UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION IV
1600 EAST LAMAR BOULEVARD
ARLINGTON, TEXAS 76011-4511

April 13, 2018

Mr. Robert S. Bement
Executive Vice President Nuclear/
Chief Nuclear Officer
Arizona Public Service Company
P.O. Box 52034, MS 7602
Phoenix, AZ 85072-2034

SUBJECT: PALO VERDE NUCLEAR GENERATING STATION – NRC INSPECTION OF THE LICENSEE'S IMPLEMENTATION OF INDUSTRY INITIATIVE ASSOCIATED WITH THE OPEN PHASE CONDITION DESIGN VULNERABILITIES IN ELECTRIC POWER SYSTEMS – INSPECTION REPORT 05000528/2018010, 05000529/2018010, AND 05000530/2018010

Dear Mr. Bement:

On March 22, 2018, the U.S. Nuclear Regulatory Commission (NRC) completed an inspection at the Palo Verde Nuclear Generating Station. On March 22, 2018, the inspectors discussed the results of this inspection with Ms. M. Lacal, Senior Vice President Regulatory and Oversight, and other members of your staff. The results of this inspection are documented in the enclosed report.

The NRC inspectors did not identify any findings or violations of more than minor significance.

This letter, its enclosure, and your response (if any) will be made available for public inspection and copying at http://www.nrc.gov/reading-rm/adams.html, and at the NRC Public Document Room in accordance with 10 CFR 2.390, "Public Inspections, Exemptions, Requests for Withholding."

Sincerely,

/RA James Drake Acting for/

Gregory E. Werner, Chief
Engineering Branch 2
Division of Reactor Safety

Docket Nos. 50-528, 50-529, and 50-530
License Nos. NPF-41, NPF-51, and NPF-74

Enclosure:
Inspection Report 05000528/2018010,
05000529/2018010, and 05000530/2018010
w/ Attachments: 1. Table 1 – Information Gathered for TI 2515/194
2. TI 2515/194 Inspection Documentation Request

U.S. NUCLEAR REGULATORY COMMISSION
Inspection Report

Docket Number(s):	05000528, 05000529, 05000530
License Number(s):	NPF-41, NPF-51, NPF-74
Report Number(s):	05000528/2018010, 05000529/2018010, and 05000530/2018010
Enterprise Identifier:	I-2018-010-0018
Licensee:	Arizona Public Service Company
Facility:	Palo Verde Nuclear Generating Station
Location:	Tonopah, Arizona
Inspection Dates:	March 19, 2018, to March 22, 2018
Inspectors:	S. Graves, Team Lead, Senior Reactor Inspector, Region IV B. Correll, Reactor Inspector, Region IV
Accompanying Personnel:	K. Nguyen, Electrical Engineer, NRR/DE/EEOB I. Kafeez, Reactor Inspector, Region III/DRS/EB3 H. Kodali, Electrical Engineer, NRR/DE/EEOB J. Quichocho, Chief, NRR/DE/EEOB
Approved By:	G. Werner, Branch Chief, Engineering Branch 2

Enclosure

SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) continued monitoring licensee's performance by conducting Temporary Instruction 2515/194, "Inspection of the Licensee's Implementation of Industry Initiative Associated with the Open Phase Condition Design Vulnerabilities in Electric Power Systems (NRC Bulletin 2012-01)," at Palo Verde Nuclear Generating Station, in accordance with the Reactor Oversight Process. The Reactor Oversight Process is the Nuclear Regulatory Commission program for overseeing the safe operation of commercial nuclear power reactors. Refer to https://www.nrc.gov/reactors/operating/oversight.html for more information.

List of Findings and Violations

None.

Additional Tracking Items

None.

INSPECTION SCOPE

This inspection was conducted using Temporary Instruction 2515/194 (ADAMS Accession No. ML17137A416), dated October 31, 2017. The inspectors reviewed the licensee's implementation of Nuclear Energy Institute Voluntary Industry Initiative in compliance with Commission guidance. The team discussed the licensee's open phase condition system design and ongoing implementation plans with plant staff and vendor staff. The team reviewed licensee and vendor documentation, and performed system walkdowns to verify that the installed equipment was supported by the design documentation. The team verified that the licensee had completed the installation and testing of equipment (with the exception of the tripping functions), installed and tested alarming circuits both local and in the control room, and analyzed potential impacts associated with the design implementation on the current licensing basis.

OTHER ACTIVITIES – TEMPORARY INSTRUCTIONS, INFREQUENT AND ABNORMAL

Temporary Instruction 2515/194 - Inspection of the Licensee's Implementation of Industry Initiative Associated with the Open Phase Condition Design Vulnerabilities in Electric Power Systems (NRC BULLETIN 2012-01)

The objective of Temporary Instruction 2515/194, is to verify that licensees have appropriately implemented the Nuclear Energy Institute Voluntary Industry Initiative including updating their licensing basis to reflect the need to protect against open phase conditions, and to gather the information necessary for Office of Nuclear Reactor Regulation staff to determine whether the licensees have adequately addressed potential open phase conditions.

Temporary Instruction 2515/194-03.01 - Voluntary Industry Initiative (Part 1)

Palo Verde Nuclear Generating Station selected the open phase detection system designed and manufactured by Power System Sentinel Technologies, LLC, as the design vendor for their open phase condition system. At the end of this inspection the power system sentinel technologies system was still in the "monitoring mode" of operation to facilitate continued data gathering of grid perturbations for evaluation of alarm and trip setpoints. The open phase condition equipment was installed on the startup transformers (SUTs) AE-NAN-X01, AE-NAN-X02, and AE-NAN-X03 which provide power to station busses, including the station's six engineered safety feature (ESF) busses. The licensee is scheduled to transition the power system sentinel technologies system to full implementation (tripping functions enabled) in December 2018. The licensee was preparing design modifications and associated documentation for this transition, however they were not available for review at the time of inspection.

Section 03.01 of the Temporary Instruction required the determination of whether the licensee appropriately implemented the voluntary industry initiative, dated March 16, 2015 (ADAMS Accession No. ML15075A454), by verifying the following:

a. Detection, Alarms and General Criteria

   1. Either open phase conditions are detected and alarmed in the control room, or

      (a) The licensee has demonstrated that open phase conditions do not prevent the functioning of important-to-safety systems, structures, and components,

        (b) Open phase condition detection will occur within a reasonably short period of time (e.g., 24 hours), and

        (c) The licensee has established appropriate documentation regarding open phase condition detection and correction.

    2. Either detection circuits are sensitive enough to identify an open phase condition for credited loading conditions (i.e., high and low loading), or if automatic detection may not be possible in very low or no loading conditions when offsite power transformers are in standby mode, automatic detection must happen as soon as loads are transferred to this standby source. Additionally, the licensee has established appropriate shiftly surveillance requirements to look for evidence of open phase conditions.

    3. Open phase condition design/protective schemes minimize misoperation or spurious action in the range of voltage unbalance normally expected in the transmission system that could cause separation from an operable offsite power source. Licensees have demonstrated that the actuation circuit design does not result in lower overall plant operation reliability.

    4. New non-Class-1E circuits are not used to replace existing Class-1E circuits.

    5. The Updated Final Safety Analysis Report (UFSAR) has been updated to discuss the design features and analyses related to the effects of, and protection for, any open phase condition design vulnerability.

b. <u>Protective Actions</u>

    1. If the licensee determines there is no single credible failure that could cause an open phase condition, then verify that the licensee has developed and issued a full engineering evaluation to document the basis for open phase condition as a non-credited event. The Bruce Power and Forsmark operating experience must be considered as part of this analysis.

    2. With open phase condition occurrence and no accident condition signal present, either an open phase condition does not adversely affect the function of important-to-safety system, structures, and components, or,

        (a) Technical Specification Limiting Condition of Operations (LCOs) are maintained or the technical specification actions are met without entry into Technical Specification Limiting Condition of Operation 3.0.3 (or equivalent), and

        (b) Important-to-safety equipment is not damaged by the open phase condition, and

        (c) Shutdown safety is not compromised.

