CATEGORY 1

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SUBJECT: LER 93-011-02:on 930114,completed addl preliminary analysis indicating possibility of having substandard voltages on Class 1E 480V power sys.Caused by lack of design control. Undervoltage relay replaced.W/960617 ltr

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TITLE: 50.73/50.9 Licensee Event Report (LER), Incident Rpt, etc.

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Arizona Public Service Company
PALO VERDE NUCLEAR GENERATING STATION
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192-00973-JML/BAG/KR
June 17, 1996

JAMES M LEVINE
VICE PRESIDENT
NUCLEAR PRODUCTION

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
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Washington, D.C. 20555

Dear Sirs:

Subject: **Palo Verde Nuclear Generating Station (PVNGS)**
Units 1, 2, and 3
Docket Nos. STN 50-528, 50-529, 50-530
License Nos. NPF-41, NPF-51, NPF-74
Licensee Event Report 93-011-02

Attached please find Supplement 2 to Licensee Event Report (LER) 93-011 prepared and submitted pursuant to 10CFR50.73. This supplement reports that two additional degraded switchyard voltage scenarios have been identified related to possible double sequencing of safety-related equipment.

In accordance with 10CFR50.73(d), a copy of this LER is being forwarded to the Regional Administrator, NRC Region IV. If you have any questions, please contact Burton A. Grabo, Section Leader, Nuclear Regulatory Affairs, at (602) 393-6492.

Sincerely,

James M. Levine

JML/BAG/KR/pv

Attachment

cc: L. J. Callan (all with attachment)
K. E. Perkins
K. E. Johnston
INPO Records Center

IE22 1/1

LICENSEE EVENT REPORT (LER)

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
Palo Verde Unit 1	0 5 0 0 0 5 2 8	1 OF 1 7

TITLE (4)
Potential Safety-Related Equipment Problems Due to Degraded Grid Voltage

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAMES	DOCKET NUMBERS
									Palo Verde Unit 2	0 5 0 0 0 5 2 9
0 1	1 4	9 3	9 3	- 0 1 1 -	0 2	0 6	1 7	9 6	Palo Verde Unit 3	0 5 0 0 0 5 3 0

OPERATING MODE (9): 1

POWER LEVEL (10): 1 0 0

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more of the following) (11)

[ ]	20.402(b)	[ ]	20.405(c)	[ ]	50.73(a)(2)(iv)	[ ]	73.71(b)
[ ]	20.405(a)(1)(i)	[ ]	50.36(c)(1)	[X]	50.73(a)(2)(v)	[ ]	73.71(c)
[ ]	20.405(a)(1)(ii)	[ ]	50.36(c)(2)	[ ]	50.73(a)(2)(vii)	[ ]	OTHER (Specify in Abstract below and in Text, NRC Form 366A)
[ ]	20.405(a)(1)(iii)	[ ]	50.73(a)(2)(i)	[ ]	50.73(a)(2)(viii)(A)		
[ ]	20.405(a)(1)(iv)	[X]	50.73(a)(2)(ii)	[ ]	50.73(a)(2)(viii)(B)		
[ ]	20.405(a)(1)(v)	[ ]	50.73(a)(2)(iii)	[ ]	50.73(a)(2)(x)		

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER (AREA CODE)
Burton A. Grabo, Section Leader, Nuclear Regulatory Affairs	602 393-6492

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS

SUPPLEMENTAL REPORT EXPECTED (14)

[ ] YES (If yes, complete EXPECTED SUBMISSION DATE) [X] NO

EXPECTED SUBMISSION DATE (15): MONTH | DAY | YEAR

ABSTRACT (Limit to 1400 spaces, i.e., approximately fifteen single-space typewritten lines) (16)

On December 19, 1992, APS Engineering personnel identified that preliminary auxiliary power system calculations indicated that with the switchyard voltage at its design basis minimum of 95 percent and with the startup transformer (SUT) secondary winding fully loaded, downstream voltages could be less than the Class 1E 4.16 kV bus undervoltage (UV) relay setpoints. This scenario would result in shedding of Class 1E 4.16 kV loads from preferred power and automatically starting and sequentially loading the emergency diesel generators (EDG). As an immediate corrective action, switchyard voltages were administratively maintained between 100 to 102.5 percent. Additional preliminary analysis completed on January 14, 1993 indicated that it may be possible to have substandard voltages on the Class 1E 480V power system, with the switchyard voltage between 95 and 100 percent and with the SUT secondary winding fully loaded, without actuation of the Class 1E 4.16 kV bus UV relays nor load shed and EDG start. On December 23, 1993, a postulated UV scenario was documented in which Class 1E equipment could be subjected to double sequencing. That is, following a unit trip and a safety injection actuation signal, with the switchyard voltage less than 99.5 percent, the SUT secondary windings fully loaded, and a successful fast bus transfer, the UV relays would drop out during load sequencing on offsite power and may not reset, resulting in a load shed, the closing of the EDG breakers, and resequencing of loads on to the EDG.

