10 CFR 50.54(f)

A subsidiary of Pinnacle West Capital Corporation

Palo Verde Nuclear Generating Station

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102-06610-JJC/RKR
October 25, 2012

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Dear Sir or Madam:

Subject: Palo Verde Nuclear Generating Station (PVNGS)
Units 1, 2, and 3
Docket Nos. STN 50-528, 50-529, and 50-530
NRC Bulletin 2012-01, Design Vulnerability in Electric Power System

Pursuant to 10 CFR 50.54(f), this letter provides the Arizona Public Service Company (APS) response to NRC Bulletin 2012-01, *Design Vulnerability in Electric Power System,* dated July 27, 2012. The NRC Bulletin identified the following three objectives:

1. To notify the addressees that the NRC staff is requesting information about the facilities' electric power system designs, in light of the recent operating experience that involved the loss of one of the three phases of the offsite power circuit (single-phase open circuit condition) at Byron Station, Unit 2, to determine if further regulatory action is warranted.

2. To require that the addressees comprehensively verify their compliance with the regulatory requirements of General Design Criterion (GDC) 17, *Electric Power Systems*, in Appendix A, *General Design Criteria for Nuclear Power Plants*, to 10 CFR Part 50 or the applicable principal design criteria in the updated final safety analysis report; and the design criteria for protection systems under 10 CFR 50.55a(h)(2) and 10 CFR 50.55a(h)(3).

3. To require that addressees respond to the NRC in writing, in accordance with 10 CFR 50.54(f).

The industry established a template to guide development of plant responses to Bulletin 2012-01. APS used the established industry template as a guide in developing the Bulletin response. NRC Bulletin 2012-01 requested that licensees submit a response within 90 days. The APS 90-day response is provided in the Enclosure.

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NRR

This response is submitted in accordance with 10 CFR 50.4. APS has reviewed the response and it does not contain any proprietary, sensitive, safeguards or classified information.

No commitments are being made to the NRC by this letter.

Should you need further information regarding this response, please contact Robert K. Roehler, Licensing Section Leader, at (623) 393-5241.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 10/25/12
(Date)

Sincerely,

JJC/RKR/CJS/hsc

Enclosure: NRC Bulletin 2012-01 - Palo Verde Nuclear Generation Station Response

cc:

E. E. Collins Jr.	NRC Region IV Regional Administrator
L. K. Gibson	NRC NRR Project Manager for PVNGS
J. R. Hall	NRC NRR Senior Project Manager
M. A. Brown	NRC Senior Resident Inspector for PVNGS

Enclosure

NRC Bulletin 2012-01
Palo Verde Nuclear Generation Station Response

- Attachment 1 - NRC Bulletin 2012-01 Response

  Overview:

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Attachment 1 - NRC Bulletin 2012-01 Response

PVNGS Bulletin 2012-01 Response

For clarity, the bulletin requested actions have been grouped together into topical sections. This approach is consistent with the template presented to the NRC in an industry meeting on August 21, 2012.

System Description

Items 2, 1.d, 2.a, and 2.c request system information and will be addressed in this section:

> ***2. Briefly describe the operating configuration of the ESF buses (Class 1E for current operating plants or non-Class 1E for passive plants) at power (normal operating condition).***

At Palo Verde Nuclear Generating Station (PVNGS), the Class 1E Engineered Safety Feature (ESF) buses are normally powered directly from offsite power (preferred source). The offsite power system consists of seven independent circuits from the Arizona-New Mexico-California-Southern Nevada power grid to the PVNGS 525 kV switchyard. The 525 kV switchyard is constructed with a breaker-and-a-half design in which three breakers are provided for every two terminations, either line or transformers. The 525 kV system provides continuously connected offsite power to three, four-winding startup transformers (AENANX01, AENANX02, and AENANX03), and feeds six 13.8 kV intermediate buses. These intermediate buses are arranged in three pairs, each pair feeding one Unit, distributing power to the ESF load groups.

The onsite ESF electric power system for each unit is split into two independent load groups (ESF Bus A and ESF Bus B), each with its own offsite and onsite power supplies, buses, transformers, loads, and associated 125 V-dc control power. The ESF buses distribute power at 4.16 kV, 480 V, and 120 V to all Class 1E loads. Also, the Class 1E AC system supplies power to certain selected loads that are not directly safety-related but are important to the plant (e.g., Normal Chilled Water Pumps and containment building reactor cavity normal cooling fans). The non-Class loads connected to ESF buses are tripped upon an accident actuation signal. Either ESF bus is independently capable of safely shutting down the unit and/or supporting design basis accident mitigation. An independent 5500 kw diesel generator is provided for each ESF bus as standby emergency power.

During normal plant operation, the unit auxiliaries are supplied from the main turbine generator through the Unit Auxiliary Transformer (UAT) and the ESF buses are continuously supplied from the Startup Transformers (SUT) powered from preferred offsite sources as described above. Preferred power source alignment for the ESF buses is supplied from the SUT through the 13.8 kV intermediate buses and the 13.8 kV-4.16 kV ESF Transformers. Each SUT supplies power to one ESF bus in two different Units. See response for Item 2.c for the description of the alignment configuration from the SUT to the ESF buses for all three Units.

Reactor Coolant Pumps (RCP) and Circulating Water Pumps (CWP) are normally powered from the UAT by the main turbine generator. However, in an event of a loss of supply from the UAT, such as a Unit trip, the RCP and CWP supply buses are automatically transferred (fast bus transfer) from the onsite power source to the offsite power source through the SUT.

See Attachment 2, Figure 1, for the PVNGS simplified one-line diagram (Unit 1 – typical for all three Units).

1.d. Describe the offsite power transformer (e.g., start-up, reserve, station auxiliary) winding and grounding configurations.

The three, 525-13.8 kV/13.8 kV, shell-form SUTs are equipped with four windings: a primary, a tertiary, and two secondaries. The SUT primary winding is solidly grounded and the buried tertiary winding is corner grounded. The SUT secondary windings Y and Z are connected to low resistance grounding resistors. Each grounding resistor limits the ground fault current to 2000 A in the 13.8 kV system.

The 13.8-4.16 kV, 3-legged core-form ESF Transformers are delta-wye connected. The primary winding is ungrounded and the secondary winding is connected to a low resistance grounding resistor to limit the ground fault current to 600 A in the 4.16 kV system.

See Attachment 3, Table 5 for the detailed offsite power transformer winding and grounding configurations.

2.a. Are the ESF buses powered by offsite power sources? If so, explain what major loads are connected to the buses including their ratings.

During normal plant operation, the ESF buses are powered by offsite power sources (preferred source). The safety-related equipment is divided into two load groups per Unit (ESF Bus A and ESF Bus B). Each SUT supplies power to one ESF bus of two different Units. Either one of the ESF buses is capable of providing power for safely shutting down the Unit and/or supporting design basis accident mitigation. The ESF buses also supply power to certain selected non-Class loads that are not directly safety-related but are important to plant operation, such as Normal Chilled Water Pumps and containment building reactor cavity normal cooling fans. These non-Class loads are tripped upon a Safety Injection Accident Signal (SIAS).

The major loads connected to the ESF buses during normal operating condition are shown in Attachment 3, Table 2. During normal operation, certain sets of major loads are continuously powered by an ESF bus. Operations will alternate selected loads powered by either ESF Bus A or ESF Bus B during certain evolutions, such as plant maintenance or periodic testing. Also, other major components may intermittently be loaded on the ESF buses, such as for performance of periodic maintenance testing, inspections, or surveillance tests.

