends on the offsite power configuration, transformer loading conditions, and transformer core and winding constructions, it is important to envisage all credible unbalanced conditions. All expected operating conditions of the APR1400 electric power system are to be considered and a reasonable basis provided for determining the protection scheme to properly address the unbalanced conditions.

Therefore, a series of computer simulations have been performed to demonstrate how the APR1400 electric power system would respond and to determine the expected safety bus trips, alarms, and operator actions. These simulation results are used to ensure that the OPD system provides the necessary protection for OPCs based on the level of unbalanced conditions, such as negative sequence voltage and current, which are calculated by the open phase simulations.

The simulations have been performed using the Electrical Transient Analysis Program (ETAP) Version 12.6.0N (including the unbalanced load flow module), which is qualified for nuclear power plants. To precisely simulate the transformer loading condition, the ETAP model of the APR1400 electric power system was used for the OPC simulation. This model was originally developed for the onsite power system analyses (i.e., load flow, short-circuit, motor starting, etc.). The same initial conditions (i.e., bus initial voltages, transformer taps, etc.) that were used in the onsite power system analyses was also considered appropriate for the simulations of OPCs and high-impedance ground fault conditions.

Expected vulnerable connection points

An open phase event consists of a failure in the three-phase power supply where one or two phase conductor(s) becomes disconnected from the transmission interconnection while the other phase conductor(s) remain intact. Since the primary sides of the UATs are connected to the MG and MT by the isolated phase bus (IPB), a loss of phase(s) on the primary side of the UATs (secondary side of the MT) is not a credible event and, therefore, is not considered to constitute a vulnerable connection point.

Accordingly, the vulnerable connection points of the APR1400 electric power system with regard to the OPCs with or without high-impedance ground fault were considered as follows.

- Normal offsite power circuit: offsite circuit connection between the switchyard and high voltage side of the MT
- Alternate offsite power circuit: offsite circuit connection between the switchyard and high voltage side of the SATs

For each circuit, the following types of vulnerable conditions have been configured in the analysis.

- The disconnected single-phase (or double phases) conductor(s) remains suspended above the ground on the transformer side and does not short to ground. The energized line does not short to ground on the transmission line side. Pole discrepancies of switchyard breakers can cause the same condition as above.
- The disconnected single-phase conductor shorts to ground on the transformer side, connecting the transformer high-voltage (HV) winding to ground. The energized line does not short to ground on the transmission side.

- The disconnected single-phase conductor remains suspended above the ground on the transformer side and does not short to ground. The energized line shorts to ground on the transmission line side.

- The energized single-phase conductor shorts to ground on the transmission line without generating an open phase fault.

<u>Expected operating condition of the APR1400</u>

The unbalanced results can vary according to the loading conditions (e.g., heavy loading, light loading, and no-load condition). In order to simulate the unbalanced load flow of all expected operating modes of the APR1400, the following operating modes of APR1400 are included in the analysis.

<table>
<tr><th>Transformer Loading</th><th>Operating mode</th><th>Configuration</th></tr>
<tr><td rowspan="2">Heavily loaded</td><td>Normal operation</td><td>• All plant electrical loads are fed from the MG through the UATs.
• The MG delivers generated power to the grid through the MT.</td></tr>
<tr><td>Hot-standby operation</td><td>• All plant electrical loads are fed from the grid through the MT and UATs or SATs.
• The generator circuit breaker (GCB) is open.</td></tr>
<tr><td>Lightly loaded</td><td>Minimum loading operation (e.g., plant overhaul or refueling phase)</td><td>• All plant electrical loads are fed from the grid through the MT and UATs or SATs.
• The GCB is open.
• 5% of normal operating load is assumed as a minimum operating load.</td></tr>
<tr><td rowspan="2">No-load condition</td><td>Normal operation</td><td>• The SATs are under no-load condition during plant normal operation.</td></tr>
<tr><td>Hot-standby operation</td><td>• The MT and UATs are under no-load condition when plant electrical loads are fed from the grid through the SATs.</td></tr>
</table>

All of the open phase and high-impedance ground fault cases considered in the study are provided in Table 2 and listed by the combination of the electrical configuration, operating condition of the power system, and the vulnerable connection points.

