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December 10, 2012

PG&E Letter DCL-12-127

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

10 CFR 50.73

Docket No. 50-323, OL-DPR-82
Diablo Canyon Unit 2
Licensee Event Report 2-2012-002-00, Coupling Capacitor Voltage Transformer Bushing Failure Causes Reactor Trip

Dear Commissioners and Staff:

Pacific Gas and Electric Company (PG&E) is submitting the enclosed Licensee Event Report (LER) identifying reactor trip and an auxiliary feedwater pump auto-start as a result of a flashover of a 500kV insulator. PG&E is submitting this LER in accordance with 10 CFR 50.73(a)(2)(iv)(A).

PG&E makes no new or revised regulatory commitments (as defined by NEI 99-04) in this report.

This event did not adversely affect the health and safety of the public.

Sincerely,

for

Barry S. Allen

ssz1/4040/50518473
Enclosure
cc/enc: Elmo E. Collins, NRC Region IV
Thomas R. Hipschman, NRC Senior Resident Inspector
Joseph M. Sebrosky, NRR Senior Project Manager
INPO
Diablo Distribution

NRC FORM 366 (10-2010) U.S. NUCLEAR REGULATORY COMMISSION	APPROVED BY OMB: NO. 3150-0104 EXPIRES: 10/31/2013
LICENSEE EVENT REPORT (LER) (See reverse for required number of digits/characters for each block)	Estimated burden per response to comply with this mandatory collection request: 80 hours. Reported lessons learned are incorporated into the licensing process and fed back to industry. Send comments regarding burden estimate to the FOIA/Privacy Section (T-5 F53), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by internet e-mail to infocollects.resource@nrc.gov, and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202, (3150-0104), Office of Management and Budget, Washington, DC 20503. If a means used to impose an information collection does not display a currently valid OMB control number, the NRC may not conduct or sponsor, and a person is not required to respond to, the information collection.

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4. TITLE
Coupling Capacitor Voltage Transformer Bushing Failure Causes Reactor Trip

5. EVENT DATE			6. LER NUMBER			7. REPORT DATE			8. OTHER FACILITIES INVOLVED	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REV NO.	MONTH	DAY	YEAR	FACILITY NAME	DOCKET NUMBER
10	11	2012	2012	- 002 -	00	12	10	2012	FACILITY NAME	DOCKET NUMBER

9. OPERATING MODE	11. THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: *(Check all that apply)*			
1	☐ 20.2201(b)	☐ 20.2203(a)(3)(i)	☐ 50.73(a)(2)(i)(C)	☐ 50.73(a)(2)(vii)
	☐ 20.2201(d)	☐ 20.2203(a)(3)(ii)	☐ 50.73(a)(2)(ii)(A)	☐ 50.73(a)(2)(viii)(A)
	☐ 20.2203(a)(1)	☐ 20.2203(a)(4)	☐ 50.73(a)(2)(ii)(B)	☐ 50.73(a)(2)(viii)(B)
	☐ 20.2203(a)(2)(i)	☐ 50.36(c)(1)(i)(A)	☐ 50.73(a)(2)(iii)	☐ 50.73(a)(2)(ix)(A)
10. POWER LEVEL	☐ 20.2203(a)(2)(ii)	☐ 50.36(c)(1)(ii)(A)	☑ 50.73(a)(2)(iv)(A)	☐ 50.73(a)(2)(x)
100	☐ 20.2203(a)(2)(iii)	☐ 50.36(c)(2)	☐ 50.73(a)(2)(v)(A)	☐ 73.71(a)(4)
	☐ 20.2203(a)(2)(iv)	☐ 50.46(a)(3)(ii)	☐ 50.73(a)(2)(v)(B)	☐ 73.71(a)(5)
	☐ 20.2203(a)(2)(v)	☐ 50.73(a)(2)(i)(A)	☐ 50.73(a)(2)(v)(C)	☐ OTHER
	☐ 20.2203(a)(2)(vi)	☐ 50.73(a)(2)(i)(B)	☐ 50.73(a)(2)(v)(D)	Specify in Abstract below or in NRC Form 366A

12. LICENSEE CONTACT FOR THIS LER

FACILITY NAME	TELEPHONE NUMBER *(Include Area Code)*
Steven S. Zawalick, Sr. Engineer, Regulatory Services	(805) 545-4040

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

CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX	CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX
B	EL	XFMR	N/A	Y					

14. SUPPLEMENTAL REPORT EXPECTED		15. EXPECTED SUBMISSION DATE	MONTH	DAY	YEAR
☑ YES *(If yes, complete 15. EXPECTED SUBMISSION DATE)*	☐ NO		06	30	2013

ABSTRACT *(Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines)*

On October 11, 2012, at 12:08 PDT, the Diablo Canyon Power Plant Unit 2 500kV line differential relay actuated, resulting in a unit trip. The 500kV coupling capacitor voltage transformer bushing experienced a flashover to ground, resulting in a unit trip and turbine trip. With the turbine tripped and Unit 2 operating above the P-9 50 percent power permissive, the reactor protection system initiated a reactor trip as designed. All plant equipment, including the auto-start of the auxiliary feedwater (AFW) system, responded as designed.