    3. With open phase condition occurrence and an accident condition signal present, automatic detection and actuation will transfer loads required to mitigate postulated accidents to an alternate source and ensure that safety functions are preserved, as

required by the current licensing bases, or the licensee has shown that all design basis accident acceptance criteria are met with the open phase condition, given other plant design features. Accident assumptions must include licensing provisions associated with single failures. Typically, licensing bases will not permit consideration of the open phase condition as the single failure since this failure is in a non-safety system.

4. Periodic tests, calibrations, setpoint verifications, or inspections (as applicable) have been established for any new protective features. The surveillance requirements have been added to the plant Technical Specifications if necessary to meet the provisions of 10 CFR 50.36.

Temporary Instruction 2515/194-03.02 - Information Gathering for Voluntary Industry Initiative Assessment (Part 2)

Section 03.02 of the Temporary Instruction required information gathering as part of the initial inspections to enable the Nuclear Reactor Regulation staff to determine whether the modifications implemented by the licensee of each unique open phase condition system design for the voluntary industry initiative adequately address potential open phase conditions. The information gathered for this section is tabulated in attachment, “Table 1 – Information Gathered for TI 2515/194,” to this report.

INSPECTION RESULTS

Based on interviews and discussions with the licensee and the vendor, review of available design, testing, grid data trending results documentation, and walkdowns of installed equipment, the team had reasonable assurance the licensee appropriately implemented, with noted exceptions discussed below, the voluntary industry initiative.

TI 2515/194-03.01 - Voluntary Industry Initiative (Part 1)

a. Detection, Alarms and General Criteria

(1) The team determined by walkdowns and observation that open phase conditions will be detected and alarmed in the control room for each unit.

(2) The team determined that detection circuits were sensitive enough to identify an open phase condition for all credited loading conditions.

(3) No Class-1E circuits were replaced with non-Class 1E circuits in the design.

b. Protective Actions Criteria

(1) The team determined the licensee identified they were susceptible to an open phase condition and were implementing design changes to mitigate the effects.

(2) The team determined that with an open phase condition present and no accident condition signal, the power system sentinel technologies system would not adversely affect the function of important-to-safety systems, structures, and components. The licensee’s open phase condition design solution added a set of additional tripping inputs in parallel to the existing transformer isolation controls. This addition added a

new tripping condition (open phase) to the electrical faults which result in loss of one preferred source of power to one train of ESF loads. The credited plant response would be the same regardless of the conditions that generated the isolation of the transformer.

No findings were identified, however the team identified the following exceptions to the Temporary Instruction criteria resulting from the incomplete design modifications:

c. Detection, Alarms and General Criteria Exceptions

(1) The licensee's design was operating in the monitoring mode with vendor recommended setpoints enabled, to gather data to ensure the open phase condition design and protective schemes would minimize misoperation, or spurious actions in the range of voltage unbalance normally expected in the transmission system. Because actual demonstration of this criterion requires the system to be in operation with final trip setpoints established, the team was not able to fully verify this criterion. After discussions with licensee and vendor staff, design document and test results reviews, and historical monitoring date reviews, the team had reasonable assurance that the actuation circuit design would not result in lower overall plant operation reliability. The team did not identify any issues of concern.

(2) The Final Safety Analysis Report had not been updated to include information related to open phase conditions at the conclusion of the onsite inspection. The licensee provided and the team reviewed proposed changes to the licensing basis that discussed the design features and analyses related to the effects of, and protection for, any open phase condition design vulnerability. The team verified the proposed changes had been entered into the corrective action program as Condition Report CR NON 18-04437 to track the completion of the Updated Final Safety Analysis Report. The team did not identify any issues of concern.

d. Protective Actions Criteria Exceptions

(1) The licensee's open phase condition design solution used the existing isolation and power scheme for safety-related accident loads; only a new tripping condition (open phase) had been added to the electrical faults which result in loss of one preferred source of power to one train of ESF loads. A loss of voltage, including a loss of voltage caused by isolation of the preferred source due to an open phase condition, on the affected ESF bus results in the affected train loading being automatically transferred to the onsite emergency power source, if available (single failure), or manually to a different SUT. While no changes to this configuration were planned due to the inclusion of the power system sentinel technologies system, actual demonstration of this criterion requires the system to be in full operation.

Through review of available design documents and discussions with plant and vendor staff, the team had reasonable assurance that with an open phase condition present and an accident condition signal, the power system sentinel technologies system automatic detection and actuation would isolate the affected transformer. Due to the configuration of Palo Verde Nuclear Generating Station's electrical distribution system, a loss of a SUT would only affect one train of equipment, and loads required to mitigate postulated accidents would be available on the non-affected train ensuring that safety functions are preserved as required by the current licensing bases. The team did not identify any issues of concern.

(2) The licensee had not finalized documentation for periodic tests, calibrations, setpoint verifications, or inspection procedures for open phase condition-related components at the time of this inspection. The team held discussions with licensee and vendor staff and identified that the vendor guidance, including periodic tests, setpoint verification, and equipment maintenance and inspection would be integrated into plant procedures and processes.

The licensee had existing Condition Report CR-17-12228 which was written to establish maintenance strategies for the open phase protection equipment. The licensee updated this condition report to develop additional strategies for the transformer neutral cables which are an integral part of the power system sentinel technologies system. The licensee created Condition Report CR-18-04542 to add additional inspection criteria to existing outside area operator log procedures for visual inspection of the transformer neutral cable, neutral bushing, and ground connection integrity. The team also held discussions about the licensee's plans to include open phase condition-related components into the Maintenance Rule (10 CFR 50.65) program. The licensee generated Condition Report CR NON 18-04442 to create an enhancement action item which tracked the scoping process for inclusion into their maintenance rule program. Existing plant equipment will continue to be maintained according to the licensee's current preventative maintenance program. The team did not identify any issues of concern.

EXIT MEETINGS AND DEBRIEFS

On March 22, 2018, the team presented the Temporary Instruction 2515/194 inspection results to Ms. M. Lacal, Senior Vice President Regulatory and Oversight, and other members of the licensee staff.

The inspectors verified no proprietary information was retained, however some material used by the team to document compliance was characterized as proprietary by the vendor.

DOCUMENTS REVIEWED

Inspection Procedure TI 2515/194

Condition Reports

18-04439

NON 18-04437*

18-04442*

NON 18-04542*

*Issued as a result of inspection activities.

Drawings Number	Title	Revision
A0-E-NAB-008	Elementary Diagram 13.8 kV Non-Class 1E Power System Startup XFMR A-E-NAN-X03 Tripping	11
A0-E-NAB-008, Sheet 2	Elementary Diagram 13.8 kV Non-Class 1E Power System Startup XFMR A-E-NAN-X03 Tripping	11
A0-E-NAB-009	Elementary Diagram 13.8 kV Non-Class 1E Power System Startup XFMR A-E-NAN-X03 Tripping	10
A0-E-NAF-008, Sheet 1 of 4	Elementary Diagram 13.8 kV Non-Class 1E Power System Startup XFMR A-E-NAN-X03 Tripping	4
A0-E-NAF-008, Sheet 2	Control Wiring Diagram 13.8kV Non-Class 1E Power System Startup XFMR A-E-NAN-X03 Tripping	4
A0-E-NAF-008, Sheet 4	Control Wiring Diagram 13.8kV Non-Class 1E Power System Startup XFMR A-E-NAN-X03 Tripping	4
13-E-MAA-001	Main Single Line Diagram	31

Engineering Change Numbers	Title	Date
LDCR 15-F029/15-B011	Updated Final Safety Analysis Report, Section 8.2.2 and Technical Specification Bases Section 3.8.1 and 3.8.2	January 25, 2018
DCN: IEGR-DD-184 Draft	Open Phase Protection System Non-Class 1E Open Phase Protection Settings, Palo Verde Nuclear Generating Station Startup Transformers (SUTs) AE-NAN-X01, AE-NAN-X02, and AE-NAN-X03	March 20, 2018