NOTE: Scenarios 3 and 4 were added to supplement 2 to LER 528/93-011.

TEXT

1. EVENT CLASSIFICATION:

LER 528/529/530/93-011 is being submitted to report a condition that alone could have prevented the fulfillment of the safety function of a system that is needed to: (A) shut down the reactor and maintain it in a safe shutdown condition; (B) remove residual heat; (C) control the release of radioactive material; and (D) mitigate the consequences of an accident, as specified in 10 CFR 50.73(a)(2)(v).

Specifically, the current Updated Final Safety Analysis Report (UFSAR) 6.3.3.2.1.2 language with respect to loss of coolant accident (LOCA) analyses states that the actual time delay for safety injection (BP/BQ) flow from the time the safety injection actuation signal (SIAS) (JE) setpoint is reached until pump flow is delivered to the reactor coolant system (RCS) (AB) will not exceed 29 seconds following a SIAS. UFSAR 15.1.5.3.C (Large Steam Line Break during Full Power Operation with Concurrent Loss of Offsite Power) states that within 30 seconds of a SIAS, the operable high pressure safety injection (HPSI) pump is loaded on the emergency diesel generator (EDG) (EK) and reaches full speed, and the HPSI valves are fully open and the operable HPSI delivers full flow. The double sequencing scenario (discussed in the EVENT DESCRIPTION Section entitled SCENARIO 2) would cause an interrupt in the HPSI flow when the loadshed occurred due to the undervoltage relays dropping out and not resetting, resulting in a time delay greater than 30 seconds.

In addition, contrary to the conclusion stated in the PVNGS Safety Evaluation Report (SER) (NUREG-0857), UFSAR 3.1.13, and the BASES to Technical Specification (TS) 3.8.1, PVNGS is currently unable to meet the requirements of General Design Criterion (GDC)-17 at lower switchyard voltages. The double sequencing scenario would occur following a reactor trip and a SIAS which results in 1) the loss of power generation by the unit, 2) a fast bus transfer (FBT) of non-Class 1E loads to the startup transformers, 3) the sequencing engineered safety feature (ESF) (JE) loads on preferred offsite power, 4) a load shed due to degraded voltage relay actuation, and 5) the loading of ESF loads on the EDG, not as a result of an actual sustained degraded grid voltage. This condition occurs within the lower ranges of the expected grid voltages described in UFSAR section 8.3.1.1.3. This condition would cause the abandonment of preferred power to standby power (EDG) even with acceptable voltages on the grid.

This LER is also being submitted to report a condition that resulted in the nuclear power plant being in a condition that was outside of the design basis of the plant, as specified in 10 CFR 50.73(a)(2)(ii).

Specifically, safety analyses calculations do not explicitly incorporate postulated ESF time delays associated with the full initiation of required ESF system(s) which may occur during a double sequencing

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scenario. For example, UFSAR 15.1.5.3 shows for steam line (SB) break scenarios that HPSI pumps reach full speed (safety injection flow begins) 30 seconds after a SIAS is generated. The time delay associated with double sequencing during a steam line break would exceed the assumed 30 second time delay.

Also, UFSAR 6.3.3.2.1.2 indicates for a large break LOCA that the actual time delay (for safety injection pump flow) will not exceed 29 seconds following a SIAS. The double sequence scenario would cause an interruption in the HPSI flow when loadshed occurred due to the undervoltage relays dropping out and not resetting. The resulting time delay for providing safety injection pump flow would therefore exceed the 29 seconds specified in the UFSAR. In addition, the UFSAR LOCA analyses assume a loss of offsite power for safety injection pumps (except containment spray pumps) and therefore is not susceptible to the double sequencing scenario. However, this analyses does not necessarily bound a LOCA in a double sequence scenario.

Contrary to the conclusion stated in the SER, UFSAR 3.1.13, and the bases to TS 3.8.1, PVNGS is currently unable to meet the requirements of GDC-17 at lower switchyard voltages. Double sequencing presents a more severe failure than that used in UFSAR Chapter 15 as the limiting event such that a failure of a different type has been introduced and it can no longer be shown to be able to withstand the effects of a single failure.

2. EVENT DESCRIPTION:

SCENARIO 1:

At approximately 1300 MST on December 19, 1992, Palo Verde Units 1, 2, and 3 were in Mode 1 (POWER OPERATION), operating at approximately 100 percent power when, during the Electrical Design Basis Reconstitution effort, APS Engineering personnel (utility, non-licensed) identified that preliminary auxiliary power system calculations indicated that with the switchyard (FK) voltage at its design basis minimum of 95 percent of 525 kV and with the startup transformer (EA) (XFMER) secondary winding fully loaded at its rated capacity of 70 MVA, Class 1E 4.16 kV bus (EB) voltages could be less than the Class 1E undervoltage relay setpoints. This scenario would result in shedding of Class 1E 4.16 kV loads from preferred power and automatically starting and sequentially loading the EDGs [NOTE: The Palo Verde Electrical Distribution System (EDS) is described in Section 8. ADDITIONAL INFORMATION].