See Attachment 3, Table 1 for ESF bus power sources.

See Attachment 3, Table 2 for ESF bus major loads energized during normal power operation, including their ratings.

See Attachment 3, Table 3 for ESF bus major loads intermittently energized during normal power operation, including their ratings.

See Attachment 3, Table 4 for major loads energized by an ESF Bus (alternated between ESF Bus A and ESF Bus B) during normal power operation, including their ratings.

2.c. Confirm that the operating configuration of the ESF buses is consistent with the current licensing basis. Describe any changes in offsite power source alignment to the ESF buses from the original plant licensing.

The offsite power system consists of seven transmission lines from the Arizona-New Mexico-California-Southern Nevada power grid to the PVNGS switchyard. Offsite power from the switchyard through three SUTs and six intermediate buses is provided to supply two, physically independent, preferred power circuits to the ESF power distribution system of each unit.

In original plant licensing, four independent 525 kV transmission lines supplied the offsite power to the PVNGS switchyard. Three 525 kV transmission lines have been added to the PVNGS switchyard since original plant licensing (UFSAR updated in revisions 3, 11, 12, and 14).

There have been no changes to the offsite power source alignment to the ESF electrical distribution system from original plant licensing. The following at power (normal operating condition) configurations are consistent with the current licensing basis:

1. Unit 1 Circuit: Power to ESF buses via 525 kV switchyard (SUT and ESF Service Transformer)
   (a) SUT(AENANX03) Z-winding/Intermediate Bus 1ENANS05/ Bus 1ENANS03/ESF Service Transformer 1ENBNX03/1EPBAS03 ESF Bus A

(b) SUT(AENANX02) Y-winding/Intermediate Bus 1ENANS06/ Bus 1ENANS04/ESF Service Transformer NBNX04/1EPBBS04 ESF Bus B

2. Unit 2 Circuit: Power to ESF buses via 525 kV switchyard (SUT and ESF Service Transformer)
   (a) SUT(AENANX01) Z-winding/Intermediate Bus 2ENANS05/ Bus 2ENANS03/ESF Service Transformer 2ENBNX03/2EPBAS03 ESF Bus A
   (b) SUT(AENANX03) Y-winding/Intermediate Bus 2ENANS06/ Bus 2ENANS04/ESF Service Transformer 2ENBNX04/2EPBBS04 ESF Bus B

3. Unit 3 Circuit: Power to ESF buses via 525 kV switchyard (SUT and ESF Service Transformer)
   (a) SUT(AENANX02) Z-winding/Intermediate Bus 3ENANS05/ Bus 3ENANS03/ESF Service Transformer 3ENBNX03/3EPBAS03 ESF Bus A
   (b) SUT(AENANX01) Y-winding/Intermediate Bus 3ENANS06/ Bus 3ENANS04/ESF Service Transformer 3ENBNX04/3EPBBS04 ESF Bus B

See Attachment 2, Figure 1 for PVNGS simplified single line diagram (Unit 1 – typical for all three units). Attachment 2, Figures 2 and 3 provide the protective relaying zones of protection and relay designations, respectively. Attachment 3, Table 6 provides the settings of the protective relays.

See Attachment 3, Table 1 for the offsite power source alignment to the ESF buses. The alignment is consistent with original plant licensing.

System Protection

Items 1, 1.a, 2.b, and 2.d request information regarding electrical system protection and are addressed in this section:

> ***1. Given the requirements above, describe how the protection scheme for ESF buses (Class 1E for current operating plants or non-Class 1E for passive plants) is designed to detect and automatically respond to a single-phase open circuit condition or high impedance ground fault condition on a credited off-site power circuit or another power sources.***

Consistent with the PVNGS current licensing basis and GDC 17, existing protective circuitry will separate the ESF buses from a connected failed offsite source due to a loss of voltage or a sustained, balanced, degraded grid voltage. The relay systems are not designed to detect a single-phase open circuit condition of a three phase system. It is the APS position that detection of a single-phase open circuit or high impedance ground fault condition is beyond the approved design and licensing basis of PVNGS.

A postulated single-phase open circuit or high impedance ground fault condition located on the high side of the SUT affects only one ESF bus, of two different Units. A single-phase open circuit or high impedance ground fault condition located on the low side of the SUT would only affect the associated ESF bus of one Unit. The redundant train is capable of safely shutting down the Unit and/or supporting design basis accident mitigation.

PVNGS performed a preliminary evaluation of the effect of an offsite power supply single-phase open circuit condition and high impedance ground fault condition on the electrical distribution system for the following cases:

Case 1: Single-phase open circuit condition on high side of SUT, lightly loaded

During normal plant operation, the SUT is lightly loaded with the major loads on the ESF buses listed in Attachment 3, Tables 2 through 4 and the RCPs and other major "house" loads on the UAT.

The current PVNGS protective relaying scheme may not be able to detect an open phase on the primary of the SUT under all conditions. This is particularly true under lightly loaded or no load conditions, where voltages and currents remain relatively unaffected. The unbroken phases and the buried tertiary winding can create sufficient flux in the leg of the open phase in the SUT transformer to induce a voltage in the secondary windings related to the open phase. Since the SUT is lightly loaded, with insignificant current flow in the secondary winding on the transformer, there is no discernible voltage drop. Therefore, the voltages and currents at the safety related 4.16 kV ESF buses would be relatively unaffected by an open phase on the high side of an SUT, when lightly loaded (each SUT supplies power to one ESF bus of two different Units).

It is not expected that the degraded voltage and negative sequence relaying at the ESF buses would be initiated. Thus, with a lightly loaded condition, protective devices for the ESF buses would likely not detect or automatically respond to a single-phase open circuit condition located on the high side of the SUT.

Since ESF loads are a small fraction of the SUT capacity, the SUT tertiary winding may allow the affected ESF bus of each Unit to carry its safe shutdown or emergency loads without interruption. Further investigation would be needed to quantify these transient effects on the supported equipment. Regardless, the unaffected ESF bus would remain available to perform the safe shutdown or accident mitigation safety functions.

Case 2: Single-phase open circuit condition on the secondary side of SUT, lightly loaded

The PVNGS offsite power alignment to the ESF buses from the SUT includes both underground cables and overhead lines going into the 13.8 kV/4.16 kV ESF service transformer. A potential loss of a single phase has been evaluated, as a failure of overhead line insulators could be comparable to the Byron insulator failure.

The APS preliminary evaluation indicates that an open phase on the primary side of the ESF transformer (secondary of the SUT) would result in a significant drop in two of the phase-to-phase voltages on the ESF bus. This is due to the difference in performance characteristics between the Delta/Wye winding of the ESF transformer as compared to the Wye/Delta/Wye winding configuration of the SUT. Since the safety-related degraded voltage relaying design senses all three phase-to-phase voltages in a 2-out-of-4 logic, this would actuate a transfer of the ESF buses to the emergency diesel generators. Thus, a loss of a single phase on the primary side of the ESF transformer would be detected by the existing safety related degraded voltage relaying on the ESF bus.

Case 3: Single-phase open circuit condition on high side or low side of SUT, heavily loaded

From the normal plant operating condition, a fast bus transfer would be initiated automatically by a major equipment problem (main turbine, main generator, main transformer, or UAT) or by a reactor trip (causing a main turbine trip and then a main generator trip). The fast bus transfer shifts RCP and CWP supply buses from the UAT to the SUT, resulting in a heavily loaded condition on the SUT.

