Palo Verde Nuclear
Generating Station

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102-05376-CDM/TNW/RJR
November 16, 2005

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

Reference: APS letter 102-05119-CDM/SAB/TNW/GAM, "Information Regarding PVNGS Offsite Power Grid Reliability," dated June 17, 2004.

Dear Sirs:

Subject: Palo Verde Nuclear Generating Station (PVNGS) Units 1, 2 and 3, Docket No.s STN 50-528/529/530 Results of the Investigation of the June 14, 2004 230 kV Transmission Line Fault

In the referenced letter, Arizona Public Service (APS) agreed to forward the findings of the study being conducted by the Western Electricity Coordinating Council (WECC) of the June 14, 2004 230 kV transmission line fault when they became available. The investigation has been finalized and APS has completed its review.

The findings of the study conducted by the WECC are attached to this letter. This letter does not make any commitments to the NRC. Please contact Thomas N. Weber at (623) 393-5764 if you have any questions or require additional information.

Sincerely,

David Mauldin

CDM/TNW/RJR/ca

Attachment: Results of 6-14-04 Westwing/Palo Verde Disturbance Validation Study

cc: B. S. Mallett
M. B. Fields
G. G. Warnick

A-001

Attachment

Western Electricity Coordinating Council
Technical Studies Subcommittee
Results of 6-14-04 Westwing/Palo Verde Disturbance Validation Study

WesternElectricityCoordinatingCouncil

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October 31, 2005

Dana Cabbell, Chair
Technical Studies Subcommittee

Subject: Results of 6-14-04 Westwing/Palo Verde Disturbance Validation Study

The attached report summarizes work performed by the Modeling and Validation Work Group (MVWG) to simulate the June 14 2004 West Wing/Palo Verde disturbance. This is part of an on-going effort calibrate WECC's system planning models.

As in previous instances, simulation of this event revealed shortcomings of the existing models and gave us an opportunity to correct them. Specifically, the existing models for the Palo Verde units underestimate the effects of field saturation at the high excitation levels that the Palo Verde units experienced during the event. After the appropriate model adjustments were made, very close agreement between simulation and actual recordings was obtained.

Following the model validation, additional "what if" scenarios were conducted. The conclusions of these additional simulation scenarios are given below:

1. If the Palo Verde – Hassayampa 500 kV transmission lines had not tripped during the event, the simulations show that the Palo Verde generators still would have tripped. However, after the fault clears and assuming that all other Palo Verde 500 kV trip as they did, the simulations show that the Palo Verde 500 kV voltage would have recovered to an acceptable level, provided that the 500 kV lines from Jojoba and/or North Gila to Hassayampa had remained in service.

2. If the fault had cleared before the Palo Verde OEL took action, the simulations show that the Palo Verde units would not have tripped, and the system would have recovered to a stable condition.

If you have any further questions, please do not hesitate to contact me.

Sincerely,

Abraham Ellis

cc.

Robert Jenkins, Chair, Planning Coordination Committee

Disturbance Simulation Report for the June 14, 2004 Westwing Fault and Palo Verde Trip Event

Modeling and Validation Work Group
October 31, 2005

Introduction

The June 14, 2004 WECC disturbance [1] resulted in tripping of all 7 Palo Verde 500 kV lines and all 3 Palo Verde nuclear units. The event caused the system frequency to dip to 59.55 Hz, and produced significant power oscillations in Northwest as well as very low voltages in Palo Verde area. This disturbance was very complex in the sense that the fault type changed many times during the event. Single-line-to-ground, 2-line-to ground, and 3-phase faults occurred before the fault was finally cleared, 40 seconds after it started.

WECC's Modeling and Validation Work Group (MVWG) performed a detailed simulation of this event as part of an on-going effort to calibrate WECC's planning models. Several entities provided data required to conduct the simulation. WECC staff obtained generation, load, and line flow information from member utilities, and assembled the power flow and stability case data. WECC's Disturbance Monitoring Work Group (DMWG) provided high-speed recordings of the event at various key locations. Arizona Public Service Company assembled a detailed switching sequence, and provided the fault impedance data necessary to simulate the asymmetrical faults involved in the event.

Summary of the Model Validation Effort

The initial simulation effort using the most up-to-date models was reasonably successful in reproducing the system frequency dip (Figure 1). However, the initial simulation failed to reproduce the voltage profile in the Palo Verde area (Figure 2). The actual voltage profile at the Palo Verde 500 kV bus was much worse than the simulation showed. The initial simulation also failed to reproduce the voltage collapse that occurred at the Palo Verde 500 kV bus. It was observed that the simulated Palo Verde generator reactive power response was too optimistic compared to actual measurements. The simulation showed that reactive power output of the Palo Verde units peaked at approximately 1500 MVAR (gross), whereas the actual recordings showed a maximum output of only 1200 MVAR (gross).