Per the UFSAR 8.3.1.1.3.13 and the SER and its supplements (SER Section 8.4.7, Adequacy of Station Electric Distribution System Voltages), the PVNGS EDS design provides for two redundant and independent emergency buses (Class 1E 4.16 kV), and each bus has the following two levels of

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undervoltage protection: (1) loss of power (LOP) and (2) degraded grid voltage. Selection of undervoltage setpoints and time delays are determined from an analysis of the voltage requirements of all Class 1E loads at all onsite system distribution levels. The scheme for the first level of protection (i.e., LOP) consists of four induction disc undervoltage relays for each of the two Class 1E 4.16 kV buses for each unit. The induction disc undervoltage relays have inverse time characteristics. The time delay varies from 2.2 seconds at 0 percent voltage to 11.4 second at 78 percent voltage. For each Class 1E 4.16 kV bus, the four induction disc undervoltage relays will initiate a loss-of-voltage signal using two-out-of-four logic. This protection alone does not protect the plant loads from damaging, sustained low voltages above this setpoint. The second level of undervoltage protection (i.e., degraded grid voltage) is provided by instantaneous undervoltage definite-time relays connected in parallel with each of the induction disc undervoltage relays. The instantaneous undervoltage relays are set at 90 percent of the design voltage with a maximum time delay of 35 seconds to avoid spurious trips due to short duration transients, such as those occurring when starting large motors. The instantaneous undervoltage relays will also initiate a trip signal using two-out-of-four logic. The objective is to ensure that a degraded voltage condition will not adversely affect the Class 1E equipment or prevent Class 1E equipment from performing their safety function (e.g., starting and running) in response to a design basis event.

In addition, the SER provided for the Class 1E buses to be optimized for the full load at the minimum expected switchyard voltage and minimum load at the maximum expected switchyard conditions by the adjustment of the voltage tap settings on the transformers (TTC). The EDS was analyzed to determine optimum safety-related bus voltages when operating from the grid through the startup transformers. The analysis considered variations in switchyard voltages along with maximum and minimum expected plant load on the 4.16 kV and the 480 V power systems to ensure satisfactory voltage at all Class 1E loads. The results of these analyses demonstrated that all Class 1E loads were capable of being started and continuously operated over the expected grid voltage range. In addition, a criterion for setting of the Class 1E load center transformer taps was accepted. A precedent was set to adjust the taps until the voltage to Class 1E 480 V electrical equipment fell within a specified range.

In response to the Electrical Distribution System Functional Inspection (EDSFI) (December 1990), an Electrical Design Basis Reconstitution effort was undertaken to upgrade and reverify the voltage regulation calculations. Preliminary auxiliary power system calculations performed by APS Engineering personnel indicated that with the switchyard voltage at its design basis minimum of 95 percent of 525 kV (UFSAR 8.3.1.1.3) and with the startup transformer secondary winding fully loaded [i.e., a

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main turbine (TA) trip with a successful fast bus transfer or after the manual transfer of house loads to the startup transformer], the startup transformer secondary output voltages may be less than 90 percent of 13.8 kV. In addition, cable and transformer impedances downstream of the startup transformer would further reduce available bus voltage, resulting in downstream voltages that could be less than the Class 1E 4.16 kV bus undervoltage relay setpoints. This scenario would result in shedding of Class 1E 4.16 kV loads from preferred power and automatically starting and sequentially loading the EDGs due to the Class 1E 4.16 kV undervoltage relay setting overlapping the lower portion of expected voltages at the Class 1E 4.16 kV power system.

An investigation of this condition was initiated in accordance with the APS Incident Investigation Program to develop recommendations for interim corrective actions and final resolution to ensure that plant vulnerability to these scenarios was minimized. As an immediate corrective action, switchyard voltages were administratively maintained between 100 to 102.5 percent. No determinations had been made that any components would fail to perform their safety function(s) at switchyard voltages below 100 percent. However, there existed some probability that components could fail due to low voltage.

On January 14, 1993, Palo Verde Units 1, 2, and 3 were in Mode 1, operating at approximately 100 percent power when additional preliminary analysis indicated that it may be possible to have sustained, substandard voltages on the Class 1E 480 V power system (ED). With switchyard voltage and/or startup transformer loading less severe than that postulated previously, the Class 1E 4.16 kV bus undervoltage relays may not actuate even though sustained, substandard voltages might occur at the terminals of Class 1E loads. This scenario would result in the safety-related equipment powered from the Class 1E 480 V buses to be subject to operating below the voltage specified for minimum continuous operation.

The scenario for the potential deficiency on the Class 1E 480 V power system requires two specific conditions to be in effect concurrently. The first condition is that the switchyard voltage must be below its nominal value of 525 kV. The second condition is that the startup transformer secondary winding must be loaded at or near its rated capacity of 70 MVA. This would be expected to occur during a main generator/turbine trip with a successful fast bus transfer or a manual transfer of house loads to the startup transformer. Under these conditions, the startup transformer secondary output would be providing a substandard voltage to the Class 1E 4.16 kV power system. A projection of the required voltage for Class 1E loads at the 4.16 kV bus shows that the expected, delivered voltage to some equipment would fall within the tolerance of the relay setting, creating the potential for unprotected equipment.