For an open phase on the primary side or secondary side of the SUT, under heavily loaded conditions, there would be significant undervoltage and voltage imbalance occurring on all downstream buses. The safety related degraded voltage relaying design at the ESF buses senses all three phase-to-phase voltages in a 2-out-of-4 logic. With the sustained degraded voltage, this would likely result in transfer of the ESF buses to the emergency diesel generators.

Thus, an open phase on the high side or low side of the SUT could be detected by the existing safety related degraded voltage relaying on the ESF bus, under heavily loaded conditions. For an open phase on the high side of the SUT, under heavily loaded conditions, one ESF bus in two different Units would have a similar degraded voltage response. The unaffected ESF bus for each Unit, not associated with the impacted SUT, would be available to perform the safe shutdown or accident mitigation safety functions.

After a fast bus transfer, it is possible that the protective relaying of the RCPs and CWPs would trip these large motors on negative sequence overcurrent or bus undervoltage, before the degraded voltage relays at the ESF bus time out. For a single-phase open circuit condition on the high side of the SUT, such equipment protection relaying actuation would restore the lightly loaded condition on the SUT, restore balanced voltages at the ESF bus, and may allow the ESF bus to carry its emergency loads without interruption. Further investigation would be required to quantify these transient effects.

Case 4: High Impedance ground fault on high side of SUT

The electrical protection on the primary side of the SUT includes ground fault protection. This protection functions to provide control room annunciation and upstream / downstream breaker trips. Actuation of these relays depends on the level of impedance at the ground fault. The ground fault impedance may be high enough where the neutral current is not significant enough to actuate the relays. APS will continue to participate in industry efforts to better understand the high impedance ground fault condition with all three phases intact when the high impedance ground fault is outside the sensitivity of the ground fault relays. Each SUT supplies power to one ESF bus in two different Units.

See Attachment 3, Table 6 for the settings of the ground fault protective relays.

Case 5: High impedance ground fault on the secondary side of SUT

The result of a high impedance ground fault with all three phases intact occurring on the secondary side of the SUT is similar to high impedance ground fault on the high side of the SUT. At a medium voltage level, it is likely that a high impedance fault will propagate into a solid fault or multi-phase fault and the corresponding overcurrent devices would actuate and clear the fault.

APS will continue to participate in industry efforts to better understand the high impedance ground fault condition with all three phases intact when the high impedance ground fault is outside the sensitivity of the ground fault relays.

1.a. The sensitivity of protective devices to detect abnormal operating conditions and the basis for the protective device setpoint(s).

Consistent with PVNGS current licensing basis and GDC 17, existing electrical protective devices are sufficiently sensitive to detect design basis conditions like a loss of voltage or a sustained, balanced degraded voltage, but are not designed to detect a single-phase open circuit or high impedance ground fault condition.

Protective relaying is a compromise between reliability (always tripping when tripping is desired), and security (never tripping when tripping is not desired). The basis for most protective relay settings at PVNGS is the Arizona Public Service Protection, Metering and Automated Control (PMAC) criteria, which were developed from many years of experience with Arizona Public Service (APS) power plants and transmission systems, and include recommendations given in the relay manufacturer's instruction manuals, when applicable. The relay settings proceed from these criteria, and account for available fault currents, current and potential transformer ratios, data for the protected equipment, and coordination with other protective relays and devices, as applicable. Relay settings that do not meet the PMAC criteria are evaluated on a case-by-case basis.

See Attachment 3, Table 6 for PVNGS protective relaying/alarm devices and the basis for the device setpoints.

2.b. If the ESF buses are not powered by offsite power sources, explain how the surveillance tests are performed to verify that a single-phase open circuit condition or high impedance ground fault condition on an off-site power circuit is detected.

The ESF buses at PVNGS are powered by offsite power sources and not aligned to the UAT at PVNGS.

A walkdown of the 525 kV switchyard was performed to assess the configuration of the offsite power lines and the vulnerability to an open phase or high impedance ground fault condition. Although the PVNGS design includes two conductors per phase and multiple insulators, APS recognizes the possibility of a single-phase open circuit or high impedance ground fault condition. Operator rounds have been revised to require operators to verify the integrity of the 525 kV overhead lines feeding the start-up transformers daily, to detect a single-phase open circuit condition.

See Attachment 4, Photograph 1, for a picture of PVNGS SUT in the switchyard.

2.d. Do the plant operating procedures, including off-normal operating procedures, specifically call for verification of the voltages on all three phases of the ESF buses?

The current plant operating procedures, including operating procedures for alarm response, emergency, and off-normal alignments, do not specifically call for verification of voltages on all three phases of the ESF buses.

Indication of ESF bus voltage is available for only one phase in the main control room. Voltage indication is available locally for each of the three phases at the ESF switchgear. As described in the response to Item 1, Case 1, the PVNGS ESF buses normally operate in a lightly loaded condition, such that voltage difference for a single-phase open circuit condition would not be obvious, even if the voltage for each of the three phases were available in the control room. Operator rounds have been revised to require operators to verify the integrity of the 525 kV overhead lines feeding the start-up transformers daily.

APS will continue to participate in industry efforts to develop diagnostic and response strategies to a postulated single-phase open circuit or high impedance ground condition. As the electrical distribution system transient response is better quantified, plant symptoms may be identified and direction developed that could be added to off-normal operating procedures. Enhancements to plant operating procedures are being evaluated, to improve detection and response to a single-phase open circuit or high impedance ground condition. The enhancements include improvements to the alarm response procedures for negative sequence voltage alarms.

Consequences

Items 1.b, 1.c, and 2.e request information regarding the electrical consequences of an event and will be addressed in this section:

> ***1.b. The differences (if any) of the consequences of a loaded (i.e., ESF bus normally aligned to offsite power transformer) or unloaded (e.g., ESF buses normally aligned to unit auxiliary transformer) power source.***

The current PVNGS installed protection relays are not designed to detect open phase conditions. Existing degraded voltage relays may respond depending on load conditions and possible grounds. The consequences of different loading conditions for an open phase or high impedance ground fault condition are discussed in the previous response to Item 1, in the *System Protection* section of this Bulletin response.

> ***1.c. If the design does not detect and automatically respond to a single-phase open circuit condition or high impedance ground fault condition on a credited offsite power circuit or another power sources, describe the consequences of such an event and the plant response.***

Existing protective relaying and indication may not detect and automatically respond to a single-phase open circuit or high impedance ground fault condition, due to the unpredictability of currents and voltages from the postulated event. During a high impedance ground fault, with all three phases intact, protective relay actuation may occur but cannot be guaranteed due to variability in the impedance to ground condition. APS will continue to participate in industry efforts to develop modeling techniques to better understand the electrical distribution system transient response.

Under the PVNGS normal operating electrical configuration, with a lightly loaded condition, a single-phase open circuit or high impedance ground fault condition occurring on the primary side of the SUT would likely result in essentially unaffected indications for voltages and currents.

PVNGS performed a preliminary evaluation of the effect of an offsite power supply single-phase open circuit condition on the electrical distribution system. The consequences under different loading conditions are discussed in the previous response to Item 1, in the *System Protection* section of this Bulletin response.

For PVNGS, a single-phase open circuit or high impedance ground fault condition located on the high side of the SUT affects only one ESF bus, in two different Units. A single-phase open circuit or high impedance ground fault condition located on the low side of the SUT would only affect the one associated ESF bus in one Unit. The redundant unaffected train is capable of safely shutting down the Unit and/or supporting design basis accident mitigation.