Table 1 List of OPC Study Cases

Scenario No.	Case No.	Operating mode	Power source	Fault location	Transformer Loading	Open phase condition	Ground fault location
A	Case 1	Normal operation	MG, UATs	MT primary side	Heavily loaded	'A' phase open	-
	Case 2	Normal operation	MG, UATs	MT primary side	Heavily loaded	'A, B' phase open	-
	Case 3	Normal operation	MG, UATs	MT primary side	Heavily loaded	'A' phase open with high-impedance ground fault	Transformer side
	Case 4	Normal operation	MG, UATs	MT primary side	Heavily loaded	'A' phase open with high-impedance ground fault	Line side
B	Case 5	Hot-standby	MT, UATs	MT primary side	Heavily loaded	'A' phase open	-
	Case 6	Hot-standby	MT, UATs	MT primary side	Heavily loaded	'A, B' phase open	-
	Case 7	Hot-standby	MT, UATs	MT primary side	Heavily loaded	'A' phase open with high-impedance ground fault	Transformer side
	Case 8	Hot-standby	MT, UATs	MT primary side	Heavily loaded	'A' phase open with high-impedance ground fault	Line side
C	Case 9	Hot-standby	SATs	SATs primary side	Heavily loaded	'A' phase open	-
	Case 10	Hot-standby	SATs	SATs primary side	Heavily loaded	'A, B' phase open	-
	Case 11	Hot-standby	SATs	SATs primary side	Heavily loaded	'A' phase open with high-impedance ground fault	Transformer side
	Case 12	Hot-standby	SATs	SATs primary side	Heavily loaded	'A' phase open with high-impedance	Line side

Scenario No.	Case No.	Operating mode	Power source	Fault location	Transformer Loading	Open phase condition	Ground fault location
						ground fault	
D	Case 13	Minimum loading operation	MT, UATs	MT primary side	Lightly loaded	'A' phase open	-
	Case 14	Minimum loading operation	MT, UATs	MT primary side	Lightly loaded	'A, B' phase open	-
	Case 15	Minimum loading operation	MT, UATs	MT primary side	Lightly loaded	'A' phase open with high-impedance ground fault	Transformer side
	Case 16	Minimum loading operation	MT, UATs	MT primary side	Lightly loaded	'A' phase open with high-impedance ground fault	Line side
E	Case 17	Minimum loading operation	SATs	SATs primary side	Lightly loaded	'A' phase open	-
	Case 18	Minimum loading operation	SATs	SATs primary side	Lightly loaded	'A, B' phase open	-
	Case 19	Minimum loading operation	SATs	SATs primary side	Lightly loaded	'A' phase open with high-impedance ground fault	Transformer side
	Case 20	Minimum loading operation	SATs	SATs primary side	Lightly loaded	'A' phase open with high-impedance ground fault	Line side
F	Case 21	Normal operation	MG, UATs	SATs primary side	No-load condition	'A' phase open	-
	Case 22	Normal operation	MG, UATs	SATs primary side	No-load condition	'A, B' phase open	-
	Case 23	Normal operation	MG, UATs	SATs primary side	No-load condition	'A' phase open with high-impedance ground fault	Transformer side

Scenario No.	Case No.	Operating mode	Power source	Fault location	Transformer Loading	Open phase condition	Ground fault location
	Case 24	Normal operation	MG, UATs	SATs primary side	No-load condition	'A' phase open with high-impedance ground fault	Line side
	Case 25	Hot-standby	SATs	MT primary side	No-load condition	'A' phase open	-
	Case 26	Hot-standby	SATs	MT primary side	No-load condition	'A, B' phase open	-
	Case 27	Hot-standby	SATs	MT primary side	No-load condition	'A' phase open with high-impedance ground fault	Transformer side
	Case 28	Hot-standby	SATs	MT primary side	No-load condition	'A' phase open with high-impedance ground fault	Line side
G	Case 29	Normal operation	MG, UATs	MT primary side	Heavily loaded	High-impedance ground fault with no open phase fault	-
	Case 30	Hot-standby	MT, UATs	MT primary side	Heavily loaded	High-impedance ground fault with no open phase fault	-
	Case 31	Hot-standby	SATs	SAT primary side	Heavily loaded	High-impedance ground fault with no open phase fault	-
	Case 32	Hot-standby	MT, UATs	SAT primary side	No-load condition	High-impedance ground fault with no open phase fault	-