Pacific Gas and Electric Company (PG&E) determined that the causes of the bushing failure were inadequate insulator material performance and inadequate engineering design practices. PG&E will redesign and replace plant bushings, improve maintenance, testing and observation, and revise plant design and procurement standards.

Additionally, an unintended AFW pump restart occurred following this event as a result of a human performance error that resulted in a procedure not being revised following a plant modification. PG&E will revise procedure supporting documents and tailboard procedure writing staff on use of the supporting documents to identify all changes required by a plant modification.

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NARRATIVE

I. Plant Conditions

Just prior to the event, Unit 2 was operating in Mode 1 (Power Operation) at approximately 100 percent reactor power with normal operating reactor coolant temperature and pressure.

II. Problem Description

A. Background

The Diablo Canyon Power Plant (DCPP) is equipped with a Class 1E alternating current electrical power distribution system [EB] that is divided into three load groups. The power sources for this system consist of two physically-independent offsite sources and multiple onsite standby power sources (three engine-driven diesel generators (DG's)[DG] for each unit). These systems have independent controls, independent protection, and separate switchyards, transmission lines, and tie-lines to the plant. In the normal alignment, the power produced at DCPP is transmitted offsite via the 500kV system [EL] and also feeds normal onsite loads via the auxiliary transformer [XFMR]. Backup power is available immediately via the 230kV system [EK] and startup transformer and in a delayed manner (for vital loads) from onsite DG's. The alternating current electrical power sources provide sufficient capacity, capability, redundancy, and reliability to ensure the availability of necessary power to engineered safety systems so that the fuel, reactor coolant system [AB], and containment design limits are not exceeded.

DCPP's 500kV system has metering hardware that provides real-time generation and consumption data to the Independent System Operator (ISO). Independent bushing current transformers (CT's) and 500kV coupling capacitor voltage transformers (CCVT's) are the sensors used for this application. The CCVT's and CT's are connected to each unit's Main Bank Transformer (MBT).

A catastrophic failure of the Unit 2 "C" phase high-voltage (HV) bushing (insulator) in 2008 led to a 2009 replacement of two of the six ceramic HV insulator bushings with a silicone polymer design that had less potential for collateral damage upon failure. All of the DCPP lightning arresters (LA's) and CCVT's have also been replaced with this same silicone polymer design.

There are three key factors to consider for an insulating system to be able to adequately withstand the applied system voltage: insulator material properties, creepage distance, and environmental conditions (contaminants, such as salt, dust, industrial pollutants, etc.). A contaminated insulator without adequate creepage margin will suffer arcing and eventually flashover.

Silicone polymer provides exceptional performance as an insulator material, especially in adverse environmental conditions. By continuously extruding a layer of silicone, it encapsulates contaminants on the surface of the insulator. This prevents the buildup of a conductive film when the insulator is exposed to moisture. The silicone layer performs the same function as the silicone grease some plants apply to porcelain insulators.

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Creepage distance is the shortest path between two conductive parts. The Institute of Electrical and Electronics Engineers (IEEE) standard C57.19.100, "IEEE Guide for Application of Power Apparatus Bushings," provides recommendations for various environmental conditions. DCPP's location exposes these systems and components to environmental contaminants such as salt, dust, industrial pollutants, etc. Per IEEE C57.19.100, DCPP's environment is classified as a heavy or very heavy contamination area, which establishes the recommended minimum creepage distance as 502 or 616 inches, respectively. PG&E's corporate transmission line design standard indicates a minimum creepage distance of 400 inches, but does not refer to environmental classifications. The installed polymer CCVT's have a vendor stated guaranteed minimum of 400 inches of creepage distance. The previous porcelain CCVT's had a specified creepage distance of 435 inches per vendor documents; it was actually found to be 521 inches.

Relative to the auxiliary feedwater pump, PG&E had implemented a temporary setpoint change in March 2012 to address a deficiency related to Rosemount transmitter uncertainty error increase. This resulted in a setpoint change for each of the steam generator (SG) low-low level setpoints from 15 percent to 17 percent for the auxiliary feedwater (AFW) pump autostarts. Procedures were reviewed to identify necessary changes due to the level setpoint changes, particularly reviewing all 15 percent level values in the procedures to implement necessary changes.