TEXT

Operation of the ESF-actuated equipment only slightly below its voltage rating would not be expected to prevent all ESF-actuated equipment from performing their intended safety function(s). In addition, Control Room personnel could mitigate the consequences of the undervoltage condition by starting and loading the EDG in emergency mode, manually closing the breaker if the EDG had already started in response to an ESFAS signal, or taking other appropriate action in response to Control Room annunciation.

A Voltage Regulation Assessment which compared original, interim, and present design calculations was completed in October 1993.

SCENARIO 2:

On December 23, 1993, Palo Verde Units 1 and 2 were in Mode 1, operating at approximately 85 percent power and Unit 3 was in Mode 3 (HOT STANDBY) with the reactor coolant system (RCS) temperature at approximately 450 degrees Fahrenheit and RCS pressure at approximately 900 psia when an additional postulated undervoltage scenario was documented in which Class 1E equipment could be subjected to double sequencing. The summary stated that this could occur during ESF sequencing, with offsite power available, and a successful fast bus transfer if the Class 1E 4.16 kV bus voltage dipped below the undervoltage relays setpoint during sequencing on preferred offsite power and the voltage did not restore to a value which would cause the relays to reset after completion of sequencing. The relays would time out which would initiate a load shedding from offsite power and resequencing onto the EDG. In this postulated scenario, the equipment motors could be subjected to two starting cycles in rapid succession, the first of which could be at substandard voltages. The scenario was tagged for further assessment.

On April 7, 1994, following further voltage regulation calculation reverification efforts, APS Engineering personnel requested that an evaluation conducted in accordance with the APS Incident Investigation Program be performed to document and address the concerns associated with the degraded voltage scenario that could result in the possible double sequencing of safety-related equipment. That is, following a fast bus transfer and an ESF sequence (e.g., a LOCA), combined with the switchyard being at or near its anticipated minimum voltage, the following sequence of events could potentially occur:

- start sequencing ESF loads onto the preferred offsite power,
- load shed the ESF loads from preferred power due to the Class 1E 4.16 kV undervoltage relays dropping out during sequencing onto offsite power and failing to reset during the time delay period (less than 90 percent for a maximum of 35 seconds),
- isolate the Class 1E 4.16 kV bus from the offsite source,

TEXT

- close the EDG breaker, and
- resequence the ESF loads on to the EDG.

The scenario for double sequencing requires two conditions to be in effect concurrently. The first condition is that the unit is confronted with a fast bus transfer and an ESF sequence from events such as a LOCA. The second condition is that the switchyard voltage must be less than 99.5 percent. In this scenario, the undervoltage relays would drop out during load sequencing, and there exists the possibility that they would not reset. The scenario will not occur if the switchyard voltages remain between 100 and 102 percent, as currently administratively maintained. An investigation of this condition was initiated in accordance with the APS Incident Investigation Program to develop recommendations for interim corrective actions and final resolution to ensure that plant vulnerability to these scenarios was minimized.

SCENARIO 3:

New TS 3.8.1.1 ACTIONs f and g (operability may be restored to one train of A.C. sources, within one hour by blocking the FBT in that train; the other train remains vulnerable to double sequencing and is considered inoperable) were approved on November 28, 1995 (discussed in CORRECTIVE ACTIONS TO PREVENT RECURRENCE Section).

For the purposes of evaluating the effect of compensatory actions on plant safety, the unblocked train was conservatively assumed to be completely inoperable, and incapable of completing its intended safety function. However, no explicit action was taken to preclude the unblocked train of safety-related equipment from experiencing double sequencing and spurious actuation (i.e., the train was not rendered incapable of operation and there may exist some adverse system interaction).

Since analysis does not exist to demonstrate that the effects of double sequencing in the remaining inoperable train are within the design bases, APS Engineering personnel performed an evaluation to consider the potential detrimental effects that may occur from a single train of safety-related equipment experiencing double sequencing. Each safety system was evaluated individually to determine the relevant failure modes that could be present in a double sequencing scenario, and safety functions were evaluated for potential system interaction effects.

As a result of the evaluation, a scenario was postulated which could potentially result in uncontrolled auxiliary feedwater (AFW) flow to the ruptured and/or intact steam generator during secondary system line breaks. For example, following a degraded switchyard voltage conditions, Train A FBT has been blocked within the first hour, and Train B remains vulnerable to double sequencing and considered

TEXT

inoperable. APS Engineering personnel have identified that, if a steam line break or feedwater line break were to occur under these circumstances, the degraded voltage condition could result in the failure of both of Train B's AFW discharge motor operated valves to close, affecting the ability to isolate the feedwater to the faulted SG, as well as overfilling the intact generator, which may result in a waterhammer condition which could damage steam lines associated with the intact steam generator. The key feature of the scenario is the initiation of AFW to steam generators with an uncontrolled flow to either the intact or the ruptured steam generator. Since the discovery of this scenario, procedures have been revised to require actions (blocking both trains of FBT upon discovery or notification of the degraded grid voltage condition) to prevent double sequencing in both trains within the first hour.