After a thorough review, it was determined that the existing generator model for the Palo Verde units underestimated the effects of saturation at the extreme conditions experienced during the disturbance. During the June 14th 2004 event, the Palo Verde field voltage reached its maximum limit, while field current was at a very high level (1.4 pu of AFFL). It is not possible to test saturation characteristics of the Palo Verde units at this operating point. During off-line model verification tests, the Palo Verde generator model had been verified with generator terminal voltage up to 1.08 pu. At this terminal voltage, the field voltage was well below its ceiling and the field current was well below 1.0 pu. To match the measured reactive power output of the Palo Verde units during the June 14th 2004 event, the saturation constant "s1.2" had to be increased significantly. MVWG is currently investigating whether a similar model adjustment applies to other WECC generator models.

It is worth noting that, during this event, the Palo Verde over-excitation limiter (OEL) operated. The OEL action, which took place 20 seconds after the disturbance started, had a decisive effect on the outcome of the event. Fortunately, OEL performance recordings were available, allowing the OEL model to be adjusted to match the actual behavior.

With accurate OEL modeling and after adjusting the saturation constant, close agreement was obtained between recorded and simulated reactive power output of Palo Verde generators. Palo Verde 500 kV bus

voltage also matched the recorded data reasonably well as shown in Figures 3a and 3b. Additional comparison plots are shown in Figure 4a to 4c.

Additional simulations

Approximately 12 seconds into the fault, the three 500 kV lines connecting Palo Verde to Hassayampa tripped on a negative sequence condition. As part of an investigation of this event, the Nuclear Regulatory Commission (NRC) expressed interest in studying whether the Palo Verde units would have tripped under certain variations of the actual event. Two "what if" scenarios were simulated to address questions posed by the NRC. These scenarios and the simulation results are briefly described below.

Scenario 1 – Assume that the Palo Verde to Hassayampa transmission lines do not trip.

Assuming that the fault is cleared in 40 seconds, as it happened during this event, the Palo Verde units OEL would have operated and a voltage collapse at Palo Verde 500 kV bus would have occurred. Therefore, the Palo Verde units still would have tripped under this scenario.

The simulation also shows that if the Hassayampa lines had not tripped, then the Palo Verde 500 kV switchyard would have recovered to an acceptable voltage level following tripping of the lines from Palo Verde to Devers, Rudd and Westwing, provided that the 500 kV transmission lines from Hassayampa to Jojoba and/or North Gila had remained unaffected by the fault (Figure 5a and 5b). Tripping of the Palo Verde lines separates the fault from Palo Verde 500 kV bus and the Palo Verde 500 k V bus voltage recovers. This is seen in Figures 5a. Tripping of the Palo Verde units causes the frequency to dip to 59.3 Hz but the frequency also recovers. This recovery of the Palo Verde 500 kV voltage is due to it being connected to Hassayampa 500 kV bus and the assumption that the Hassayampa 500 kV bus sources remained in service.

Scenario 2 – Assume that the fault clears before the OEL operates and no Palo Verde 500 kV lines trip.

Since the fault is assumed to clear before OEL action takes place, the Palo Verde 500 kV voltage would not have collapsed. The studies show that no lines or units at Palo Verde would have tripped, and the system would have remained in a stable condition (Figure 6).

Reference

[1] WECC Detailed System Disturbance Report by WECC Disturbance Report Task Force , Dec 3, 2004 (http://www.wecc.biz/documents/library/disturbance/6-14/14Jun04_Westwing_final_review_draft.pdf).