The Emergency Operating Procedure EOP E-0.1, "Reactor Trip Response," Response Not Obtained, Step 6.c, checks whether the turbine-driven (TD) AFW pump should be secured by verifying SG level greater than 16 percent in at least 3 SG's. The 16 percent value is derivative of the 15 percent AFW start setpoint, but is not explained as such in the setpoint basis documents or in the text of the procedures. Without a clear link between the 15 percent and the 16 percent value provided in the procedure or setpoint bases documents, procedure writers failed to identify the need to increase the 16 percent procedure requirement.

B. Event Description

On October 11, 2012, during a light rain, plant personnel identified visible arcing on the Unit 2 "A" and "B" Phase MBT CCVT's. At 1208 PDT, the "A" Phase MBT CCVT flashed over to ground, causing a single-line-to-ground fault. This caused the 500kV tie-line differential relay to actuate, resulting in a Unit 2 trip. The Unit 2 trip actuated a turbine trip and, because Unit 2 was operating above the 50 percent power permissive, the reactor protection system initiated a Unit 2 reactor trip. All plant equipment, including the auto start of the AFW system, responded as designed.

About 18 minutes after the reactor trip, plant operators manually closed the steam supply valve to the TD AFW pump to secure the pump. Operators performed this action in accordance with plant operating procedures after they verified that the indicated SG levels were greater than the procedural requirement of 16 percent narrow range span. However, because the SG low-level bistables associated with the AFW actuation circuits had not yet cleared, the emergency safeguards actuation signal drove the steam-supply valve back open, restarting the TD AFW pump. Operators increased steam generator levels to clear the bistables and successfully reclosed the steam-supply valve.

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C. Status of Inoperable Structure, Systems, or Components That Contributed to the Event

None.

D. Other Systems or Secondary Functions Affected

None.

E. Method of Discovery

Annunciators in the control room alerted licensed control room operators of the 500kV system problem.

F. Operator Actions

Plant operators verified appropriate plant trip response using Emergency Operating Procedure (EOP) E-0, "Reactor Trip or Safety Injection" and EOP E-0.1, "Reactor Trip Response."

G. Safety System Responses

Vital buses transferred from auxiliary power to startup power as designed.

III. Cause of the Problem

A. Immediate Cause

Inadequate material performance of the silicone polymer insulator prevented proper control of environmental contamination. Furthermore, the insulator design criteria, including creepage distance and operating environment assumptions, were not sufficiently conservative.

B. Root Cause

PG&E identified the following root causes:

(1) PG&E found that inappropriate material performance of the silicone polymer insulator prevented proper control of environmental contamination. Detailed material testing of the failed CCVT bushing is ongoing and a supplement to this Licensee Event Report will be submitted following receipt of this report to address any additional findings.

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(2) PG&E concluded that engineers violated INPO 10-005, "Principles for Maintaining an Effective Technical Conscience," principle 4, "Engineers adhere to sound engineering principles," by not using applicable codes and standards in the design of the CCVT.

a. Plant design standards had not been updated for minimum creepage distance for HV insulators in contaminated environments to reflect industry codes and standards; and

b. DCPP design engineers over-relied on PG&E and industry experts at the expense of industry codes and standards as it pertained to the selection of the creepage distance.

C. Contributing Cause

PG&E identified the following contributing causes:

(1) An inadequate mental model resulted in underestimating contamination levels due to the environment.

(2) The design of the Unit 2 Emergency Diesel Generators (EDG's) exhaust stacks contributes to the hydrocarbon contamination on the equipment in the Unit 2 MBT area.

(3) Weaknesses in planning and executing construction projects contributed to contamination on the equipment in the Unit 2 MBT area.

D. AFW Pump Setpoint

The cause of the AFW pump setpoint procedure issue was a human knowledge based error.

IV. Assessment of Safety Consequences

There were no safety consequences as a result of this event. The transfer of plant loads to startup occurred as designed. Equipment necessary decay heat removal was available and operated as required by plant procedures. The unexpected restart of the AFW pump did not challenge operator restoration actions or operational limits. Unit 1 remained at full power and all vital buses remained powered by auxiliary power. Therefore, the event is not considered risk significant and did not adversely affect the health and safety of the public.

V. Corrective Actions

A. Interim Corrective Actions

PG&E will take the following actions:

(1) Ramp the unit off line if arcing becomes visible on the CCVT with arcs increasing in diameter and spanning multiple sheds over the full length of the insulator, as these symptoms show that a flashover is highly likely.

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(2) Clean Unit 1 and Unit 2 CCVT's and LA's prior to the first rain in the fall of 2013. Perform Effective Salt Deposit Density (ESDD) and hydrocarbon contaminant sampling, and as-found and as-left hydrophobicity tests while cleared.