SCENARIO 4:

An additional discrepancy which could result in double sequencing has been discovered by APS Engineering personnel. The scenario involves taking one of the startup transformers out of service and connecting its loads to the other two startup transformers. Whenever two units share a secondary winding from a startup transformer, two major concerns involving the availability of power to support safety-related plant equipment exist. First, there is a potential to significantly affect voltage to all equipment fed from the winding. That is, voltage levels could drop below design ratings, possibly resulting in equipment failure, or inadequate voltage to the Class 1E equipment in the event of an accident. Second, there is a potential to overload the winding and exceed the winding's maximum continuous rating. The thermal limit of each secondary winding is 70 MVA or 2929 amps.

Per an approved procedure, when one of the startup transformers (e.g., NAN-X01) is taken out of service, its loads are connected to the other two startup transformers (e.g., NAN-X02 and NAN-X03). The procedure provides for an administrative limit of transformer loading up to the thermal limit of each secondary winding (i.e., 70 MVA or 2929 amps) by either [1] blocking FBT of the nonClass 1E "house" loads in one unit, or [2] monitoring the load to the startup transformer winding to remain less than 70 MVA. With Option 2 (monitoring), the possibility exists that double sequencing could occur in the event of ESF sequencing in one unit. If the accident loading on a startup transformer secondary winding were 2929 amps, as allowed by the procedure, the switchyard voltage would need to be higher than 525 kV to ensure adequate voltage to safety-related equipment, and to preclude double sequencing from occurring. This configuration could be avoided by blocking FBT in one of the two units connected to the same winding (Option 1).

TEXT

The procedure has since been modified by eliminating Option 2 to ensure that adequate voltage will be maintained and that secondary windings will not be overloaded whenever two units share a secondary winding.

Two immediate concerns associated with double-sequencing are (1) non-compliance with GDC-17 and (2) potential safety-related equipment damage. Contrary to the conclusion stated in the PVNGS SER, PVNGS is unable to meet GDC-17 at lower switchyard voltages. GDC-17 states, in part, that "[p]rovisions shall be included to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit, the loss of power from the transmission network, or the loss of power from the onsite electric power supplies." During the double-sequencing scenario, it is calculated that the Class 1E 4.16 kV undervoltage relays actuate and cause ESF equipment loading to the EDG because of substandard voltages in the onsite system. The substandard voltages are due to tripping of the main generator (i.e., the loss of power generated by the nuclear power unit) which results in a FBT, not due to a true, sustained degraded grid voltage. This configuration causes the abandonment of preferred power by ESF equipment to the standby power source even with acceptable voltages on the grid. In other words, the loss of power by the unit results in the loss of both preferred power circuits.

The evaluation to document and address the concerns associated with the degraded voltage scenario that could result in the possible double sequencing of safety-related equipment was completed on August 25, 1994 and reviewed for reportability. Based on the information provided in the evaluation, the condition was determined not to be reportable and a supplement to the voluntary LER was to be submitted. However, based on a subsequent review of historical documentation, new information was discovered that described how the current configuration would allow a condition such as double sequencing to occur and the evaluation was reopened. In summary, the following events were recreated:

- In March 1982, in a letter to the NRC, FBT blocking was credited as the additional action for undervoltage protection to prevent a "situation similar to the Millstone II undervoltage event" which occurred in July 1976. Subsequently, an ITE 227-B supply transfer blocking relay was installed.
- In March 1983, the justification for the installation of the 227-B blocking relay was requested from Bechtel (BEC). In addition, a request was made to remove the relay and restore the circuit design to its original configuration or to incorporate the function of 227-B into the 227-1 undervoltage relay.
- In May 1983, BEC credited the 227-B relay with compliance to GDC-17. BEC stated that the 227-B relay was added to ensure that

given a reactor and turbine trip (loss of power generated by the unit), the reactor coolant pumps are not connected to the startup transformers (preferred power supply to the ESF buses) should a degraded voltage condition occur. BEC advised that the functions of the 227-1 undervoltage relay could be incorporated into the 227-B blocking relay.

- In July 1983, APS concurred with BEC on how to combine both relay functions. However, the relay was named 227-1 and used for transfer blocking and generator coast down. The tap setting of the relay was set at 95.7 percent to assure that the FBT would not drop the Class 1E 4.16 kV voltage below 90 percent following the sequencing of ESF loads.
- Three years later, in July 1986, the relay setting was cited by Engineering personnel as "too high and [could] cause a unit trip under load rejection conditions." A temporary relay setting of 93.2 percent was approved in order to "operate the plant on the start-up transformers instead of the normal unit auxiliary transformers." No design change documentation was referenced nor justification provided.
- In October 1986, Engineering personnel approved a new relay setting of 90 percent for the 227-1 undervoltage relay. Again, no design change documents or 10 CFR 50.59 safety evaluation have been located to support the change. The relay was referenced as an undervoltage relay indicating that Engineering personnel may have overlooked its primary function as FBT blocking.