Analysis results of simulation of open phase scenarios

The result of unbalanced load flow (ULF) analysis on the study cases considered is summarized in Attachment 1. The behavior of the existing protection feature for each study case is shown in Attachment 2.

The following provides anticipated effects and consequences on the major electrical equipment and responses of the APR1400 electric power system under the studied cases based on the performed ULF analysis.

1) Scenario A: Normal Operation (Cases 1, 2, 3, and 4)

When an open phase condition occurs on the primary side of the MT under Scenario A condition, the MG will experience significant amount of negative sequence current.

The MV motors (e.g., reactor coolant pumps (RCPs), circulating water pump, etc.) will also experience a negative sequence current.

In all cases, the Class 1E and non-Class 1E undervoltage relays (27P/27S/27M) will not operate since all phase voltages are maintained by the power supply from the MG.

Following is the sequence of events as a result of the operation of the existing protection features for each studied case.

- Cases 1, 3, and 4
  - ✓ Due to the voltage imbalance on the MV buses, 13.8 kV motors such as RCPs, circulating water pumps, condensate pumps, feed water booster pumps trip by operation of the negative sequence current relays (46) after time delays (e.g., 12 - 13 seconds).
  - ✓ RCP trip causes turbine trip and subsequent generator circuit breaker (GCB) trip.
  - ✓ The MV buses are fed from the normal preferred power supply without clearance of the single phase open condition.
  - ✓ Refer to Case 5 for the following sequence of events of Cases 1, 3, and 4.
- Case 2
  - ✓ Due to large amount of voltage imbalance on the MG, the power circuit breakers (PCBs) in the switchyard trip by operation of the negative sequence current relays (46) of the MG after time delay (approximately 6.5 seconds).
  - ✓ By opening the PCBs, the main power circuit is disconnected from the grid, and the unit will operate in house load operation (HLO) mode, which may last up to 4 hours.

2) Scenario B: Hot-Standby with Normal Offsite Power (Cases 5, 6, 7, and 8)

When an open phase condition occurs on the primary side of the MT under Scenario B condition, the Class 1E buses will be subject to abnormal voltage condition (unbalanced), which potentially may cause actuation of the degraded voltage relays on the Class 1E buses.

The non-Class 1E undervoltage relays (27M) will not operate except in Case 6 since all phase-to-phase voltages (V_{ab}, V_{bc}, and V_{ca}) are maintained above the setpoints of the undervoltage relays (27M).

Following is the sequence of events as a result of the operation of the existing protection features for each studied case.

- Cases 5 and 8
  - ✓ There is a possibility of actuation of degraded voltage relays (27S) on the Class 1E buses.
  - ✓ The degraded voltage relays (27S) initiate EDG starting and load shedding of the affected Class 1E buses.
  - ✓ The affected Class 1E buses are energized and fed from the respective EDGs through load sequencing.
  - ✓ The other MV buses (Class 1E and non-Class 1E) remain fed from the degraded offsite power circuit.
- Case 6
  - ✓ Loss of two phases on the primary side of the MT causes an undervoltage on all Class 1E and non-Class 1E buses.
  - ✓ The incoming circuit breaker on each Class 1E bus trips by operation of the LOV relay (27P) after a time delay (e.g., 1 second) and the LOV relay (27P) also initiates EDG starting and load shedding of the Class 1E bus.
  - ✓ The non-Class 1E MV motors are tripped by operation of the LOV relay (27M) at each bus after a time delay (e.g., 2 seconds).
  - ✓ The 4.16 kV Class 1E buses (trains A, B, C, and D) are energized and fed from the EDGs through load sequencing.
- Case 7
  - ✓ Due to the voltage imbalance on the MV buses, 13.8 kV motors such as RCPs, circulating water pumps, startup feed water pump trip by operation of the negative sequence current relays (46) after time delays (e.g., 12 - 13 seconds).
  - ✓ There is a possibility of actuation of degraded voltage relays (27S) on the Class 1E buses.