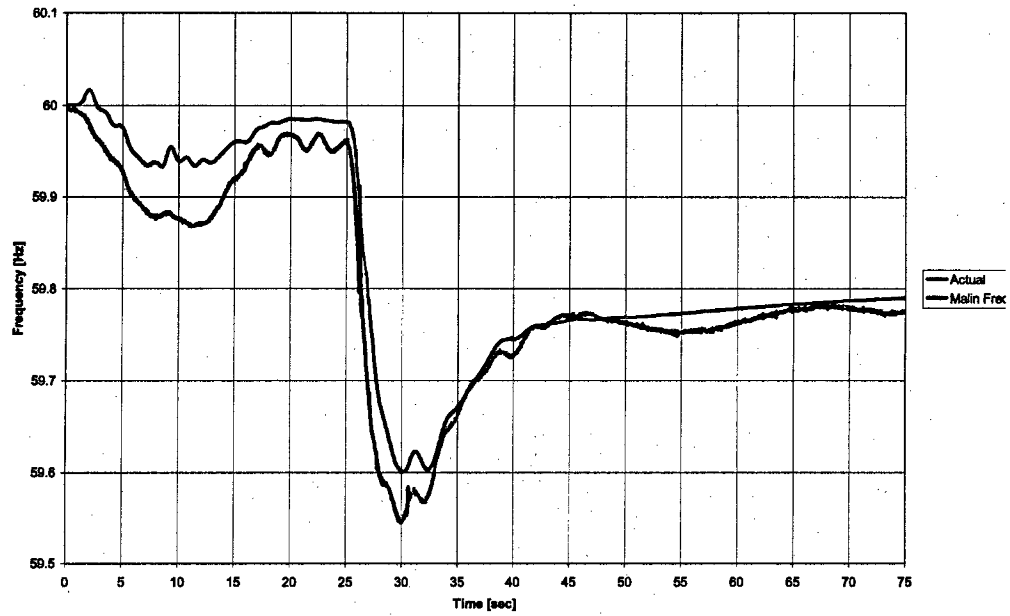

Figure 1: Comparison of simulated and actual frequency at Malin 500 kV before model adjustments

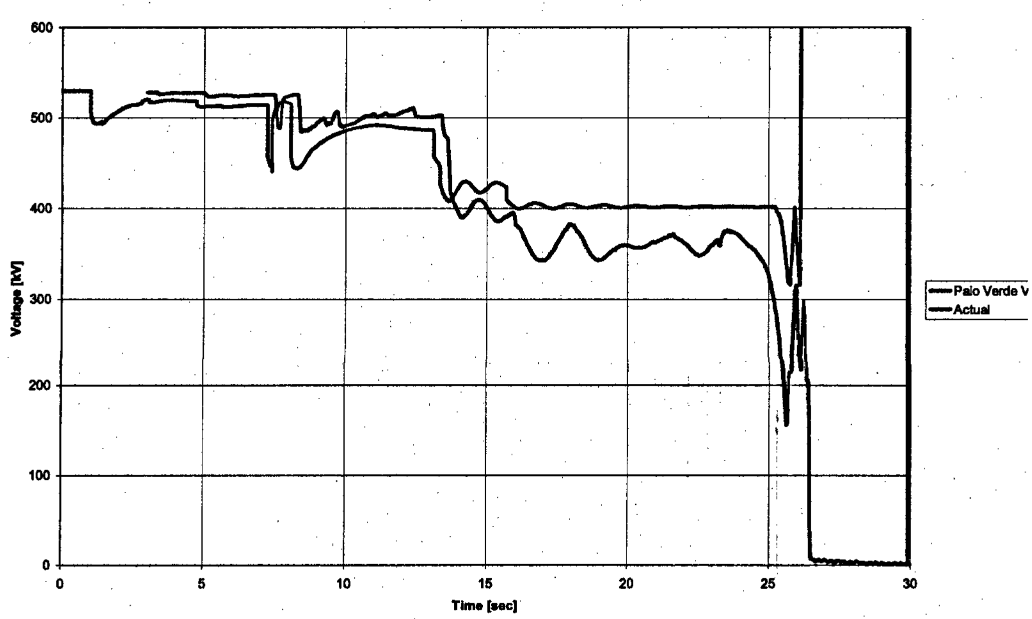

Figure 2: Comparison of simulated and actual Palo Verde 500 kV bus voltage before model adjustments