The supplement to the evaluation was approved on January 6, 1995 and revealed how the FBT blocking relay setting was changed outside the scope of the PVNGS Configuration Control, Design Control, and Quality Assurance Programs. The evaluation identified that because a 10 CFR 50.59 evaluation was not performed, the relay setting change resulted in the creation of an unreviewed safety question in that it created a malfunction of a different type than any evaluated previously in the UFSAR. In addition, the supplement included a safety analysis review that concluded that the UFSAR does not explicitly incorporate postulated ESF time delays associated with the full initiation of a required ESF system which may occur during a double sequencing scenario (as previously discussed in Section 1, EVENT CLASSIFICATION). For example, UFSAR section 15.1.5.3 shows for steam line break scenarios that HPSI pumps reach full speed (safety injection flow begins) 30 seconds after a SIAS is generated. The double sequencing scenario during a steam line break would cause an interrupt in the HPSI flow when the loadshed occurred due to the undervoltage relays dropping out and not resetting, resulting in a time delay greater 30 seconds. In addition, the UFSAR LOCA analyses assume a loss of offsite power for safety injection pumps (except containment spray pumps) and therefore is not susceptible to the double sequence scenarios. However, this analyses does not necessarily bound a LOCA in a double sequence scenario.

TEXT

At approximately 1000 MST on January 5, 1995, Units 1, 2, and 3 were in Mode 1, operating at approximately 100 percent power when APS Nuclear Regulatory Affairs personnel completed a review of the supplement to the original evaluation for the postulated double sequencing scenario and determined that the event was reportable under 10 CFR 50.73 as described in Section 1, EVENT CLASSIFICATION.

3. ASSESSMENT OF THE SAFETY CONSEQUENCES AND IMPLICATIONS OF THIS EVENT:

On January 15, 1993, a special meeting of the APS Plant Review Board (PRB) was held to discuss the potential undervoltage condition (i.e., supplying substandard voltage to the energized ESF equipment under certain conditions). The PRB determined that with the administrative corrective actions in place, the EDS was operable and capable of performing its intended function, that continued operation of the three units would not involve an unreviewed safety question, and that the corrective actions were sufficient to ensure continued safe operation of the units. A subsequent probabilistic risk assessment confirmed this determination.

In subsequent meetings, the PRB members asked whether any safety-related equipment would be damaged if grid voltage dropped below 100 percent and an accident occurred concurrently. Cognizant APS Engineering personnel stated that no evaluation has been made to determine if any components would fail to perform their safety function as a result of low voltage (e.g., unable to operate under degraded electrical conditions). However, there is some probability that components could fail due to low voltage. Some equipment has never been operated in the worst case conditions that would be outside its rating. Operation of the ESF-actuated equipment only slightly below its voltage rating would not be expected to prevent all ESF-actuated equipment from performing their intended safety function(s). In addition, Control Room personnel could mitigate the consequences of the undervoltage condition by starting and loading the EDG in emergency mode, manually closing the breaker if the EDG had already started in response to an ESFAS signal, or taking other appropriate action in response to Control Room annunciation.

A further meeting with the APS Plant Review Board was held on January 11, 1995 to discuss the additional discovery of double sequencing and its effect on the existing compensatory actions and administrative controls. The PRB concurred with the recommendation to maintain the switchyard voltage between 100 percent and 102 percent. Further, they directed APS Engineering to determine if the control of communication between the APS Energy Control Center and the Palo Verde Unit 1 Control Room could be strengthened. Additionally, they requested APS Engineering to determine if an alarm could be added to the Unit 1 Control Room. Finally, they concurred with the stated action to enter TS LCO 3.8.1.1 ACTION d (two offsite circuits inoperable) upon

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notification by the APS Energy Control Center of switchyard voltage below 100 percent.

As discussed previously, safety analyses calculations do not explicitly incorporate postulated ESF time delays associated with the full initiation of a required ESF system which may occur during a double sequencing scenario. UFSAR section 15.1.5.3 shows for steam line break scenarios that HPSI pumps reach full speed (safety injection flow begins) 30 seconds after a SIAS is generated. The time delay associated with a double sequence during a steam line break would exceed the assumed 30 second time delay. In addition, the UFSAR LOCA analyses assume a loss of offsite power for safety injection pumps (except for containment spray pumps) and therefore is not susceptible to the double sequence scenario. However, this analyses does not necessarily bound a LOCA in a double sequence scenario.