- ✓ The degraded voltage relays (27S) initiate EDG starting and load shedding of the affected Class 1E buses.

- ✓ The affected Class 1E buses are energized and fed from the respective EDGs through load sequencing.

- ✓ The other MV buses (Class 1E and non-Class 1E) remain fed from the degraded offsite power circuit.

3) Scenario C: Hot-Standby with Alternate Offsite Power (Cases 9, 10, 11, and 12)

When an open phase condition occurs on the primary side of the SATs under Scenario C condition, the Class 1E buses will be subject to abnormal voltage conditions (unbalanced), which is very likely to cause actuation of degraded voltage relays on the Class 1E buses. The non-Class 1E undervoltage relays (27M) will not operate, except in Case 10, since all phase-to-phase voltages are maintained above the setpoints of the undervoltage relays (27M).

In all cases, all Class 1E and non-Class 1E MV buses will experience negative sequence voltage larger than the voltage imbalance alarm setpoint (5%).

Following is the sequence of events as a result of the operation of the existing protection feature for each studied case.

- Cases 9, 11, and 12:

  - ✓ Due to the voltage imbalance on the MV buses, 13.8 kV motors such as RCPs, circulating water pumps, startup feed water pump trip by operation of the negative sequence current relays (46) after time delays (e.g., 12 - 13 seconds).

  - ✓ It is very likely that degraded voltage relays (27S) on all Class 1E buses are actuated and initiate EDG starting and load shedding of the Class 1E buses.

  - ✓ The Class 1E buses are energized and fed from the respective EDGs through load sequencing.

  - ✓ The non-Class 1E MV buses remain fed from the degraded offsite power circuit.

- Case 10

  - ✓ Loss of two phases on the primary side of the SAT causes an undervoltage on all Class 1E and non-Class 1E buses.

  - ✓ The incoming circuit breaker on each Class 1E bus trips by operation of the LOV relay (27P) after a time delay (e.g., 1 second) and the LOV relay (27P) also initiates EDG starting and load shedding of the Class 1E bus.

  - ✓ The non-Class 1E MV motors are tripped by operation of the LOV relays (27M) after a time delay (e.g., 2 seconds).

- ✓ The 4.16 kV Class 1E buses (trains A, B, C, and D) are energized and fed from the EDGs through load sequencing.

4) Scenario D: Plant Minimum Loading with Normal Offsite Power (Cases 13, 14, 15, and 16)

When an open phase condition occurs on the primary side of the MT under Scenario D condition, most of protective relays will not operate, except for Case 14. In Case 15, the Class 1E buses will be subject to abnormal voltage conditions (unbalanced), which potentially may cause actuation of degraded voltage relays on the Class 1E buses.

Following is the sequence of events as a result of the operation of the existing protection feature for each studied case.

- Cases 13 and 16
  - ✓ None of the existing protective relays will operate and the Class 1E and non-Class 1E buses will be fed from the normal preferred power supply without clearance of the OPCs.
- Case 14
  - ✓ Loss of two phases on the primary side of MT causes an undervoltage on all Class 1E and non-Class 1E buses.
  - ✓ The incoming circuit breaker on each Class 1E bus trips by operation of the LOV relay (27P) after a time delay (e.g., 1 second) and the LOV relay (27P) also initiates EDG starting and load shedding of the Class 1E bus.
  - ✓ The non-Class 1E MV motors are tripped by operation of the LOV relays (27M) after a time delay (e.g., 2 seconds).
  - ✓ The 4.16 kV Class 1E buses (trains A, B, C, and D) are energized and fed from the EDGs through load sequencing.
- Case 15
  - ✓ Due to the voltage imbalance on the MV buses, 13.8 kV motors such as RCPs, circulating water pumps, condensate pumps, feed water booster pumps trip by operation of the negative sequence current relays (46) after time delays (e.g., 12 - 13 seconds).
  - ✓ There is a possibility of actuation of degraded voltage relays (27S) on the Class 1E buses.
  - ✓ The degraded voltage relays (27S) initiate EDG starting and load shedding of the affected Class 1E buses.
  - ✓ The affected Class 1E buses are energized and fed from the respective EDGs through load sequencing.