> ***2.e. If a common or single offsite circuit is used to supply redundant ESF buses, explain why a failure, such as a single-phase open circuit or high impedance ground fault condition, would not adversely affect redundant ESF buses.***

PVNGS does not have a common or single offsite circuit supplying the redundant ESF buses. Two physically independent, offsite power circuits are provided to power the onsite ESF distribution system for each Unit. Therefore, a single-phase open circuit or high impedance ground fault condition would not adversely affect the redundant ESF buses.

Attachment 2 - Figures

FIGURE 1 - PVNGS Simplified One-Line Diagram (For Unit 1 – typical for all three units)

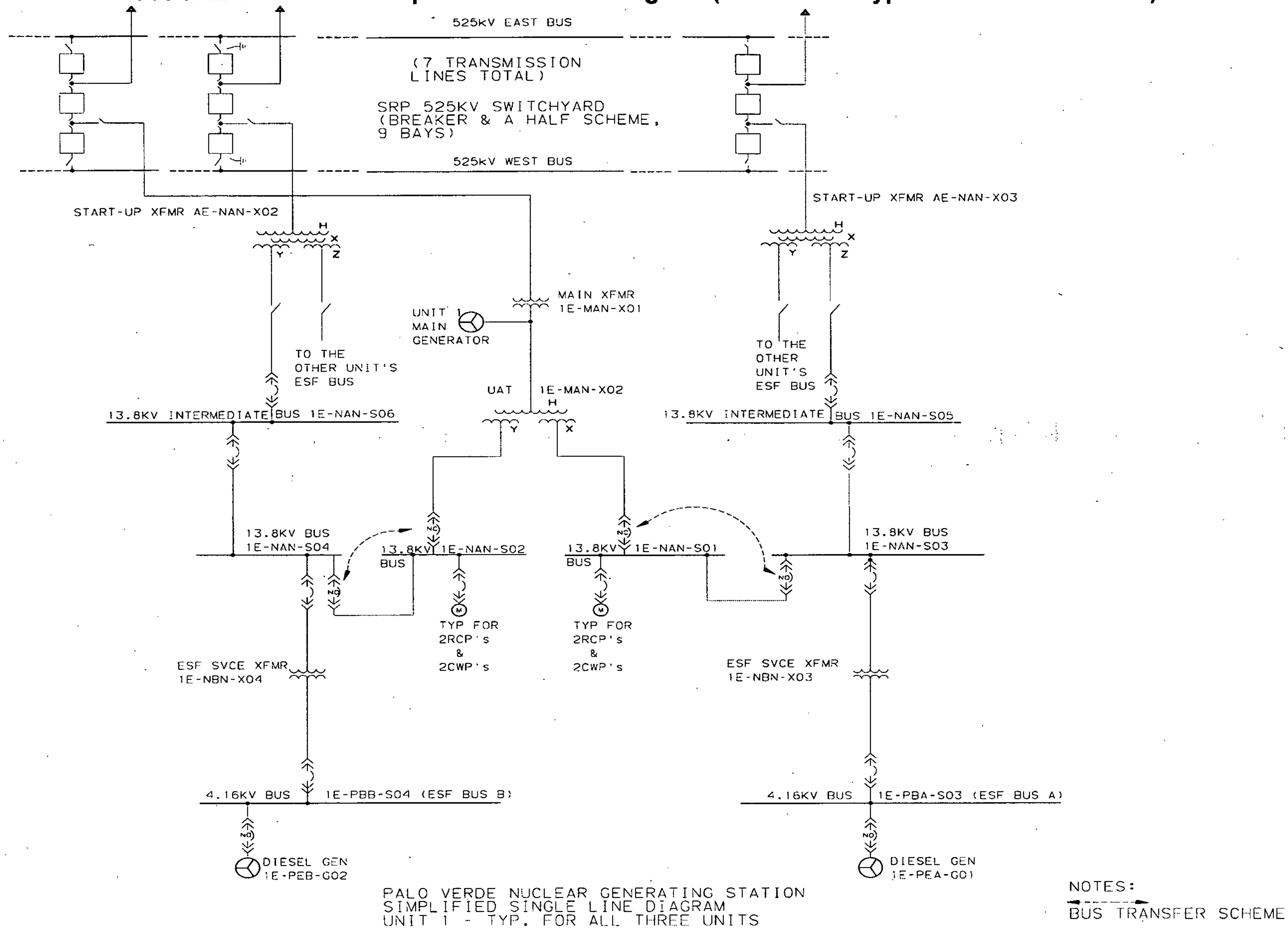


Figure 2 – PVNGS Protective Relaying, Differential Zones of Protection

Note: Attachment 3, Table 6 provides the setpoints for the relays

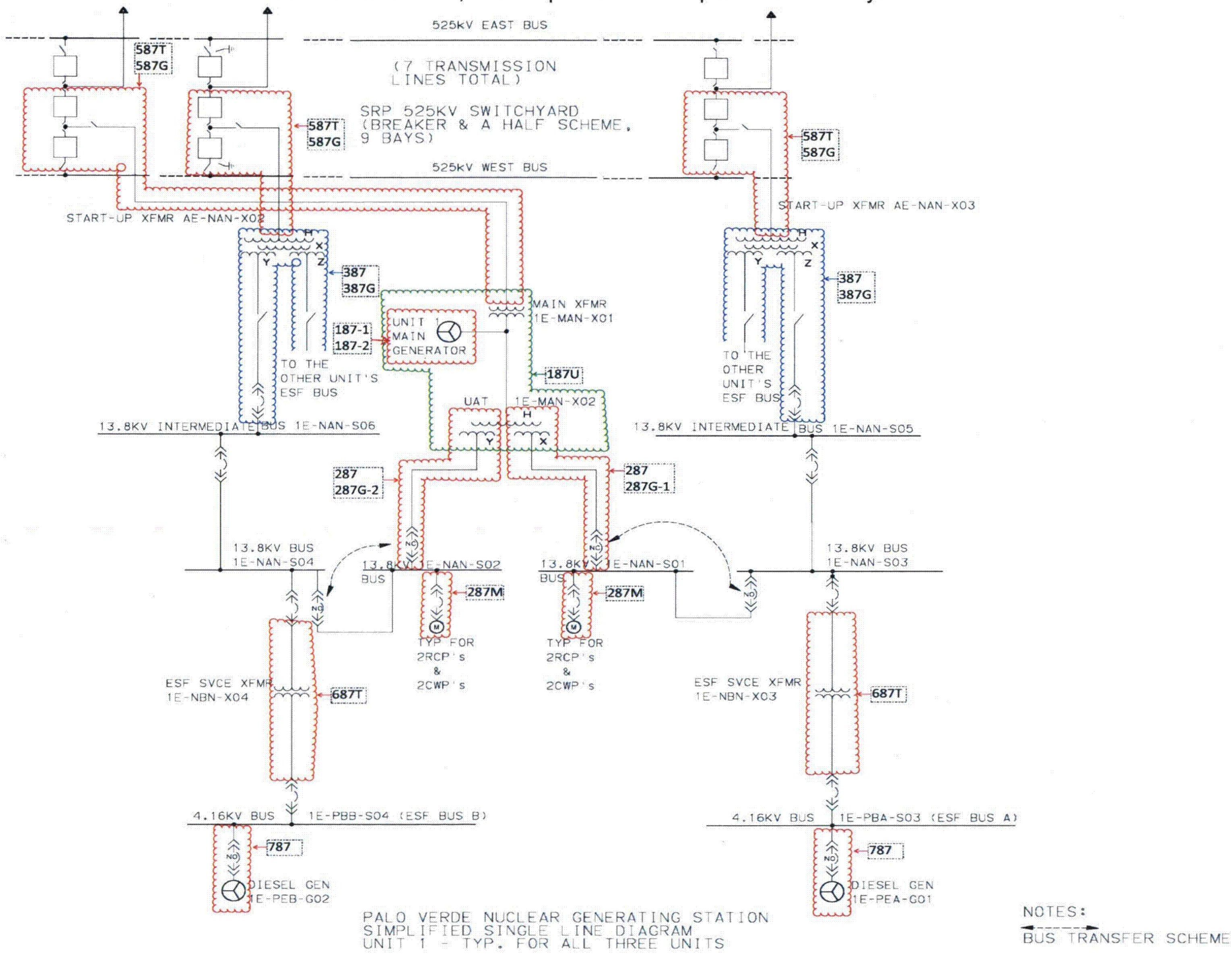
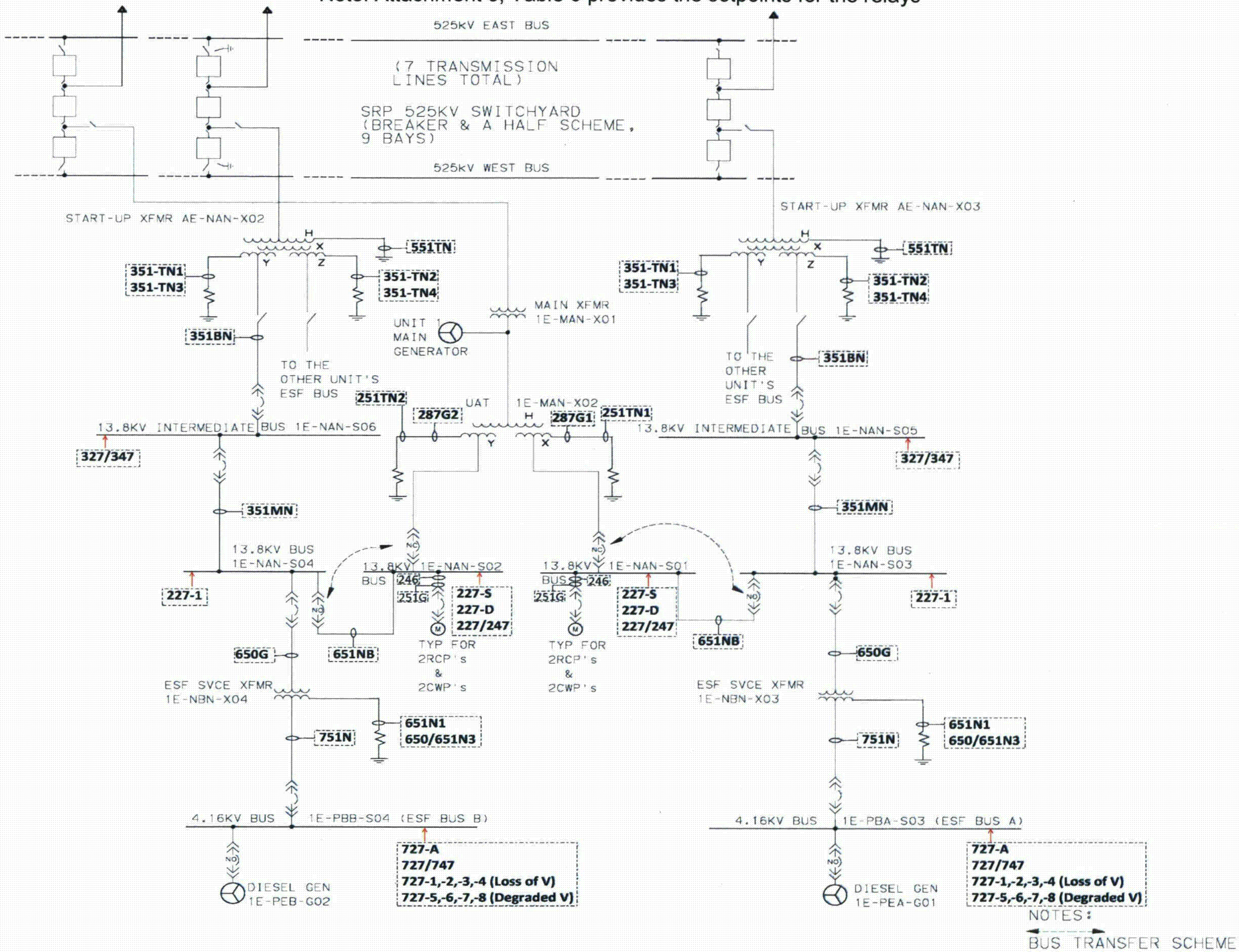


FIGURE 3 – PVNGS Protective Relaying (Undervoltage, Negative Sequence Voltage, Neutral Overcurrent Relays)

Note: Attachment 3, Table 6 provides the setpoints for the relays



Attachment 3 - Tables

Table 1 - ESF Buses Continuously Powered From Preferred Offsite Power Sources

Description of ESF Bus Power Source	ESF Bus Name (normal operating condition).	Original licensing basis configuration (Y/N)
525 kV Offsite Power through Start-Up Transformer AE-NAN-X03 Z-winding (Unit 1 Circuit (a))	Unit 1 – 4.16 kV Bus E-PBA-S03	Y
525 kV Offsite Power through Start-Up Transformer AE-NAN-X02 Y-winding (Unit 1 Circuit (b))	Unit 1 – 4.16 kV Bus E-PBB-S04	Y
525 kV Offsite Power through Start-Up Transformer AE-NAN-X01 Z-winding (Unit 2 Circuit (a))	Unit 2 – 4.16 kV Bus E-PBA-S03	Y