LOCA analyses do not credit safety injection pump flow until the safety injection tanks are empty. UFSAR Table 6.3.3.2-1 indicates that SI pump flow is credited a minimum of 55.8 seconds after the break and a maximum of 224.1 seconds after the break, for those breaks analyzed. Estimates for reestablishing HPSI flow in a double sequencing scenario are approximately 51 to 57 seconds for the LOCA which credits flow at 55.8 seconds. However, details are not provided in this table regarding the time delay the SIAS signal is generated to facilitate a detailed calculation of actual delay time between SIAS signal and full safety injection flow. The event did not result in any challenges to the fission product barriers or result in any releases of radioactive materials. This event did not adversely affect the safe operation of the plant or the health and safety of the public.

4. CAUSE OF THE EVENT:

An independent investigation of this event was initiated in accordance with the APS Incident Investigation Program to develop recommendations for interim corrective actions and final resolution to ensure that plant vulnerability to these scenarios was minimized.

The supplement to the evaluation concluded that the introduction of double sequencing into the current EDS configuration and the degraded voltage problems was attributable to a lack of design control (i.e., not assuring that the design conformed to GDC-17), and ineffective implementation of quality assurance control measures for verifying design adequacy (SALP Cause Code B: Design, Manufacturing, Installation Error). It appears that in 1986, Engineering personnel did not recognize the full purpose of the FBT blocking relay or the basis for the setting when approving the setting changes. In 1990, as a result of a Quality Assurance investigation initiated by APS Engineering,

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deficiencies in the design change process for relay setting changes were identified.

In addition, the original evaluation determined that the potential for safety-related equipment problems due to degraded grid voltage exists because the original EDS design did not fully address the properties of voltage spread. Specifically,

1. Configuration control of transformer tap settings was not auditable. Changes in transformer tap settings must be supported by analysis which indicate acceptable results at minimum switchyard voltage with maximum load and maximum switchyard voltage with minimum loads for the specific tap settings.

2. The minimum loading conditions originally used in analyses were greater than actual plant operating experience has indicated.

3. The maximum loading conditions used in the previous analyses were less than those used in the current analysis. Actual plant operating experience and current industry practice support the current analysis.

4. The anticipated switchyard variance is greater than the system design could accommodate and still provide acceptable EDS voltage spread characteristics.

APS Engineering has created a setpoint change process which now encompasses both relay settings and transformer tap settings. In closing the investigation, APS Engineering credited the ongoing Electrical Design Basis Reconstitution effort to upgrade and verify the voltage regulation calculations and to identify and correct any existing design deficiencies. The conditions identified in this LER were discovered as a result of those continuing actions. No unusual characteristics of the work location (e.g., noise, heat, poor lighting) directly contributed to this event. There were no procedural errors which contributed to this event.

5. STRUCTURES, SYSTEMS, OR COMPONENT INFORMATION:

No structures, systems, or components were inoperable at the start of the event which contributed to this event. No component or system failures were involved. No failures of components with multiple functions were involved. No failures that rendered a train of a safety system inoperable were involved. There were no safety system responses and none were necessary.

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6. CORRECTIVE ACTIONS TO PREVENT RECURRENCE:

Actions to prevent recurrence were developed based upon the results of the investigation and are being tracked to completion under the PVNGS Commitment Action Tracking System.

Since the original submittal of this LER on December 25, 1993, the Voltage Regulation Improvement Project has been tasked with developing the recommendations for final resolution to ensure that plant vulnerability to these scenarios was minimized. In addition, the replacement of the undervoltage relays has been completed in all three units with solid-state relays that can be calibrated to an improved tolerance, and UFSAR 8.3.1.1.3 has been changed to narrow the range of anticipated switchyard voltage (i.e., 98 to 102 percent). Further, tap changes have been made on the EDS transformers to optimize the settings.

These transformer taps are set for optimal minimum and maximum downstream voltages under anticipated loading and switchyard voltage conditions. Since the worst case voltage swing on the Class 1E buses occurs suddenly (i.e., during a unit trip with a fast bus transfer), it is not practical to improve the voltage by further adjustment of the taps to accommodate different operating modes. During full power operation, the voltages on the Class 1E buses are high due to very light loading on the startup transformer and downstream distribution equipment. A unit trip and fast bus transfer causes a sudden voltage dip at the Class 1E buses due to the increase in loading on the startup transformer and downstream distribution equipment. Existing tap settings provide adequate voltages before and after such an event provided that the switchyard voltage before the event is in the range of 99.5 percent to 102 percent of 525 kV. There is no benefit to adjustment of the taps when transitioning to a different operating mode, such as shutdown or startup, since the loading conditions are no more adverse than those which would occur as described above.

These changes, including the administrative controls on switchyard voltages to be maintained between 100 to 102 percent, have minimized the plant vulnerability to these scenarios. The EDS voltage regulation calculation has also been completed. Calculations and modifications are progressing which are expected to allow grid operation between 98 percent and 102 percent upon completion. Grid voltage will remain restricted until corrective actions in the final unit are completed. An additional action to date includes developing a permanent solution such that GDC-17 as interpreted by NUREG 75/087 can be met.