- ✓ The other MV buses (Class 1E and non-Class 1E) remain fed from the degraded offsite power circuit.

5) Scenario E: Plant Minimum Loading with Alternate Offsite Power (Cases 17, 18, 19, and 20)

When the open phase condition occurs on the primary side of the SAT under Scenario E condition, most of protective relays will not operate, except for Case 18. In Case 19, the Class 1E buses will be subject to abnormal voltage conditions (unbalanced), which potentially may cause actuation of degraded voltage relays at the Class 1E buses.

The OPCs under Scenario E condition will generally cause the same consequences as Scenario D.

Following is the sequence of events as a result of the operation of the existing protection feature for each studied case.

- ▪ Cases 17 and 20
  - ✓ None of the existing protective relays will operate and the Class 1E and non-Class 1E buses will be fed from the alternate preferred power supply without clearance of the OPCs.
- ▪ Case 18
  - ✓ Loss of two phases at the primary side of SAT causes undervoltage on all Class 1E and non-Class 1E buses.
  - ✓ The incoming circuit breaker on each Class 1E bus trips by operation of the LOV relay (27P) after a time delay (e.g., 1 second) and the LOV relay (27P) also initiates EDG starting and load shedding of the Class 1E bus.
  - ✓ The non-Class 1E MV motors are tripped by operation of the LOV relays (27M) after a time delay (e.g., 2 seconds).
  - ✓ The 4.16 kV Class 1E buses (trains A, B, C, and D) are energized and fed from the EDGs through load sequencing.
- ▪ Case 19
  - ✓ There is a possibility of actuation of degraded voltage relays (27S) on the Class 1E buses.
  - ✓ The degraded voltage relays (27S) initiate EDG starting and load shedding of the affected Class 1E buses.
  - ✓ The affected Class 1E buses are energized and fed from the respective EDGs through load sequencing.
  - ✓ The other MV buses (Class 1E and non-Class 1E) remain fed from the degraded offsite power circuit.

6) Scenario F: Transformer No-Load Condition (Cases 21, 22, 23, 24, 25, 26, 27, and 28)

When an open phase condition occurs on the primary side of the MT or SATs while the transformer is energized, but under no-load, none of the existing protective relays will detect the OPC.

In this condition, there is basically no immediate impact on the Class 1E and non-Class 1E electric power system since the transformer is not connected to the onsite power system. However, non-detection of this degraded offsite power source with open phase(s) permits unfavorable bus transfer (automatically or manually) to the degraded offsite power source, which may cause further propagation of the effect of open phase condition into the onsite power system.

7) Scenario G: High-Impedance Ground Fault without Open Phase(s) (Cases 29, 30, 31, and 32)

When a high-impedance ground fault without an open phase fault occurs on the primary side of the MT or SATs, the onsite electrical loads will experience a slight increase of negative sequence voltage and current.

In all cases, the fault does not cause an undervoltage on the Class 1E and non-Class 1E buses and the level of voltage imbalance at the buses is much less than the voltage imbalance alarm setting (technically ignorable). Other ground fault detection measures (i.e., transformer ground fault protection relays (87G)) are not sensitive enough to detect the high-impedance ground fault condition.

In this condition, there is no immediate impact on the Class 1E and non-Class 1E electric power system and, therefore, no specific protection measures against the condition is considered necessary. However, to protect personnel and facilities against the effect of high-impedance ground fault since it is frequently accompanied by an electrical arc, a dedicated detection measure is necessary. The high-impedance ground detection measure is part of the feeder protection from the switchyard.