Engineering Study Number	Title	Revision
13-ES-A060	Engineering Study for Open Phase Condition on the High Side of SUT Transformer	0

Miscellaneous Documents Number	Title	Revision/Date
NLR17R050100	NLR17R050100 Required Reading	August 9, 2017
3002004432	Interim Report: Electric Power Research Institute (EPRI) Open-Phase Detection Method	October 2014
13-NA-00001	PSSTech - Critical Digital Review and Related Software Quality Assurance Report documents	0
0002282	Service Bulletin: One Phase Protection System Injection Source Upgrade	February 21, 2017
2944	Service Bulletin: Phoenix Contact QUINT-PS/1AC/24DC/10 – 2866763 Direct Current (DC) Power Supplies and Phoenix Contact QUINT-PS/1AC/24DC/20 – 2866776 DC Power Supplies	January 23, 2018
NA-1635	Design Input Requirements Checklist - Install Loss of Phase Detection On SUTs	0
	Engineering Disposition for ENG-DMWO # 4411244	February 01, 2018
	Presentation – Palo Verde Nuclear Generating Station Open Phase Protection for Offsite Power Sources	

Modifications Number	Title	Revision
S-15-0116	50.59 Screening for DMWO 4411244	0
DMWO 4411244	NA-1635 Open Phase Detection System	0

Procedures Number	Title	Revision
40AL-9RK1B	Panel B01B Alarm Responses	4
40AL-9MA01	Transformer Trouble Alarm Responses	42C

Vendor Documents Number	Title	Revision/Date
2015APS5714	One Phase Protection System Operating and Maintenance Manual	0.0.3
E003-00162	PSSTech - Open Phase Detection System Factory Acceptance Test Report (FAT) Cabinet S/N 7E0668419 (AENANX01 - Channel 1)	0
SB 0002282	One Phase Protection System Injection Source Upgrade	February 21, 2017
SB 2944	2866763 DC Power Supplies and Phoenix Contact	January 23, 2018

Table 1 – Information Gathered for TI 2515/194

A	Open Phase Condition Detection and Alarm Scheme		Describe Observations/Comments
1	Are all credited offsite power sources specified in UFSAR Chapters 8.1, 8.2, and 8.3 and plant Technical Specifications considered in the design of open phase condition detection and protection schemes?	☒ Yes ☐ No	Palo Verde Nuclear Generating Station (PVNGS) UFSAR Section 8.1 states that six offsite sources of power provide preferred power to the three units through secondary windings of three startup transformers (SUTs). The Updated Final Safety Analysis Report, Section 8.2 states that the transmission system associated with PVNGS supplies offsite air conditioning (AC) power at 525 kV for startup, normal operation, and safe shutdown of Units 1, 2, and 3. Both 525 kV transmission system, which is the credited offsite power source, and the SUT described in the UFSAR were considered in the design of open phase condition detection and protection schemes.
2	Are Open Phase Condition detection scheme(s) installed to monitor the qualified offsite power paths to the ESF buses during all modes of operation?	☐ Yes ☒ No	The Power System Sentinel Technologies open phase condition detection scheme monitors the SUT connections through the SUT high side wye winding neutral. The detection scheme does not monitor the offsite power paths from the low side of the SUT to the ESF buses. The impact of an open phase occurring between the SUT and the ESF transformer is documented in Engineering Study 13-ES-A061, "Open Phase Condition on the High side of ESF Transformer," Revision 0. There are no modifications planned to install separate open phase detection systems on the low side of the SUTs.
3	a. What is the scope of open phase conditions considered by the licensee?		a. The open phase condition scope includes the following: • Phase 1 (DM 4411244 Revision 0) – Installation of open phase detection system designed and made by PSSTech to monitor the SUT connections through the SUT transformer high side wye winding neutral. The system provides alarms in the control room. • Phase 2 (DM 4411244 Revision 1) – activation of the tripping logic

	b. Did the licensee exclude certain open phase conditions (e.g., high voltage or low voltage side of power transformers), operating and loading configurations in their analyses? If so, identify the technical justifications for any exclusion.	☒ Yes ☐ No	b. The Palo Verde Nuclear Generating Station open phase condition detection scheme does not monitor the power paths from the low side of the SUT to the ESF buses. The impact of an open phase occurring between the SUT and the ESF transformer is documented in Engineering Study 13-ES-A061, Revision 0, and summarized below. For the steady state operation during normal, shutdown, and loss-of-coolant accident (LOCA) modes, the open phase condition on high side of the ESF transformer resulted in notable voltage unbalance conditions that were detected and isolated by existing degraded voltage relay and loss of voltage relay scheme. Only one gap of protection was identified for the existing degraded voltage relay and loss of voltage relay scheme occurring during normal operation where the inverse time delay of the loss of voltage relay would not trip prior to the start of the spray pond pump motor due to exposure to damaging overheat conditions. To address this gap, the loss of voltage relay was modified to the fixed-voltage and time delay characteristics. The minimum loss of voltage relay dropout occurs at 3220V with time delay of 2.3 seconds. The steady state normal, shutdown, or LOCA operating conditions modeled with consideration of maximum and minimum switchyard voltage would now be isolated within the 2.3 seconds time frame ensuring that no damage or lock-out of the Class-1E loads occur. The ESF transformer's local connection between ENANS03/ENANS04 switchgear and ESF transformer ENBNX03/ENBNX04 has no underhung insulator. This connection is an overhead copper bare wire mounted from top of ESF transformer to top of switchgear that is of a very short distance with a pole in between for support. The insulators mounted on top of structure transformer, pole, or switchgear. The insulators support a very short distance of 500 MCM (thousands of circular mils) stranded bare copper overhead that is bolted twice on each end. A break anywhere in the path between the switchgear and the transformer would result in a loose bare energy conductor failing onto a grounded enclosure. This type of fault will separate the affected offsite source and start the emergency diesel generator (EDG) and transfer the ESF loads to the EDG automatically.

			Therefore, this would not be an open phase condition. The overhead line between ENANS06/ENANS05 and ENANS04/ENANS03 is a double connection with two conductors/phase. An insulator failure would have to break both conductors that are bolted on each end. A single conductor is sufficient to provide the capacity for the ESF loads. Based on the PVNGS system configuration, an open phase condition on the high side of ESF would affect a single train of one unit. For example, the open phase condition on the high side of ESF NBNX04 transformer would only affect Unit 1 “B” train. The Unit 1 “A” train is not affected and can be supplied from its normal offsite circuit feed SUT AENANX03 Z winding, the Unit 1 “A” train has alternate supply from AENANX01 Y winding, and lastly the EDG for the “A” train. Palo Verde Nuclear Generating Station is not susceptible to common train open phase condition event as such a postulated open phase condition on Unit 1 “B” train and EDG failure on the “A” train would still allow for two offsite circuit paths to provide power to the Unit 1 “A” train. Therefore an open phase condition would not affect both trains. The licensee concluded that the requirement for a separate system that monitors for open phase condition on the plant side does not appear to be justified. Additionally, detecting open phase conditions on low voltage side is not part of the industry initiative.
4	Are the detection schemes capable to identify open phase conditions under all operating electrical system configurations and plant loading conditions?	☒ Yes ☐ No	The open phase detection system consists of an active neutral injection detection element and passive neutral overcurrent detection element. The licensee indicated that combination of active and passive detection elements provides 100 percent coverage for grounded open phases and full range of loading conditions. Draft SA07.S.01.15, “Open Phase Protection System Non-Class 1E open phase detection Protection Settings, Startup Transformers AE-NAN-X01, AE-NAN-X02, AE-NAN-X03,” dated March 20, 2018, includes the electromagnetic transients program simulation results for the following open phase conditions. All simulated conditions were detected either by active or passive detection element.