Appropriate TS ACTIONs to enter when ECC determines that the switchyard voltage is at or below 100 percent were developed and approved on November 11, 1995. In accordance with TS 3.8.1.1 ACTIONs f and g, if a degraded switchyard voltage event were to occur, operability may be

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restored to one train of A.C. sources, within one hour by blocking the FBT in that train; the other train remains vulnerable to double sequencing and is considered inoperable (blocking FBT ensures that the Class 1E 4.16 kV bus voltage will not be degraded to an unacceptable condition by the FBT, and that sufficient power is available to support that train of safety-related plant equipment). Within the next hour, operability may be restored to the other train by blocking the FBT, OR operability may be restored to the remaining EDG by starting, loading, and separating it from offsite power (this second action restores reliable power to the other train of safety-related equipment, and precludes double sequencing from occurring). Current procedures require blocking both trains of FBT within the first hour due to the concern identified in Scenario 3. Appropriate TS changes are planned for submittal.

7. PREVIOUS SIMILAR EVENTS:

No other previous events have been reported pursuant to 10CFR50.73.

8. ADDITIONAL INFORMATION:

THE PALO VERDE ELECTRICAL DISTRIBUTION SYSTEM (EDS) DESCRIPTION

The Non-Class 1E 13.8 kV power system (EA) receives offsite power from the 525 kV switchyard (FK) on one set of buses and, on a separate set of buses, power from the unit auxiliary transformer (TB). The startup transformers (NAN-X01, NAN-X02, and NAN-X03) convert the 525 kV offsite power to the Non-Class 1E 13.8 kV power. The startup transformers have two secondary windings each rated at 13.8 kV and 42/56/70 MVA. The secondary windings are sized to start and carry half of the Non-Class 1E loads of one unit and two trains of ESF loads, one which is from another unit, during unit trips or during startup/shutdown operation. During power operation, the auxiliary transformers (MAN-X02) supply two 13.8 kV buses (NAN-S01 and NAN-S02) which provide the majority of the power to the Non-Class 1E loads during power operations. The auxiliary transformers convert the 24 kV power generated by the unit into 13.8 kV power and have a primary winding rated at 140 MVA and two secondary windings (one for each train of Non-Class 1E power) rated at 70 MVA. The Non-Class 1E 13.8 kV power system supplies power to Non-Class 1E 13.8 kV loads [e.g., reactor coolant pump (AB) motors and circulating water pump (KE) motors], the Technical Support Center, Emergency Operations Facility, and UPS buildings, the Non-Class 1E 4.16 kV power system (EA), the Non-Class 1E 480 V power switchgear load center system (EC), and the Class 1E 4.16 kV power system (EB).

The Class 1E 4.16 kV power system distributes the electrical power received from offsite or onsite sources to safety related loads and to

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selected loads that are important to the plant. The Class 1E 4.16 kV power system receives preferred offsite power through two ESF service transformers (NBN-X03 and NBN-X04) or standby power from two emergency diesel generators. The ESF service transformers (NBN-X03 and NBN-X04) are fed from buses NAN-S03 and NAN-S04 and convert the Non-Class 1E 13.8 kV preferred offsite power to the Class 1E 4.16 kV power, with each transformer furnishing one Class 1E load group. Load Group 1 (PBA-S03 bus) supplies safety Train A and Load Group 2 (PBB-S04 bus) supplies safety Train B. The ESF service transformers are rated at 4.16 kV and 12.5 MVA. The Class 1E 4.16 kV power system supplies power to the safety injection pump (BP) motors and the shutdown cooling system (BQ), essential spray pond (BS) pump motors, essential cooling water (BI) pump motors, auxiliary feedwater (BA) pump motors, chilled water (KM) pump motors, essential chilled water (KM) pump motors, the Class 1E 480 V load centers (ED), and the Non-Class 1E 4.16 kV - 480 V load centers (EC).

The Class 1E 4.16 kV power system receives control signals from the ESFAS system (JE), and in the case of a loss of power to the Class 1E 4.16 kV power system, generates the necessary output actuation signals to shed all Class 1E 4.16 kV loads, automatically start and sequentially load the EDGs. The standby generation Class 1E power system (EK) is capable of supplying the vital ESF loads necessary to reliably and safely shut down the affected unit.

The Class 1E 480 V power system includes both the 480 V load centers (ED) and the 480 V Class 1E motor control centers (ED). The load center transformers convert the Class 1E 4.16 kV power to the Class 480 V power and are rated at 480 V and 750 kVA. The Class 1E 480 V power system interfaces with and receives control signals from the ESFAS.

The two fast bus transfer circuit are also provided to transfer the Non-Class 1E house loads fed from NAN-S01 and NAN-S02 to 13.8 kV buses NAN-S03 and NAN-S04 respectively within seven cycles during a plant trip or manually during startup/shutdown operation. Prior to a plant trip, NAN-S01 and NAN-S02 are fed from the auxiliary transformer, and are fed from NAN-S03 and NAN-S04 respectivly after the plant trip.

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