<u>Summary and Conclusion</u>

Based on performing the computer simulations using ETAP over the selected cases of OPCs and high-impedance ground conditions and assessing the consequences as a result of each selected case, the following observations can be made.

- When a single-phase open condition* occurs on the high-voltage (HV) side of the MT or SATs and the transformer(s) is (are) heavily or lightly loaded, the Class 1E and non-Class 1E buses will experience a voltage imbalance between phases (negative sequence voltage) and the connected loads will experience a current imbalance between phases (negative sequence current) due to the single-phase open condition. Depending on the OPC case, the amount of negative sequence voltage and current will vary and the condition might or might not actuate the negative sequence voltage relays (47) and negative sequence current relays (46). Single-phase open conditions under lightly loaded transformer exhibits smaller negative sequence voltage and current on the buses and connected equipment than a transformer that is heavily loaded.

However, it is evident that the single phase open conditions on the HV side of the MT or SATs may give rise to the following degraded conditions:

- Voltage imbalance condition which may potentially cause damage to the connected electrical loads and will be followed by a protection trip of some large motors unless properly detected and addressed;
- Degraded voltage condition which may cause abnormal operation of the connected electrical loads.

With an OPD system in place, the voltage imbalance condition and degraded voltage condition will be resolved by early detection of the OPC and transfer of the degraded offsite power source to the alternate offsite or onsite power source.

- In case two-phase open conditions exist due to a failure of a transformer high voltage side circuit breaker (i.e., open failure of single phase circuit breaker), the abnormal condition will be readily cleared by the circuit breaker pole discrepancy trip or breaker failure protection provided by the switchyard protective relaying system.

Should a two-phase open condition occur on the high-voltage (HV) side of the MT with the MG online and not be cleared, the MG will experience a significant amount of negative sequence current and, by the operation of MG negative sequence current relay, the switchyard PCBs will trip and the plant will transition to house load operation (HLO) mode.

Without the MG online, a two-phase open condition on the high-voltage (HV) side of the MT or SATs which is (are) heavily or lightly loaded causes an undervoltage less than the settings of the loss of voltage (LOV) relays on all Class 1E and non-Class 1E buses. For each Class 1E bus, the EDG is started by the LOV signal, energizes and supplies power to the bus.

With an OPD system in place, the OPD system will detect the OPC, provide an alarm in the MCR, and issue trip commands to the circuit breakers associated with the degraded offsite power source (e.g., switchyard PCBs, GCB, and switchgear bus incoming breakers).

- In the current design feature of the APR1400 electric power system, a single-phase open condition* on the HV side of the MT or SATs in a no-load condition will most likely fail to be identified. Even though there would be no immediate impact on the electric power system, it is prudent that the OPC be detected, alarmed, and properly interlocked to prevent an undesired bus transfer (automatic or manual) to the degraded offsite power source.

With an OPD system in place, the OPD system will detect the OPC, provide an alarm in the MCR, and also provide a permissive interlock to block an undesired bus transfer (automatic or manual) to the degraded offsite power source.

- A high-impedance ground fault on the primary side of the MT or SATs will most likely fail to be identified by the currently designed conventional protective relays. Even though the fault may not cause direct impact on the Class 1E and non-Class 1E electric power system, a specific type of dedicated high-impedance ground detection device is necessary as part of the feeder protection from the switchyard.

** The single-phase open condition is divided into two cases: (1) a single-phase open condition without high-impedance ground fault; (2) a single-phase open condition with high-impedance ground fault.*

Item E) ITAAC to confirm that OPC conditions are detected, alarmed, and mitigated against.

In order to confirm that OPCs are properly monitored, detected, alarmed, and mitigated against, specific ITAAC will be provided as items 23, 24, and 25 in DCD Tier 1, Table 2.6.1-3.

ITAAC item 23 will be added to verify, by monitoring of the primary side of the MT and SATs, detection of an OPC over the full range of transformer loading from no load to full load.

ITAAC items 24 and 25 will also be added to verify alarm in the MCR and automatic transfer of degraded offsite power source upon detection of an OPC.

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 Attachment 3.

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 Environment Report.