			- Single Open Phase Ungrounded – SUT unloaded - Double Open Phase Ungrounded – SUT unloaded - Double Open Phase with 0Ω ground on one phase – SUT unloaded - Single Open Phase with 0Ω ground – SUT unloaded - Double Open Phase with 0Ω ground on both open phases – SUT unloaded - Single Open Phase Ungrounded – SUT loaded with 70 MVA motor load - Double Open Phase Ungrounded – SUT loaded with 70 MVA motor load - Single Open Phase with 8,000Ω ground – SUT unloaded - Single Open Phase with 25,000Ω ground – SUT unloaded - Double Open Phase with 4,000Ω ground on both phases– SUT unloaded - Double Open Phase with 12,500Ω ground on both phases – SUT unloaded - Single Open Phase Ungrounded – SUT loaded with 13 MVA motor load - Single Open Phase Ungrounded – SUT loaded with 20 MVA motor load - Double Open Phase Ungrounded – SUT loaded with 8 MVA motor load - Double Open Phase Ungrounded – SUT loaded with 70 MVA motor load The above electromagnetic transients program simulations were performed as the test cases to verify the open phase condition detection with the open phase detection algorithm.
5	a. If the licensee determined that open phase condition	☒ Yes ☐ No	a. Palo Verde Nuclear Generating Station has determined that open phase condition detection

	detection and alarm scheme was not needed, did the licensee provide adequate calculational bases or test data?		and alarm scheme is needed. The PSSTech open phase detection system will detect open phase conditions and generate alarms in Main Control Room (MCR).
	b. Are all open phase conditions detected and alarmed in the MCR with the existing relays?	☐ Yes ☒ No	b. Engineering Study 13-ES-A060, “Open Phase Condition on the High side of SUT transformer,” Revision 0, shows that a single open phase occurring on the high side of the SUT connections would be undetected by the existing relays. The study concluded that there is a need for a separate open phase detection system. To address this condition, Modification DMWO 4411244 installed PSSTech open phase detection system to detect and alarm in MCR.
6	a. Are the detection and alarm circuits independent of actuation (protection) circuits?	☒ Yes ☐ No	a. The wiring of the alarm circuit is separate and independent of the actuation circuit. The MCR alarm wiring circuit ends at the PSSTech open phase detection cabinet alarm lock-out relay for each channel. The alarm wiring is parallel to initiate the MCR SUT common trouble alarm window. The alarm will also trigger a computer point to signify that an open phase condition has been detected. The trip wiring uses a separate wire that is looped between the PSSTech open phase detection cabinet trip lock-out relay contacts and existing transformer lock-out relays. After the trip is enabled, tripping of the exiting transformer lock-out relays will also illuminate an existing MCR alarm SUT protection trip.
	b. If the detection, alarm, and actuation circuits are non-Class 1E, was there any interface with Class 1E systems?	☐ Yes ☒ No	b. The detection alarm and actuation circuits are non-Class-1E (non-safety). The non-safety protection scheme has no interface with Class-1E circuits. The trip output is wired to existing SUT tripping circuitry, which is also non-safety. In addition, the alarm is wired to existing transformer trouble alarm, which is also non-safety. When the open phase detection system detects an open phase, it will isolate the affected SUT. This removes power from a single safety-related train in the unit that is connected to each secondary winding of the affected SUT. The safety-related train then mitigates the loss of power (LOP) per the

			existing design (transferring to onsite power). There is no direct interface between the new open phase detection system and existing safety-related systems.
7	a. Did the manufacturer provide any information/data for the capability of installed relays to detect conditions, such as unbalanced voltage and current, negative sequence current, subharmonic current, or other parameters used to detect open phase condition in the offsite power system?	☒ Yes ☐ No	a. The open phase detection system consists of an active neutral injection detection element and passive neutral overcurrent detection element. The open phase detection system detects by either a) detecting changes in zero sequence impedance as measured by the change in an active injection current (the active detection element), or b) by detecting unbalanced current (i.e. zero sequence current) as measured in the transformer neutral (the passive detection element). The open phase detection system does not measure unbalanced voltage, negative sequence current, or subharmonic currents.
	b. What are the analyses and criteria used by the licensee to identify the power system unbalance due to open phase conditions; and loading and operating configurations considered for all loading conditions which involve plant trip followed by bus transfer condition?		b. Engineering Study 13-ES-A061, Revision 0, describes the impact of the power system unbalance due to an open phase as below. The open phase detection conditions on the high side of the ESF transformer results in voltage unbalance that exceeds the existing bus negative sequence alarms setpoint, which are set at 5 percent negative sequence. The resulting line-to-line 4.16 kV ESF bus voltages for open phase condition on high side of the ESF transformer under no load condition, and nominal (525 kV) or maximum switchyard voltage (535.5 kV) will fall just outside of the degraded voltage relays and loss of voltage relays detection capabilities. Specifically, the high side open phase condition for unloaded ESF transformer, resulted in line-to-line voltages of 3762V (Vab), 3762V (Vbc), 0V (Vac) respectively on the ESF bus that are above the minimum degraded voltage relay drop out of 3690V. However, the open phase condition with ESF transformer unloaded results in the worst case for calculated unbalance. Since the open phase condition for unloaded ESF transformer triggers the existing 5 percent negative sequence alarm, operators would be dispatched to determine the cause of the alarm. The ESF transformers are not operated unloaded and the transformers normally supply Class-1E loads that are energized during

			normal operation including some non-1E loads that are fed from a Class-1E. Therefore, there is no potential for the open phase condition to go undetected and not recognized for an extended period of time.
	c. If certain conditions cannot be detected, did the licensee document the technical basis for its acceptability?	☐ Yes ☐ No ☒ N/A	c. According to the licensee, there are no open phase conditions that cannot be detected with the installed system. There are no conditions that would result in spurious actuation of the system. The open phase condition detection scheme is designed based on the following thresholds. • Active detection setting – concurrence of 5th harmonic that must go up to 8 dB and excess preset time delay. The required condition would preclude spurious trip actuation. • Passive detection setting – must be greater than the neutral current resulting from maximum allowable system voltage unbalance and excess preset time delay. There are no normal/abnormal plant conditions that would defeat the open phase condition based on the setpoints coordinating with existing relays and transformer relays.
	d. Did the licensee perform functional testing to validate limitations specified by the manufacturer of the relays?	☒ Yes ☐ No	d. Functional testing is documented in the factory acceptance test, site acceptance test, and commissioning test which reflect the plant condition and settings including the relay settings.
8	a. Do open phase condition detection circuit design features minimize spurious detections due to voltage perturbations observed during events which are normally expected in the transmission system?	☒ Yes ☐ No	a. The PSSTech open phase detection system includes the following design features to minimize spurious detections: • Digital signal controller implements both active and passive detection schemes. The PSSTech active detection element is primarily intended for the no-load/light-load condition where the neutral current may not be detectable by the passive detection. • The active detection algorithm implements a truth table based on the injection current, 5th harmonic of the neutral current, and the injection voltage inputs. The active detection

			element requires a combination of parameters to be true before actuating a trip. The active injection signal level must fall below its setpoint concurrent with the 5th harmonic signal level rising above its setpoint and the injection voltage level must be within its allowable voltage level band. All three of these conditions must be met concurrently before the active detection element actuates. Additionally, the active detection element is continually monitored for normal conditions pertaining to the active injection signal level, 5th harmonic signal level, and injection voltage level. If the active detection element goes abnormal, actuation is blocked until the element returns to normal. • Time delay is selected above the passive detection timer for coordination. • Passive neutral overcurrent (50N) detection is used when there is higher load on transformer or when the open phase has a ground. • The passive detection is based on current magnitude. • The detection element is an instantaneous overcurrent element. • The instantaneous element is supervised by a definite-time timing function. • Time delay selected to coordinate with high side and low side transformer ground fault clearing. According to the licensee, to date, no spurious trips have been noted in the monitoring period.
	b. Identify whether the licensee considered alarm/trip settings coordination with other electric power system relays including transmission system protection features setup to avoid false indications or unnecessary alarms.		b. The licensee considered alarm/trip settings coordination with other electric power system relays including transmission system protection features setup to avoid false indications or unnecessary alarms. According to Draft SA07.S.01.15, the open phase detection system active and passive detection elements must coordinate with existing relaying on the primary and secondary of the SUT, as well as

other open phase detection systems on adjacent or parallel SUTs. The open phase detection system time delay setting is used to provide coordination with existing relaying. The setting coordination includes:

- <u>Passive Protection Setting</u>

  The passive detection element pickup (50N) will coordinate with:

  - Maximum neutral current resulting from system voltage unbalance.
  - Maximum neutral current resulting from open phase condition on adjacent SUTs.
  - Maximum neutral current resulting from low-side ground fault.