B. Immediate Corrective Actions

The following immediate corrective actions relative to the CCVT's were taken following the CCVT failure:

(1) Replace the Unit 2 "A" Phase CCVT and perform Power Factor (PF) testing.
(2) Replace the Unit 2 "A" Phase LA and perform PF testing.
(3) Perform PF testing of the Unit 2 "B" and "C" Phase CCVT and LA.
(4) Clean the HV Polymer Bushings on the Unit 2 MBT "A" and "B" Phases ("C" Phase is ceramic) and clean the Insulators on the Unit 2 "A," "B," and "C" Phases CCVT's and LA's.
(5) Megger the secondary circuits of the Unit 2 "A" Phase CCVT (between the CCVT and CAL-ISO metering relays).
(6) Establish monthly corona-camera monitoring and weekly infrared monitoring to identify trends.
(7) Establish visible light camera to monitor Unit 1 CCVT's with real time video.

C. Corrective Actions to Prevent Recurrence

PG&E will implement the following actions to prevent recurrence:

(1) Replace the CCVT's with an alternate design that meets IEEE C57.19.100 environmental creepage distance requirements and other electrical specifications, including appropriate insulator material.

(2) Revise plant design standards to reflect:

a. IEEE C57.19.100 and C57.19.01, "IEEE Standard Performance Characteristics and Dimensions for Outdoor Apparatus Bushings," guidance for creepage distance for all HV insulators including determination of contamination classifications; and

b. IEEE 693 guidance for seismic criteria.

(3) Develop and present a lesson plan through Engineering Training to discuss the procedural requirements to review industry standards and codes when performing design work.

(4) Establish a two year contamination monitoring program to obtain baseline data. The program will consist of installing sample points (polymer insulator segments) in the Unit 1 and Unit 2 MBT areas. Samples will be taken periodically to measure the ESDD and hydrocarbon deposition rate, and total deposition. Samples are also to be taken on Unit 1 and Unit 2 MBT HV bushings, CCVT's, and LA's during refueling outages.

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(5) Establish a requirement to implement construction dust mitigating measures when performing earth work, excavation, or any construction activities that may generate airborne contamination near the main bank transformer areas.

(6) Establish receipt-inspection criteria for HV polymer insulators to perform hydrophobicity testing per Swedish Transmission Research Institute (STRI) Guide 92/1, "Hydrophobicity Classification Guide."

(7) Replace the 230kV circuit switchers with an alternate design that meets IEEE C57.19.100 environmental creepage distance requirements including appropriate silicone insulator material and other electrical specifications.

(8) Update the maintenance program for the 230kV circuit switchers to revise the silicone grease replacement frequency to every two years.

(9) Revise design procedures to incorporate guidance on how to review industry codes and standards for content relevant to the design work being performed and use the standard's guidance as appropriate.

(10) Replace the 230kV start-up transformer bushings and LAs with an alternate design that meets IEEE C57.19.100 environmental creepage distance requirements including appropriate insulator material and other electrical specifications.

(11) Replace all porcelain MBT bushings with an alternate design that meets IEEE C57.19.100 environmental creepage distance requirements including appropriate insulator material and other electrical specifications.

D. AFW Pump Setpoint Corrective Actions

(1) Update setpoint document to identify the relationship between the SG setpoint and the TD AFW pump actions.

(2) Tailboard Operations procedure writer staff on the event and the expectation to consult supporting documents when performing Emergency Operating Procedure modification scoping.

VI. Additional Information

A. Failed Components

The DCPP Unit 2 MBT "A" phase CCVT bushing failed due to an insulator flashover.

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B. Previous Similar Events

On August 16, 2008, Diablo Canyon Unit 2 MBT "C" Phase experienced a catastrophic failure of the HV bushing. A significant amount of porcelain shrapnel resulted from the failure. The debris damaged adjacent equipment and penetrated the northeast side of the administration building in multiple locations. Debris was also found in the parking lot several hundred feet away. The event occurred at 23:56 on a Saturday. The potential for injury was very high if the catastrophic failure of that HV bushing had occurred on a normal workday.

A root cause evaluation performed as a result of the MBT "C" Phase HV bushing failure found that catastrophic failure of bushings was not an uncommon occurrence. To improve personnel safety, a recommendation was made to replace the MBT porcelain bushings, the CCVT's, and the LA's with models made with a safer insulator material. Design changes were developed and components were replaced with models made of a silicone polymer insulator rather than porcelain. Bushings of Unit 2 MBT "A" and "B" phases were replaced with polymer in 2009. The Unit 2 MBT "C" phase bushing remains of porcelain design. In Unit 2 Refueling Outage Sixteen, the CCVT's and LA's were replaced with polymer. In Unit 1 Refueling Outage Seventeen, the CCVT's and LA's were replaced with polymer. All three Unit 1 MBT's continue to have porcelain bushings.