Attachment 1: Result of ETAP unbalanced load flow (ULF) simulation for OPCs and high-impedance ground fault conditions

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Attachment 1: Result of ETAP unbalanced load flow (ULF) simulation for OPCs and high-impedance ground fault conditions

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Non-Proprietary

Attachment 1: Result of ETAP unbalanced load flow (ULF) simulation for OPCs and high-impedance ground fault conditions

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Attachment 1: Result of ETAP unbalanced load flow (ULF) simulation for OPCs and high-impedance ground fault conditions

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Attachment 2: Summary of protective relays operation under OPCs and high-impedance ground fault conditions

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20. Overcurrent protection is set for proper coordination of Class 1E ac electric distribution system.

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

Add

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.

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).

Table 2.6.1-3 (6 of 6)

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
19. The UATs and SATs are designed and sized to meet the worst case loading conditions for all modes of plant operation and accident conditions.	19.a Analyses will be performed to verify that the as-built UATs and SATs are sized for the worst case loading conditions for all modes of plant operation and accident conditions.	19.a A report exists and concludes that the as-built UATs and SATs are designed and sized for the worst case loading conditions for all modes of plant operation and accident conditions.
	19.b Inspections will be performed to verify that the ratings of as-built UATs and SATs meet the size requirements determined by the analysis for the worst case loading conditions for all modes of plant operation and accident conditions.	19.b The ratings of the as-built UATs and SATs bound the size requirements determined by the analysis.
20. Overcurrent protection is set for proper coordination of Class 1E ac electric distribution system.	20.a Analysis of the as-built Class 1E ac electrical distribution system overcurrent protection will be performed to verify proper coordination.	20.a A report exists and concludes that the as-built Class 1E ac electric distribution system overcurrent protection coordinates.
	20.b Inspections and tests will be performed on the Class 1E ac electrical distribution system to verify that the as-built overcurrent protection devices setting is in accordance with the results of the analysis for proper coordination.	20.b A report exists and concludes that the as-built Class 1E ac electrical distribution system overcurrent protection devices is set in accordance with the results of the analysis for proper coordination.
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.

Add Item 23, 24, and 25 per insert (A)

Table 2.6.1-3

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
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.	23. Analyses will be performed to verify that the open phase detection (OPD) 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) 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 system sends an alarm in the main control room.	24. Tests will be performed on the as-built OPD system using simulated signals to verify that the as-built OPD system provides an alarm in the main control room.	24. Using simulated signals, the OPD system provides 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	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).

Table 2.6.1-3

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
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).		

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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)	~~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.

Add COL 8.2(10) per insert (B)

~~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.~~

The COL applicant is to determine the specific type of OPD system on the primary side of the MT and SATs, 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 system. The COL applicant is also to provide the detail features of OPD 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 system are adequate and appropriate for the site.

Table 1.8-2 (10 of 29)

Item No.	Description
COL 8.2(10)	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.

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(2)). 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(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 information for the protective devices, ac power, and dc power that control the switchyard equipment (COL 8.2(5)).

Add

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(10)).

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(6)).

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.

Replace with "A" on the next page

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.

"A"

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.

In case of OPCs with or without a high-impedance ground fault on the primary side of MT or SATs 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).

During all plant operation, each OPD system provides continuous monitoring and self-diagnostics for the surveillance functions to ensure that the OPD 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 system, each OPD system consists of redundant detection subsystem such that a failure in any one of the constituent system will not cause a spurious trip and offsite power supply to all safety related equipment remains unaffected. This redundant protection feature of the OPD system is made up of a 2-out-of-2 logic scheme (minimum), or a 2-out-of-3 logic scheme (if applicable) of the constituent system.

Each OPD 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, 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 system. The COL applicant is also to provide the detail features of OPD 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 system are adequate and appropriate for the site (COL 8.2(7)).

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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.~~

~~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.~~

The COL applicant is to determine the specific type of OPD system on the primary side of the MT and SATs, 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 system. The COL applicant is also to provide the detail features of OPD 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 system are adequate and appropriate for the site.

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.

Add

COL 8.2(10) 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.

6. NUI
Gen
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.