  The passive detection element timer (50NDT) will coordinate with:

  - Trip time for existing relaying for high-side ground fault
  - Trip time for existing relaying for low-side ground fault
  - Transformer damage curve for grounded open phase on high side
  - Existing relaying for the main transformer - the main transformer protection will pick up instantaneously and will clear the faulted main transformer before the open phase detection system operates on any of the protected transformers.
  - Motor damage - will be set to limit motor damages based on the overcurrent trip setting of High Pressure Safety Injection (HPSI) pump motor setting.

- <u>Active Protection Setting</u>

  The active detection element will coordinate with:

			- Switching configurations – Coordinated with 50ND relay to provide 100 percent coverage during all fault conditions. The active detection element timer will coordinate with: - The passive detection element timer – will be greater than the passive detection element timer setting. - Transmission Zone 2 protection
9	Identify how the alarm features provided in the MCR including setpoints are maintained, calibrated, and controlled.		The open phase detection digital controller initiates both the alarm and tripping circuit signals. The alarm signal is routed to the MCR alarm window while the tripping signal will be tied to the existing transformer tripping circuit. The controller output will start external hardware timers, either the open phase detection or neutral current detection (50NDT). Once the timeout of the open phase detection or the 50NDT occurs, the MCR will receive an alarm. According to PSSTech, the detection algorithm does not require calibration unless it is determined through monitoring period that it misoperated for undesired conditions. The manufacturer (National Instruments) recommends that the NI 9229 analog input module and NI 9263 analog output module be calibrated periodically. These modules can be swapped out with the transformer in service in order to facilitate calibration; however, open phase protection will be unavailable while the modules are being swapped. No other controller components require periodic calibration. Palo Verde Nuclear Generating Station is developing the overall calibration and maintenance strategy as part of the phase 2 of the modification. This activity is still in progress. The open phase condition detection settings are maintained and controlled by the plant configuration management and by the relay setting sheets (RSSs). The approved RSSs at PVNGS are used by protective relaying group to make setpoint changes. The final settings for the open phase detection will be documented on the RSSs.

			After the modification is closed out, changes to the setpoint will require the PVNGS design change process to be followed. This process used to make changes to controlled documents such as RSSs.
10	Does the open phase condition detection scheme consider subharmonics in the supply power or offsite power system?	☒ Yes ☐ No	The digital control system supply power is converted to DC inside the system cabinet. The supply power harmonics will have no impact. Current readings are digitally filtered to only respond to the 60Hz current, 5th harmonic current, and the frequency of the injected current (approx. 90Hz). Offsite power system subharmonics have no impact to the open phase detection system.
11	Are open phase condition detection and alarm circuit components scoped into the licensee's maintenance rule program?	☒ Yes ☐ No	System will be scoped into the maintenance rule. The licensee generated a Condition Report CR-18-04442 to track the implementation.
B	<u>Open Phase Condition Protection scheme</u>	Yes/No	Describe Observations/Comments
1	Record location of the sensing of the protection scheme (e.g., high voltage or low voltage side of the transformer, ESF bus, etc.)		Location: The sensing occurs on the neutral of the primary winding that is wye-grounded, on the SUT.
2	a. Record the classification of the protection scheme, safety or non-safety. b. Did the licensee consider the interface requirements for non-safety with safety-related circuits?	☒ Yes ☐ No	Classification: Safety / [✓ Non-Safety] (circle one) a. Non-Safety. The non-safety protection scheme has no interface with Class-1E circuits. The trip output is wired to existing SUT tripping circuitry, which is also non-safety. In addition, the alarm is wired to existing transformer trouble alarm, which is also non-safety. b. When the open phase detection system detects an open phase, it will isolate the SUT. This removes power from a single safety-related train in the unit that is connected to each secondary winding of the affected SUT. The safety-related train then reacts to the LOP per the existing design (transfers to onsite power). There is no direct interface between the new open phase detection system and existing safety-related systems.
3			Type: [✓ Digital] / Non-Digital (circle one)

	a. Record the type of the protection scheme, digital or non-digital. b. Are cyber security requirements specified for digital detection scheme?	 ☒ Yes ☐ No ☐ N/A	a. Digital b. Cyber security initial review was conducted by the licensee on the new installed cabinets. The equipment has physical protection as they are installed in a controlled area (i.e., startup yard) and locked. Key has to be obtained to open the cabinet. System has no Wi-Fi capability. System has a keypad which is used to access the system locally. The keypad provides three levels of access to the digital controller. Levels 0 and 1 provide read-only to monitor parameters while level 2 is used to change the system monitoring setpoints, and is restricted with a programmable 4-digit alpha numeric code entry prior to access. Also, accessing to level 2 will initiate system alarm to alert any potential changes to the system setpoints. In addition, all open USB ports are blocked as required per Specification 13-JN-1022, “Cyber Security Installation Specification.”
4	Did the licensee consider any design features to prevent protective functional failures for open phase condition protection system?	☒ Yes ☐ No	The PSSTech open phase detection system includes the following design features to prevent the system failures: • <u>Redundancy</u>: - Two redundant open phase detection channels are provided for each SUT. - Redundant Primary (DC) and Backup (AC) power sources are provided for each open phase detection cabinet. • <u>Independence</u>: - The primary power source for each open phase detection cabinet is from a different 125VDC source. The DC source is provided by the existing station non-class 1E batteries. Each open phase detection channel’s 125VDC source is independent of other channels. The

			system also has a 120VAC backup source. The AC source is from different AC power panels that are also on different bus line-ups. Each open phase detection channel's 125VAC source is independent of other channel. - Within a single channel, different injection source Current Transformers (CTs) are used for measuring the current probes. The active detection element uses a low current probe and the passive detection element uses a different high current probe. The sensors are independent. - The wiring of the alarm circuit is separate and independent of the actuation circuit. • Diversity: - The main controller that houses the detection algorithm is diverse between the redundant open phase detection channels. Channel 1 has cRIO 9068 controller, which is a non-Intel based processor and utilizes Linux Real-Time. Channel 2 has cRIO 9081 – Intel based processor utilizes Windows Embedded Standard 7 Runtime Operating System. - DC (primary) and AC (backup) power sources are provided for each open phase detection cabinet. • Monitoring, Alerting, and Self-Diagnostic: - The main controller monitors and detects abnormal conditions and provides alarms of input failures. There is one condition considered normal and one condition considered as a valid open phase. If any input fails high or low the system will provide an injection abnormal alarm. The single channel failure modes and effects analysis postulates such failure, and shows the system would provide abnormal alarm. - The channel 1 and channel 2 general alarms are wired in series and initiate the SUT common trouble alarm window in the MCR. The alarm will also trigger a computer point that is different from the open phase condition computer point to alert operator of cabinet trouble/failure.