525 kV Offsite Power through Start-Up Transformer AE-NAN-X03 Y-winding (Unit 2 Circuit (b))	Unit 2 – 4.16 kV Bus E-PBB-S04	Y
525 kV Offsite Power through Start-Up Transformer AE-NAN-X02 Z-winding (Unit 3 Circuit (a))	Unit 3 – 4.16 kV Bus E-PBA-S03	Y
525 kV Offsite Power through Start-Up Transformer AE-NAN-X01 Y-winding (Unit 3 Circuit (b))	Unit 3 – 4.16 kV Bus E-PBB-S04	Y

Table 2 – ESF Bus Energized Major Loads During Normal Operation

ESF Bus	Load	Load Rating (KVA)	Voltage Level (V)
EPBAS03 (ESF Train A)	Class 1E Load Center 31: Charging pump, battery charger, and other associated 1E Class MCC supplied loads	287	480
EPBAS03 (ESF Train A)	Class 1E Load Center 33: Radiation monitor systems, DG pre-lube pump, DG water jacket heater pump, and other associated 1E Class and non-Class MCC supplied loads	78	480
EPBAS03 (ESF Train A)	Class 1E Load Center 35: Battery charger, main essential lighting panel, and other associated 1E Class and non-Class MCC supplied loads	264	480
EPBBS04 (ESF Train B)	Class 1E Load Center 32: Charging pump, battery charger, and other associated 1E Class MCC supplied loads	296	480
EPBBS04 (ESF Train B)	Class 1E Load Center 34: Radiation monitor systems, DG pre-lube pump, DG water jacket heater pump, and other associated 1E Class and non-Class MCC supplied loads	63	480
EPBBS04 (ESF Train B)	Class 1E Load Center 36: Battery charger, main essential lighting panel, and other associated 1E Class and non-Class MCC supplied loads	301	480

Note: Based on the APS preliminary analysis of the single-phase open circuit condition and high impedance ground fault condition, the worse case for detection of the condition is at minimum load. The major loads presented in Tables 2, 3, and 4 were selected as a reasonable, typical set of minimum normal loads on the ESF buses during plant operating conditions.