			Since the general alarms include alarms other than those important to functionality, the specific alarm would be identified locally at the cabinet. - The open phase detection system employed a self-diagnostic feature to alert the channel failures. Alert includes non-functional alarms and channel general alarms. The following alarms are functionally important. ➢ Controller Watchdog Timeout ➢ Injection Source Failure ➢ Channel Injection Abnormal ➢ Cabinet Temperature or Heating, ventilation, and air conditioning Compressor ➢ Malfunction Alarm ➢ Channel Function Switch in OFF Position ➢ Open Phase Alarm Lockout Relay Actuation ➢ Inverter Failure Alarm
5	Identify the number of channels provided per offsite power source, and if there is independence between channels and sensors.		Modification DM 4411244 installed two redundant open phase detection channels per SUT to monitor SUT connections through the SUT transformer high side neutral. These channels are independent of each other. Each channel has its own CTs for sensing the neutral current.
6	a. What is the safety classification of power supply for the protection scheme?		a. Power supply to each open phase detection channel is non-safety. If the protection scheme of a single channel losses power, the channel will fail in a non-tripped state. The failed channel initiates a non-functional alarm and a channel general alarm. Both open phase alarm and trip lockout relays are blocked. The failure modes and effects analysis considered bounding conditions such as loss of 24VDC supply breaker to the main controller and SEL-2411.
	b. Was a LOP to the protection scheme considered?	☒ Yes ☐ No	b. Loss of power to the channel protection scheme results in the following: • Shutdown of all DC powered devices

			• Channel Functional green LED extinguishes • Channel Non-functional alarm relay de-energizes and alerts operator • SEL2411 alarm relay de-energizes and alerts operator The wiring of the non-functional alarm and SEL-2411 alarm are wired in series and opening of either contact would initiate the MCR SUT common trouble alarm window. This is a potential failure of the channel considered as shown in the PSSTech single channel failure modes and effects analysis. However, each of redundant open phase detection cabinets powered is by the redundant, independent, and diverse power sources (AC and DC). For each SUT the primary power source for the open phase detection cabinets are from different 125VDC sources. Similarly, the backup power source are from different AC power panels that are on different bus line-ups. Upon a loss of primary power to an open phase detection channel, the dedicated inverter for that channel will transfer the power to the backup power source. The inverter sends an alarm to the MCR for LOP or failure to transfer.
7	Identify if the licensee considered the consequences of a failure or malfunction of a channel.		Malfunctions and failures were considered. For a failure or a malfunction of either channel, the MCR will receive an alarm. However, both channels of the open phase detection system for each SUT have to send a trip signal to make up the 2-out-of-2 tripping logic. • <u>Failure</u>: A failure is defined as the inability of the trip signal to function on a valid open phase. There are numerous internal diagnostics, when a problem is detected, an alarm signal is sent to the MCR and the trip function is disabled. The consequence is that the trip is disabled until the cause of the alarm is identified and corrected. However, the tripping logic can be changed to 1-out-of-1 logic scheme to allow the unaffected channel to initiate trip. Alternate compensatory measures can also be established.

			- <u>Malfunction</u>: A malfunction is defined as the generation of a trip signal with no valid open phase. When this occurs, only one of two required trip signals would be present. It will cause an alarm in the MCR but will not cause the SUT to be isolated. If a valid open phase were to occur, the remaining channel would complete the 2-out-of-2 logic and isolate the SUT.
8	Did the design consider the single failure criteria as outlined in the general design criteria or the principle design criteria specified in the Updated Final Safety Analysis Report?	☒ Yes ☐ No	Based on the plant configuration, the redundant trains for each unit at PVNGS are on different SUTs and connection to the offsite sources. An open phase condition on the high side of any single SUT would affect a single train of two different units. For example, an open phase condition on the high side of SUT AENANX02 would affect Unit 1 "B" train from the Y secondary winding and Unit 3 "A" train from the Z secondary winding. The unit 1 "A" train is not affected and can be supplied from its normal offsite circuit feed, SUT AENANX03Z winding, alternate offsite circuit supply from AENANX01 Y winding, and lastly the EDG for the "A" train. Therefore, an open phase condition on high side of any single SUT would not affect both trains simultaneously. In addition, each phase connected to the high voltage side of the SUT has two conductors coupled with the design features such as redundancy (two open phase detection channels per SUT and multiple power sources), independence, diversity (different controller types), and scoping the system into the maintenance rule will ensure availability of the open phase detection system. The open phase detection system is a non-safety related system and the loss of a single SUT due to open phase condition would not preclude the onsite electrical power system from being able to perform its safety function. A loss of a SUT would only affect one train of equipment and loads required to mitigate postulated accidents would be available on the non-affected train ensuring that safety functions are preserved as required by the current licensing bases.
9	a. Did the licensee identify the industry standards and criteria to verify	☐ Yes ☐ No ☒ N/A	a. N/A for PVNGS. An open phase event is a single train issue at PVNGS. Accordance to the licensee,

	power quality issues caused by open phase conditions that affect redundant ESF buses? b. What industry standards were used to develop the acceptance criteria for open phase condition trip setpoint or analytical limit?		there is no open phase condition event that affects redundant ESF buses. b. The Electric Power Research Institute Condition Report CR-03002010688 concluded that the stator current in an induction motor never exceeds the locked-rotor current for all voltage unbalance conditions examined. Therefore, it would be a conservative estimate to use the locked-rotor thermal limit to determine the exposure time for motors to unbalanced conditions. Since the 4.16 kV motor's over-current relaying have been coordinated with the safe stall times per Class-1E protection calculations 01-EC-PB-0200, 02-EC-PB-0200, and 03-EC-PB-0200, the overcurrent would always trip prior to motor damage. (Based on ANSI C37.96-1988: Guide for AC Motor Protection)
10	What are the analytical limits or criteria used for setpoints of the actuation/protection scheme to provide adequate protection for motors and sensitive equipment?		A concurrent open phase condition and safety injection actuations Signal (SIAS) event is assumed to be the worst case event. The SIAS condition would initiate the start of the HPSI pump motor. Assuming the HPSI motor stalls due to the open phase condition event, an overcurrent trip of 5.6 seconds for rated locked rotor and settings for HPSI A (1MSIAP02) and 5.1 seconds based on overcurrent setting of HPSI B (1MSIBP02) would occur. The open phase detection system will be installed with the tripping time of ~4.5 seconds or less to provide for coordination with the HPSI motor. This would provide at least a 0.5 second margin between open phase detection system trip and HPSI motor overcurrent trip. The 4.5 second time delay will also provide sufficient time to allow for transmission system clearing of faults, and for existing transformer high side and low side clearing. The HPSI motor has the second fastest trip time, relative to stall conditions. The electronically commutated motor is the most limiting and the overcurrent protection will trip in ~3.3 seconds under stall conditions. However, this motor is energized later in the sequence, at 25 seconds; the open phase detection system would have isolated the affected transformer well before this time. Therefore, it is not considered in selection of the open phase detection

			trip time to meet the requirement of the industry initiative. In addition, the PSSTech protection scheme will detect and trip from no load to full load levels, and varying ground fault impedance. Combination of active and passive detection provides 100 percent coverage for all loading levels. The time delay ensures no equipment damage occurs. - The passive trip is set to 4.5 seconds. - The active trip is set to 5 seconds. The time delays were set to coordinate with existing transformer high side and low side ground relaying.
11	What are the design features provided to preclude spurious trips of the offsite power source (e.g. coincidence logic)?		The open phase detection system includes the following design features to preclude spurious trips of the offsite power source: • The active detection element requires a combination of parameters to be true before actuating a trip. The active injection signal level must fall below its setpoint concurrent with the 5th harmonic signal level rising above its setpoint, and the injection voltage level must be within its allowable voltage level band. All three of these conditions must be met concurrently before the active detection element actuates. Additionally, the active detection element is continually monitored for normal conditions pertaining to the active injection signal level, 5th harmonic signal level, and injection voltage level. If the active detection element goes abnormal, actuation is blocked until the element returns to normal. • The active detection element is supervised by an external timer relay to prevent non-open phase condition transients from initiating a trip output. • The passive detection element only responds to fundamental frequency (i.e. 60 Hz) current as measured in the neutral of the transformer. The passive detection element pickup is set to exclude unbalanced currents associated with normal grid imbalances.

			• The passive detection element is supervised by an external timer relay to prevent non-open phase condition transients from initiating a trip output. • The 2-channel system with 2-out-of-2 trip logic where both channels have to send a trip signal to isolate the SUT if an open phase condition is detected. • Loss of power to the open phase detection system will not cause a spurious trip. The combination of the design of the system and requiring 2-out-of-2 trip logic will minimize spurious trips.
12	a. What analyses have been performed by the licensee which demonstrates that the open phase conditions do not adversely affect the function(s) of important-to-safety equipment required for safe shutdown during anticipated operational occurrences, design basis events, and accidents? If an analyses was not performed, what justification was provided?		a. Engineering Study 13-ES-A061, Revision 0, provides the analysis with respect to the impact of open phase condition to the function(s) of important-to-safety equipment required for safe shutdown during anticipated operational occurrences, design basis events, and accidents. Below is the summary of the analysis. The Electromagnetic Transients Program simulation of steady state running conditions during LOCA case with any postulated open phase condition impedance resulted in ESF transformer secondary voltage below loss of voltage relays, and transferred the ESF loads to the EDG within 2.3 seconds for both minimum and maximum grid conditions. The electromagnetic transients program simulations of double open phase condition results in a complete collapse of the secondary voltages and trip of loss of voltage relays. Thus there is no vulnerability gap for double open phase condition. The double open phase condition is considered as a result of operating experience from the Forsmark event. The Electric Power Research Institute Condition Report CR-03002010688, “Induction Motor Unbalanced Voltage,” concluded that the stator current in an induction motor never exceeds the locked rotor current for all voltage unbalance conditions examined. Therefore, it would be a conservative estimate to use the locked-rotor thermal limit to determine the exposure time for motors to unbalanced conditions. Since the

4.16 kV motor's over-current relaying have been coordinated with the safe stall times per Class-1E protection calculations 01-EC-PB-0200, 02-EC-PB-0200, and 03-EC-PB-0200, the overcurrent would always trip prior to motor damage.

If an open phase condition occurs exactly at the same time as the SIAS, the 4.16 kV motors will stall during initiated LOCA sequence and lock-out on overcurrent protection. Under the existing degraded voltage relays and loss of voltage relays scheme the entire sequence of 4.16 kV motors would trip and lock-out on overcurrent. Under the modified degraded voltage relays and loss of voltage relays scheme, the electromagnetic transients program result showed that only the HPSI pump motor would lock-out and trip when considering the new degraded voltage relays and loss of voltage relays scheme. The new degraded voltage relays and loss of voltage relays scheme reduced degraded voltage relay timeout delay for SIAS conditions from maximum of 35 seconds to 8.5 seconds.

The overall risk of simultaneous occurrence of an open phase condition and SIAS is small. The Palo Verde Nuclear Generating Station internal evaluation of risk from an open phase condition on the high side of an ESF transformer was determined negligible. The Palo Verde Nuclear Generating Station internal risk-assessment modeled the impact of simultaneous open phase condition and a SIAS as unavailability of a single class bus (PBAS03 or PBBS04), during and after sequencing, which is conservative. The risk incurred by a random open phase condition event that results in an unrecoverable failure of a single class bus is as follows:

Risk Metric	**Value**
Delta CDF due to random open phase condition	2.5E-8/yr
Delta LERF due to random open phase condition	4.35E-9/yr

b. Are bus transfer schemes and associated time delays considered?

☒ Yes
☐ No

b. An open phase condition at PVNGS is a single train event. If an open phase is detected, the affected SUT is isolated and the safety train connected to the low voltage winding will detect a LOP and react

			according to the existing design. This occurs within the start time of the diesel, therefore the assumptions of the accident analysis are not affected. Bus transfer schemes do not apply. The Class 1E busses are always connected to the SUT.
13	Are open phase condition protection/actuation circuit components scoped, as appropriate, into the licensee's maintenance rule program?	☒ Yes ☐ No	The open phase detection system will be scoped into the maintenance rule program. The licensee initiated Condition Report CR NON 18-04442 for tracking this implementation.
C	<u>Updated Final Safety Analysis Report Updates to Reflect the Need to Protect Against Open Phase Conditions</u>: Using items 1 to 6 below as examples, identify whether the licensee has updated the UFSAR (and supporting documents such as calculations of record, design change modifications, etc.) to ensure plant-specific licensing basis/requirements include discussions of the design features and analyses related to the effects of, and protection for, any open phase condition design vulnerability.	☒ Yes ☐ No	Describe Observations/Comments: According to the licensee, Section 8.2.2 of the UFSAR appears to be an appropriate location to add the open phase condition description as this section is intended to describe interfaces with the offsite power grid and potential sources of outages. General discussion of the open phase detection system will be added to the UFSAR, Section 8.2.2. Condition Report CR NON 18-04437 was generated to track the implementation of LDCR 15-F029 in conjunction with Revision 1 of the modification package. An open phase condition is not a new accident, so it is does not need to be added to either Chapters 6 or 15 of the UFSAR. The details of the system design, including the failure modes and effects analysis which is part of the design modification package, will not be included in the proposed UFSAR general description change. This is due to Regulatory Guide 1.70, Revision 3, to which Arizona Public Service is committed in UFSAR, Section 1.8, does not require a description of design details.
1	The plant-specific analysis and documentation that established the resolution of the open phase condition design vulnerability, including the failure mode analysis performed.		Palo Verde Nuclear Generating Station has verified by ETAP analysis that a single open phase occurring on the high side of the SUTs would go undetected by existing plant relaying. The resolution for the open phase conditions on the high side of the SUTs for PVNGS is a design change DMWO 4411244 that installed a 2 channel PSSTech open phase detection system per SUT to detect, alarm in MCR, and isolate the SUT upon an open phase condition is detected. Reference: Engineering Study 13-ES-A060, Revision 0. The single channel failure modes and effects analysis postulates failures and malfunctions, and shows the

			open phase protection system end effects and failure states. Reference: IEGR-AD-297, “Open Phase Protection System Single Channel System Failure Modes and Effects Analysis.”
2	Description of open phase condition automatic detection scheme, including how offsite power system open phase conditions are detected from sensing to alarm devices (loss of one or two phases of the three phases of the offsite power circuit both with and without a high-impedance ground fault condition on the high-voltage side of all credited qualified offsite power sources under all loading and operating configurations; and loss of one or two phases of three phases of switchyard breakers that feed offsite power circuits to transformers without ground.		The PSSTech open phase detection system consists of an active neutral injection detection element and passive neutral overcurrent detection element. Combination of active and passive detection provides 100 percent coverage for grounded open phases and full range of loading conditions. For a single channel, the alarm and tripping are based on or logic between the active detection and passive detection; i.e., 1-out-of-2 logic. For each open phase detection system, the alarm and tripping are based on 2-out-of-2 logic.
3	Detection circuit design features to minimize spurious indications for an operable offsite power source in the range of voltage perturbations, such as switching surges, transformer inrush currents, load or generation variations, and lightning strikes, normally expected in the transmission system.		See A.8
4	Alarm features provided in the MCR. Discuss the ESF bus alignment during normal plant operation and the operating procedures in place to address open phase conditions. If the plant auxiliaries are supplied from the main generator and the offsite power circuit to		The ESF trains of a unit are aligned to different SUT windings. The new open phase detection system will initiate a common SUT trouble alarm in MCR. New computer points will be created that will distinguish the open phase detection cabinet open phase alarm and open phase detection system cabinet failure/trouble alarm. The following are operating procedures that are in place to address open phase conditions:

	the ESF bus is configured as a standby power source, then open phase conditions should be alarmed in the MCR for operators to take corrective action within a reasonable time.		• The area rounds Procedure 40DP-9OPA9, Revision 14, has been revised to provide instructions to verify working state of SUT A-E-NAN-X03, “Loss of Phase Detection Cabinets.” • The general transformer trouble alarm response Procedure 40AL-9RK1B was revised to include the new open phase detection cabinet alarms. • The local alarm response Procedure 40AL-9MA01 was revised to provide guidance for operator response to PSSTech system general alarms.
5	Describe the automatic protection scheme provided for open phase conditions including applicable industry standards used for designing the scheme. Design features to minimize spurious actuations for an operable offsite power source in the range of voltage perturbations, such as switching surges, transformer inrush currents, load or generation variations, and lightning strikes, normally expected in the transmission system should be described.		The tripping logic is based on detecting changes in zero sequence impedance as measured by the change in an active injection current (the active detection element), and by detecting unbalanced current, i.e. zero sequence current, as measured in the transformer neutral (the passive detection element). The trip output is wired independently from the alarm circuit and is looped between the PSSTech open phase protection cabinet trip lock-out relay contacts and SUT lock-out relays. The system will be configured with 2-out-of-2 tripping logic required from both open phase detection channel lock-out relays to trip the lock-out relays. Tripping of either lock-out relays will trip all normal and alternate 13.8 kV breakers on the low side and 525 kV breakers on the high side. The open phase condition protection scheme has been designed to the following standards: • ANSI Stds C37 and C57 • IEEE C57.13 • EMI/RFI qualification EPRI 102323 • Surge withstand IEEE C62.45 • Electrostatic Discharge IEEE C63.16 • NEI 08-09, Revision 6 • IEEE 1012
6	Brief discussion of the licensee’s analyses performed for accident condition concurrent open		Bus transfer schemes do not apply. The Class 1E busses are always connected to the SUT.

	phase conditions which demonstrate that the actuation scheme will transfer ESF loads required to mitigate postulated accidents to an alternate source consistent with accident analyses assumptions to ensure that safety functions are preserved, as required by the licensing bases.		
D	Technical Specifications Surveillance Requirements and LCO for Equipment Used for Open Phase Condition Mitigation		Describe Observations/Comments:
	a. Are Technical Specifications Surveillance Requirements and LCO for equipment used for the mitigation of open phase condition identified and implemented consistent with the operability requirements specified in the plant Technical Specifications?	☒ Yes ☐ No	a. Palo Verde Nuclear Generating Station followed the suggested changes described in TSTF-556-T, Revision 0. The Technical Specifications Task Force (TSTF) Evaluation was performed to support changing Technical Specification 3.8.1 and Technical Specification 3.8.2 bases to address an open phase condition. The licensee generated Condition Report CR NON 18-04439 to track the implementation of LDCR 15-B011.
	b. If the licensee determined that Technical Specifications are unaffected because open phase condition is being addressed by licensee-controlled programs, is the technical justification adequate?	☒ Yes ☐ No	b. The Technical Specification Bases will be revised for surveillance requirement 3.8.1.1 to include verification of continuity of 3 phases to the SUTs. plant surveillance procedures, will be modified to reflect the operation of the system, and credit the system as one means of confirming that the required offsite power circuits are operable, in that there is no indication of an open phase condition (SR 3.8.1.1). No license amendment is required to implement the modification. Impacted procedures will be updated in the modification process.

E	<u>Provide a brief summary of the Open Phase Condition plant modification performed under 10 CFR 50.59.</u>	The licensee answered “No” to all eight questions in the draft 10 CFR 50.59 evaluation. The 10 CFR 50.59 evaluation concludes that no NRC review is required. The evaluation is summarized below: The open phase detection system will isolate a SUT that has a valid open phase condition detected. This will result in one safety train from two different PVNGS units to register a LOP and transfer the affected safety train to onsite power. The design and testing of the open phase detection system are sufficient to produce a reliable design such that there is not more than a minimal increase in the likelihood of a malfunction or spurious trip. The open phase detection system is configured in a 2-out-of-2 logic scheme to prevent against inadvertent trips. The open phase detection system for each SUT is independent from the others. The open phase detection system is designed such that no failure, such as a processor failure, loss of AC or DC power, or failure of the injection source will cause the open phase detection system to generate a trip signal. In case the open phase detection system is malfunction and generates a spurious trip, the system isolates the SUT, causing a single safety train in two separate units to transfer to onsite power. In other words, the open phase detection system activates a trip when offsite power is still available and capable. This is an undesired event, challenges the onsite power safety system, but has no real nor significant consequence to the plant. The open phase detection system can also be malfunction, in such, there is an open phase on the high voltage side of the SUT and the open phase detection system fails to isolate the SUT concurrent with an ESF actuation signal, the offsite power may not be capable of powering all of the safety-related loads (on a single safety train in a unit) required to respond to the ESF actuation signal. For this case to impact a unit, there has to be simultaneously an open phase, a failure or malfunction of the open phase detection system to operate, and there has to be a concurrent ESF actuation signal demand. The probability of all three events occurring simultaneously is relatively small.

TI 2515/194 Inspection Documentation Request

Please provide the following documentation (Items 1 – 6) to the lead inspector prior to the onsite inspection date, preferably no later than March 5, 2018. Whenever practical, please provide copies electronically (IMS/CERTREC is preferred). Please provide an index of the requested documents which includes a brief description of the document and the numerical heading associated with the request (i.e., where it can be found in the list of documents requested).

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1. Copies of any calculations, analyses, and/or test reports performed to support the implementation of your open phase condition solution. If, in your implementation, open phase conditions are not detected and alarmed in the control room please include documentation that: a) demonstrates the open phase condition will not prevent functioning of important-to-safety system, structures, and components; and b) detection of an open phase condition will occur within a short period of time (e.g., 24 hours).

2. Copies of any modification packages, including 10 CFR 50.59 evaluations if performed, used for or planned for the implementation of your open phase condition solution.

3. Copies of periodic maintenance, surveillance, setpoint calibration, and/or test procedures implemented or planned, for your open phase condition solution.

4. Copies of your licensing basis changes to Updated Final Safety Analysis Report (UFSAR) and/or Technical Specifications (TS), as applicable, which discuss the design features and analyses related to the effects of, and protection for, any open phase condition design vulnerability.

5. Copies of any procurement specifications and acceptance testing documents related to the installation of your open phase condition solution.

6. Copies of any site training the team will need to accomplish to gain access to areas with, or planned, major electrical equipment used in your open phase condition solution (i.e. switchyard).

Please provide the following documentation to the team when they arrive onsite. Whenever practical, please provide copies electronically, except for drawings. Drawings should be provided as paper copies of sufficient size (ANSI “C” or “D”) such that all details are legible.

7. A brief presentation describing your electric power system design and typical electrical transmission and distribution system alignments; open phase condition design schemes installed to detect, alarm and actuate; bus transfer schemes; and maintenance and surveillance requirements. This presentation should be a general overview of your system. Please schedule the overview shortly after the entrance meeting.

8. Plant layout and equipment drawings for areas that identify: (a) the physical plant locations of major electrical equipment used in your open phase condition solution; (b) the locations of detection and indication equipment used in the open phase condition sensing circuits.

9. If open phase condition actuation circuits are required, provide documentation that demonstrates continued coordination with the other protective devices in both the offsite electrical system (within Palo Verde Nuclear Generating Station area of responsibility) and the onsite electrical systems.

10. Access to locations in which open phase condition equipment is installed or planned (i.e. switchyard, transformer yard, etc.)

11. Copies of documentation or testing that demonstrates your open phase condition solution minimizes spurious actuation or misoperation in the range of voltage imbalance normally expected in the transmission system that could cause undesired separation from an operable offsite power source.

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PALO VERDE NUCLEAR GENERATING STATION – NRC INSPECTION OF THE LICENSEE'S IMPLEMENTATION OF INDUSTRY INITIATIVE ASSOCIATED WITH THE OPEN PHASE CONDITION DESIGN VULNERABILITIES IN ELECTRIC POWER SYSTEMS – INSPECTION REPORT 05000528/2018010, 05000529/2018010, AND 05000530/2018010 – APRIL 13, 2018

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