Table 3 – ESF Bus Energized Intermittent Major Loads During Normal Operation

ESF Bus	Load Description	Load Rating (KVA)	Voltage Level (V)
EPBAS03 (ESF Train A)	Class 1E Load Center 31: Diesel Generator (DG) fuel oil transfer pump	3	480
EPBAS03 (ESF Train A)	Class 1E Load Center 33: Battery charger (back-up), Spray Pond house exhaust fan, and pressurizer back up heaters	251	480
EPBAS03 (ESF Train A)	Class 1E Load Center 35: Normal chilled water pump, and other associated non-Class motor control center (MCC) supplied loads	63	480
EPBAS03 (ESF Train A)	Normal Chiller	1109	4160
EPBAS03 (ESF Train A)	Essential Spray Pond Pump	544	4160
EPBBS04 (ESF Train B)	Class 1E Load Center 32: DG fuel oil transfer pump, Spray Pond house exhaust fan, and pressurizer back up heaters	178	480
EPBBS04 (ESF Train B)	Class 1E Load Center 34: Battery charger (backup)	74	480
EPBBS04 (ESF Train B)	Class 1E Load Center 36: Charging pump (standby)	93	480
EPBBS04 (ESF Train B)	Essential Spray Pond Pump	546	4160

Table 4 –Energized Major Loads on One ESF Bus (ESF Bus A or ESF Bus B) During Normal Operation

ESF Bus	Load ID	Load Description	Load Rating (KVA)	Voltage Level (V)
EPBAS03 (ESF Train A) or EPBBS04 (ESF Train B)	MHCNA02	Containment Building Control Element Drive Mechanism (CEDM) Normal Air Control Units	442	480
EPBAS03 (ESF Train A) or EPBBS04 (ESF Train B)	MHCNA01	Containment Building Normal Air Control Units	272	480
EPBAS03 (ESF Train A) or EPBBS04 (ESF Train B)	MPCBP01	Fuel Pool Cooling Pump	92	480
EPBAS03 (ESF Train A) or EPBBS04 (ESF Train B)	MHCNA03	Containment Building Reactor Cavity Normal Cooling Fans	98	480
EPBAS03 (ESF Train A) or EPBBS04 (ESF Train B)	MHCNA06	Containment Building Pressurizer Normal Cooling Fans	11	480

Table 5 - Offsite Power Transformers

Transformer	Winding Configuration	MVA Size	Voltage Rating (Primary/Secondary)	Grounding Configuration
Start-Up Transformer AENANX01	Wye-Delta-Wye/Wye with buried tertiary winding	OA/FOA/FOA 84/112/140(primary) 42/56/70(secondaries)	525kV-13.8kV/13.8kV	Primary Solidly Grounded, Secondary Low Resistance Grounded(2000A)
Start-Up Transformer AENANX02	Wye-Delta-Wye/Wye with buried tertiary winding	OA/FOA/FOA 84/112/140(primary) 42/56/70(secondaries)	525kV-13.8kV/13.8kV	Primary Solidly Grounded, Secondary Low Resistance Grounded(2000A)
Start-Up Transformer AENANX03	Wye-Delta-Wye/Wye with buried tertiary winding	OA/FOA/FOA 84/112/140(primary) 42/56/70(secondaries)	525kV-13.8kV/13.8kV	Primary Solidly Grounded, Secondary Low Resistance Grounded(2000A)
ESF Service Transformer ENBNX03 (Typical for all three units)	Delta-Wye	OA/FA 10/12.5	13.8 kV-4.16 kV	Primary Ungrounded, Secondary Low Resistance Grounded(600A)
ESF Service Transformer ENBNX04 (Typical for all three units)	Delta-Wye	OA/FA 10/12.5	13.8 kV-4.16 kV	Primary Ungrounded, Secondary Low Resistance Grounded(600A)

Table 6 - Protective Devices

CTR – Current Transformer Turns Ratio; PTR – Potential Transformer Turns Ratio; MOC – Minimum Operating Current; FLA – Full Load AMPS; LRA – Locked Rotor AMPS; PMAC - (Arizona Public Service Company) Protection, Metering, and Automated Control; RCP - Reactor Coolant Pump; CWP - Circulating Water Pump; MVA - megavolt-amperes; SUT - start-up transformer

The protective devices (relays) in Table 6 are those most likely to detect a single-phase open circuit or high impedance ground fault condition on the offsite power circuit. The relay setpoints, PTRs, and CTRs, are taken from the relay setting sheets and are included as auxiliary information for the basis of the setpoints.

Protection Zone	Protective Device	Setpoint	Basis for Setpoint
ENANS01/ ENANS02 13.8 kV Fast Bus Transfer To ENANS03/ENANS 04	*227-1* *Bus Transfer Blocking and Generator Coast Down*	PTR = 14400/120 TAP = 100V	Relay device detects bus undervoltage (phase A-B) for generator coast down circuit and blocks automatic fast bus transfer. Basis for undervoltage setting is bus transfer transient response study.
ENANS01/ ENANS02 13.8 kV Bus	*227-S1&S2* *Bus Undervoltage Relay (for load shedding)*	PTR = 14400/120 Right Contact Undervoltage: Dropout = 88V Left Contact Over-Voltage: Pickup = 93V	Initiates tripping of RCPs, CWPs and non-class load centers in the event of bus undervoltage (phase B-C for relay S1 and A-B for S2) of a magnitude and duration that could cause loss of operation or damage to load equipment. Relays initiate annunciation and trip 13.8 kV selected breakers. Basis for undervoltage setting is 70-80% of nominal bus voltage, per PMAC criteria.
ENANS01/ ENANS02 13.8 kV Bus	*227/247* *Bus Undervoltage and Negative Sequence Alarm*	PTR = 14400/120 CV Undervoltage Unit: Dropout = 105V Time Dial = 2 Polar Neg Seq Unit: Overvoltage Pickup = 5%	Relay initiates alarm and annunciation in the event of bus undervoltage of a magnitude and duration that could cause loss of operation or damage to load equipment. Relay will also operate in the event of voltage imbalance which could damage load equipment. The pickup setting of the negative sequence (voltage unbalance) element is the minimum available for maximum sensitivity.

Protection Zone	Protective Device	Setpoint	Basis for Setpoint
ENANS01/ ENANS02 13.8 kV Bus	*246* *Phase Current Unbalance Relay*	CTR = 600/5 Min Pickup = 1A Slope = 125% Time Dial = 4	Relay is set to pick-up when one phase current is 25% greater than another. Relay initiates annunciation and trips motor feeder circuit breaker to the affected Reactor Coolant Pump (RCP), to prevent motor overheating damage. Relay pickup and slope settings are not adjustable.
ENANS01/ ENANS02 13.8 kV Bus	*246* *Phase Current Unbalance Relay*	CTR = 300/5 Min Pickup = 1A Slope = 125% Time Dial = 3	Relay is set to pick-up when one phase current is 25% greater than another. Relay initiates annunciation and trips motor feeder circuit breaker to the affected Circulating Water Pump (CWP) to prevent motor overheating damage. Relay pickup and slope setting are not adjustable.
ENANS01/ ENANS02 13.8 kV Bus	*250/251M* *Phase Overcurrent Relay*	CTR = 600/5 Time Unit: MOC = 540A TAP = 4.5 Time Dial = 6 Inst Units A: MOC = 6000A Inst Units B: MOC = 900A	Relay initiate annunciation and trip RCP feeder circuit breakers. The instantaneous unit shall operate in the event of phase short-circuit condition. The time delay unit shall operate in the event of a failure to accelerate to rated speed in the normal starting interval, motor stalled condition, or low-magnitude phase fault conditions. Relay settings are determined by the electrical characteristics of the motor.
ENANS05/ENANS06 Intermediate 13.8 kV Bus	*327/347* *Bus Undervoltage and Negative Sequence Alarm*	PTR = 14400/120 CV Undervoltage Unit: TAP = 105V Polar Negative Sequence Unit: Pickup = 10.4 V	Relay initiates alarm and annunciation. Relay will operate in the event of a bus undervoltage of a magnitude and duration that could cause loss of operation or damage to load equipment. Relay will operate in the event of a voltage imbalance that could damage load equipment. The pickup setting of the negative sequence element is the minimum available for maximum sensitivity.
SUT Normal feed to ENANS05/S06	*351BN* *Bus Feeder Ground Overcurrent Relay*	CTR = 4000/5 MOC = 320A TAP = 0.4 Time Dial = 7	Relays initiate annunciation and trip bus feeder circuit breakers to provide protection against ground faults. Supervised by SUT winding neutral overcurrent fault detector 351TN. Basis for pickup setting is to detect 25% or less of maximum ground fault current, per PMAC criteria.

Protection Zone	Protective Device	Setpoint	Basis for Setpoint
ENANS05/ENANS 06 Intermediate 13.8 kV Bus	*351MN* *Main Feeder Ground Overcurrent Relay* **(UNIT 1 only)**	CTR = 4000/5 MOC = 320A Tap = 0.4 Time Dial = 5	Relays initiate annunciation, and trips and blocks closing of 13.8 kV breaker to NANS03/04, to provide protection against ground faults. Basis for pickup setting is to detect 25% or less of maximum ground fault current, per PMAC criteria.
ENANS05/ENANS 06 Intermediate 13.8 kV Bus	*351TN1&2* *13.8 kV Winding Ground Fault Overcurrent Relay*	CTR = 2000/5 MOC = 320A (pri) TAP = 0.8 Time Dial = 7	Relay permits tripping of 13.8 kV breakers at buses ENANS05/S06 by bus feeder neutral overcurrent relay 351BN. Basis for pickup setting is to detect 25% or less of maximum ground fault current, per PMAC criteria.
ENANS05/ENANS 06 Intermediate 13.8 kV Bus	*351TN3&4* *13.8 kV Winding Ground Fault Overcurrent Backup Relay*	CTR = 800/5 MOC = 320A (pri) TAP = 2 Time Dial = 10	Relay initiates annunciation, trips all 13.8 kV circuit breaks for SUT, and trip 525 kV circuit breakers at the switchyard. Also, trips lockout 386T-3 (trips and blocks close 525 kV breakers). Basis for pickup setting is to detect 25% or less of maximum ground fault current, per PMAC criteria.
SUT to ENANS05/S06	*387* *Transformer Phase Differential Relay*	CTR: 525kV(H) – 300/5 Delta 13.8kV (Y) – 4000/5 Delta 13.8kV (Z) – 4000/5 Delta TAP (H) = 2.9 TAP (Y) = 8.7 TAP(Z) = 8.7 SLOPE = 25%	Relays initiate annunciation, trip all 13.8 kV circuit breaks of SUT at NANS05/S06, trip 525 kV circuit breakers at the switchyard, and trip SUT cooling pumps. Also, trips lockout 386T-1 (trips and blocks close 525 kV breakers). Basis for setting is the SUT voltages, MVA ratings, CT ratios, and available taps on the relay. Although this relay is for phase protection, it also detects ground faults.
SUT to ENANS05/S06	*387G-1* *525 kV Ground Differential Relay*	Winding "Y" 13.8kV Line: 4000/5 Y-paralleled and input to Aux CT:	This is a ground directional over-current relay, current polarized, used as a ground differential relay. The relay is Westinghouse type CWC, which is a double disk-type product relay. The polarizing current is from a current transformer in the

Protection Zone	Protective Device	Setpoint	Basis for Setpoint
		4/10 Overall Ratio: 320/1 13.8kV Neutral Winding "Y" 2000/5 Tap Prod. Pickup = 0.25 Upper Pole Tap = 1 Lower Pole Tap = 0.25 TD = 1	secondary side grounded neutral of the SUT, and the operating current is from the current transformers (residual connection) in the 13.8 kV breakers at ENANS05/S06. The basis for setting this relay is to use minimum product tap for maximum sensitivity. Relays initiate annunciation, trips all 13.8 kV circuit breakers of SUT at NANS05/S06, trip 525 kV circuit breakers at the switchyard, and trip SUT cooling pumps.
SUT to ENANS05/S06	*387G-2* *13.8kV Ground Differential Relay*	Winding "Z" 13.8kV Line: 4000/5 Y-paralleled and input to Aux CT: 4/10 Overall Ratio: 320/1 13.8kV Neutral Winding "Z" 2000/5 Tap Prod. Pickup = 0.25 Upper Pole Tap = 1 Lower Pole Tap = 0.25	This is a ground directional over-current relay, current polarized, used as a ground differential relay. The relay is Westinghouse type CWC, which is a double disk-type product relay. The polarizing current is from a current transformer in the secondary side grounded neutral of the SUT, and the operating current is from the current transformers (residual connection) in the 13.8 kV breakers at ENANS05/S06. The basis for setting this relay is to use minimum product tap for maximum sensitivity. Relays initiate annunciation, trips all 13.8 kV circuit breakers of SUT at NANS05/S06, trip 525 kV circuit breakers at the switchyard, and trip SUT cooling pumps.
Offsite Power, 525 kV Switch Yard	*551TN* *525kV Neutral Overcurrent*	CTR = 1200/5 MOC = 120A (pri) Tap = 0.5A	This is a disk-type over-current relay sensing the primary neutral current in the SUT. The relay is GE type IFC. The basis for setting this relay is to use minimum tap for maximum

Protection Zone	Protective Device	Setpoint	Basis for Setpoint
	relay		sensitivity to neutral currents. It is mainly a backup relay to the differential relays 587T and 587G. Relay initiates annunciation, trips all 13.8 kV circuit breaks of SUT at NANS05 and NANS06, trips 525 kV circuit breakers at the switchyard, and trips SUT cooling pumps. Trips in 1.3s for phase ground fault on 525 kV side only. Trips lockout 386 T-3, which trips and blocks close 525 kV breakers.
Offsite Power, 525 kV Switch Yard	*587G* *525kV Neutral Differential Relay*	Current transformers: 525kV Line 3000/5 Y-Parallel and input to Aux. CT: 5/15 Overall Ratio: 200/1 525kV Neutral Winding 1200/5 Tap Product Pickup = 0.25A Upper Pole Tap = 1 Lower Pole Tap = 0.25	This is a ground directional over-current relay, current polarized, used as a ground differential relay. Its zone of protection is from the SUT primary neutral to the switchyard breakers. The relay is Westinghouse type CWC, which is a double disk-type product relay. The polarizing current is from a current transformer in the primary side grounded neutral of the SUT, and the operating current is from the current transformers (residual connection) in the switchyard. The basis for setting this relay is to use minimum product tap for maximum sensitivity. Relays initiate annunciation, trips all 13.8 kV circuit breakers of SUT at NANS05/S06, trip 525 kV circuit breakers at the switchyard, and trip SUT cooling pumps. Also trips lockout 386 T-1, which trips and blocks close 525 kV breakers.
Offsite Power, 525 kV Switch Yard	*587T* *525kV Lead Differential Relay*	CTR = 3000/5 87L = 400V 87H = 9A	This is a phase differential relay, whose zone of protection is from the SUT primary to the switchyard breakers. The relay is GE type PVD, which is a high-impedance differential relay. The relay is, in effect, a special-purpose over-voltage relay, using current transformer inputs. The basis for setting this relay is security from tripping on faults outside the zone of protection and to avoid excessive voltage on the relay's Thyristor stack.

Protection Zone	Protective Device	Setpoint	Basis for Setpoint
			The manufacturer provides setting instructions based on the available fault current, current transformer ratio and excitation characteristics, and the resistance of the secondary conductors. Although this relay is for phase protection, it also detects ground faults. Relay initiate annunciation, trips all 13.8 kV circuit breakers of SUT at NANS05/S06, and trips and blocks closing of 525 kV breakers.
NANS03 Feed to ESF Transformer NBNX03	*650G* *Ground Overcurrent Relay*	CTR = 50/5 MOC = 5 TAP = 0.5	Relays detect ground fault conditions, which initiate annunciation and trip 13.8 kV source breakers at ENANS03 and class 1E 4.16 kV breakers to ESF buses (EPBAS03). Basis for pickup setting is to detect 25% or less of maximum ground fault current, per PMAC criteria.
NANS04 Feed to ESF Transformer NBNX04	*650G* *Ground Overcurrent Relay*	CTR = 50/5 MOC = 20 TAP = 2	Relays detect ground fault conditions, which initiate annunciation and trip 13.8 kV source breakers at ENANS04 and class 1E 4.16 kV breakers to ESF buses (EPBBS04). Basis for pickup setting is to detect 25% or less of maximum ground fault current, per PMAC criteria.
NANS03/S04 Feed to ESF Transformer NBNX03/04	*651N1* *Transformer Neutral Overcurrent Relay*	CTR = 200/5 MOC = 120A	Relay initiate annunciation and trips ESF service transformer at 13.8 kV and 4.16 kv breakers (NANS03 and PBA03/PBB04 bus). Basis for pickup setting is to detect 25% or less of maximum ground fault current, per PMAC criteria.
NANS03/S04 Feed to ESF Transformer NBNX03/04	*650/651N3* *Transformer Ground Detection*	CTR = 200/5 MOC = 120A Inst = 120A	Relays supervise tripping of 751N relays bus feeder neutral overcurrent relays on the low side of ESF transformer and located at ESF Buses. Basis for pickup setting is to detect 25% or less of maximum ground fault current, per PMAC criteria.
Bus tie ENANS01/S02 TO ENANS03/S04	*651NB – Bus Tie Ground Overcurrent Relay*	CTR = 4000/5 MOC = 320A	Relay is to pickup at setting values and trips the 13.8 kV bus tie breaker. Also actuates 686B lock-out relay. Basis for pickup setting is to detect 25% or less of maximum ground fault current, per PMAC criteria.
NANS03 Feed to ESF Transformer NBNX03	*687T* *Transformer Differential*	CTR = 800/5 Y (13.8 kV) 1500/5 Delta	Relays initiate annunciation, trip transformer feed at NANS03 and bus circuit breakers for ESF Buses PBAS03 Basis for setting is the SUT voltages, MVA ratings, CT ratios, and

Protection Zone	Protective Device	Setpoint	Basis for Setpoint
		(4.16 kV) 13.8 kV Tap = 2.9 4.16 kV: Tap = 8.7 Slope = 25%	available taps on the relay. Although this relay is for phase protection, it also detects ground faults.
NANS04 Feed to ESF Transformer NBNX04	*687T* *Transformer Differential*	CTR = 600/5 Y(13.8 kV) 1500/5 Delta (4.16 kV) 13.8 kV Tap = 3.8 4.16 kV: Tap = 8.7 Slope = 25%	Relays initiate annunciation, trip transformer feed at NANS04 and bus circuit breakers for ESF Buses PBBS04 Basis for setting is the SUT voltages, MVA ratings, CT ratios, and available taps on the relay. Although this relay is for phase protection, it also detects ground faults.
4.16 kV ESF Bus EPBAS03/EPBBS04	*727/747* *Bus Undervoltage & Negative Sequence Relay Alarm*	PTR = 4200/120 UV CV Unit: Tap = 105V Time Dial = 2 Polar Unit: 5% Negative Sequence L-N Volts Pickup = 5% = 10.4V	Relays initiate alarm and annunciation in the event of bus undervoltage of a magnitude and duration that could cause loss of operation or damage to load equipment. It shall also operate in the event of a phase-to-phase voltage imbalance that could damage load equipment. The pickup setting of the negative sequence element is the minimum available for maximum sensitivity.
4.16 kV ESF Bus EPBAS03/PBBS04	*727-A* *Bus Undervoltage Alarm*	PTR = 4200/120 Pickup = 107.56V Dropout = 106.97V Dropout Delay = 10s	Relay initiates annunciation/alarm in the control room at a sustained, degraded 90% nominal voltage after 10 seconds. The relay is connected across phases B-C. The basis for setting this alarm relay is the same as the degraded voltage relays 727-5, 6, 7, 8, except the time delay is shorter.
4.16 kV ESF Bus EPBAS03/EPBBS04	*727-1,2,3,4* *Bus*	PTR =4200/120 Tap = 93	These relays detect the loss of preferred offsite voltage to ESF bus. These relays initiate on two out of four logic to shed the bus and start the diesel generators. The relays are connected across phases, A-B, B-

Protection Zone	Protective Device	Setpoint	Basis for Setpoint
	Undervoltage (Loss of Voltage) Relays	Time Dial = 3.6 Time = 2.2s @ 0V	C, A-C, and A-B. The basis for setting these relays is analysis of the voltage-time profile of a loss of grid. The setpoints for these relays are controlled by PVNGS Technical Specifications. More information on the basis for their setpoints is in the Technical Specification Bases.
4.16 kV ESF Bus EPBAS03/EPBBS04	*727-5,6,7,8* *Bus Undervoltage (Degraded Voltage) Relays*	PTR =4200/120 Pickup = 107.56V Dropout = 106.97 Dropout Delay = 31.8s	These relays detect a sustained, degraded preferred offsite voltage to ESF bus at 90% of nominal voltage. These relays initiate on two out of four logic to shed the bus and start the diesel generators. The relays are connected across phases, A-B, B-C, A-C, and A-B. The setpoints for these relays are controlled by PVNGS Technical Specifications. More information on the basis for their setpoints is in the Technical Specification Bases.
4.16 kV ESF Bus EPBAS03/EPBBS04	*751N* *Neutral Overcurrent Relay*	CTR = 1200/5 TAP = 0.5 Time Dial = 3	Relay initiates annunciation, and trips the breaker and blocks closing of all bus supply breakers. Relays supervised by ESF transformer neutral overcurrent relays (650/651N-ENBNX03/X04). Basis for pickup setting is to detect 25% or less of maximum ground fault current, per PMAC criteria.

Attachment 4 - Photograph

Photograph: PVNGS Startup Transfomer in the Switchyard