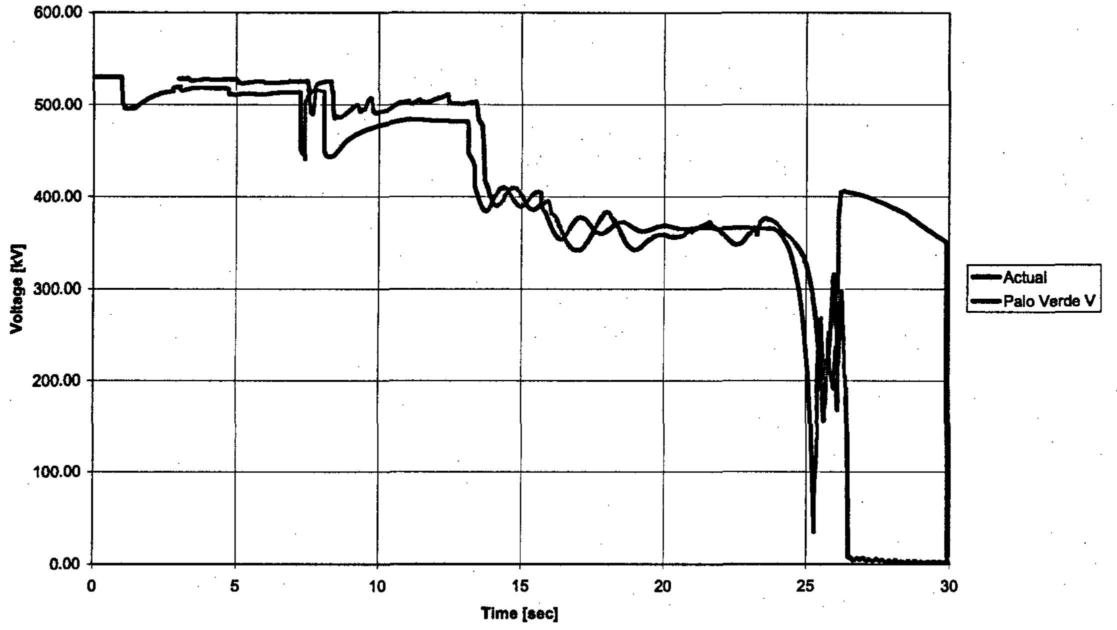

Figure 3a: Comparison of simulated and actual Palo Verde 500 kV bus voltage after model adjustments

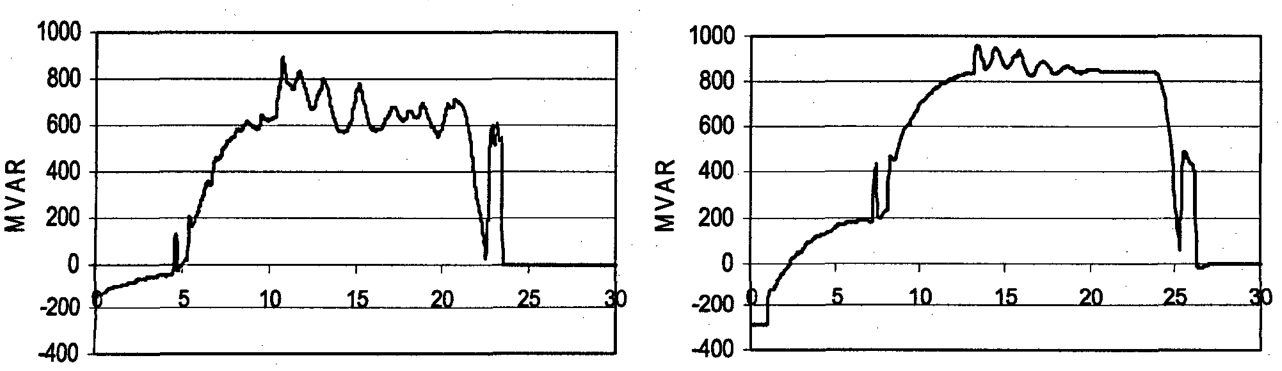

Fig 3b. Comparison of simulated (left) and actual (right) reactive power output for Palo Verde Unit #2, after model adjustments

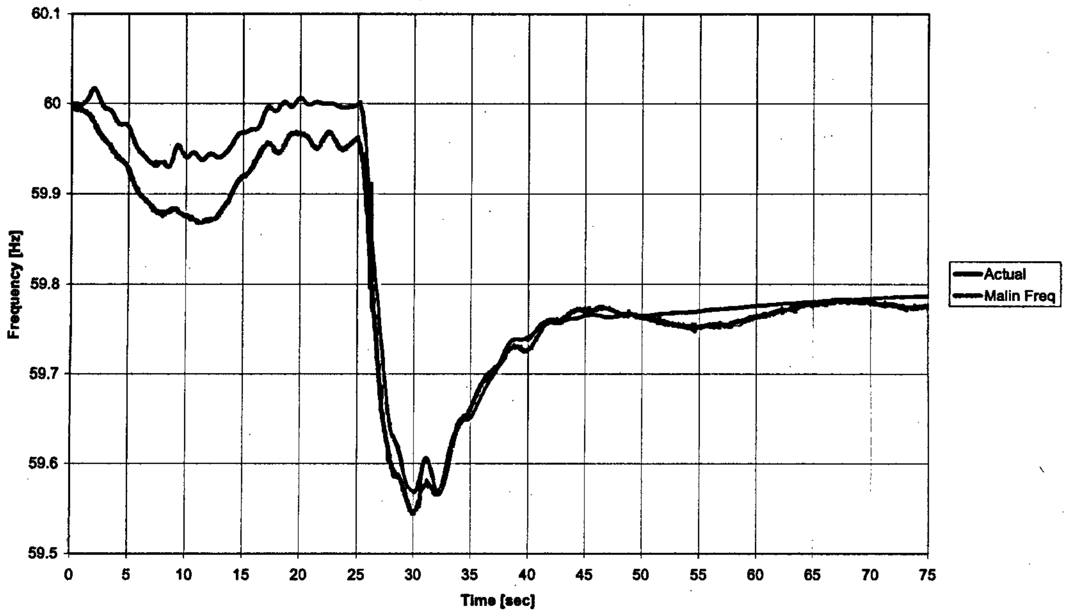

Figure 4a: Comparison of simulated and actual frequency at Malin 500 kV after model adjustments

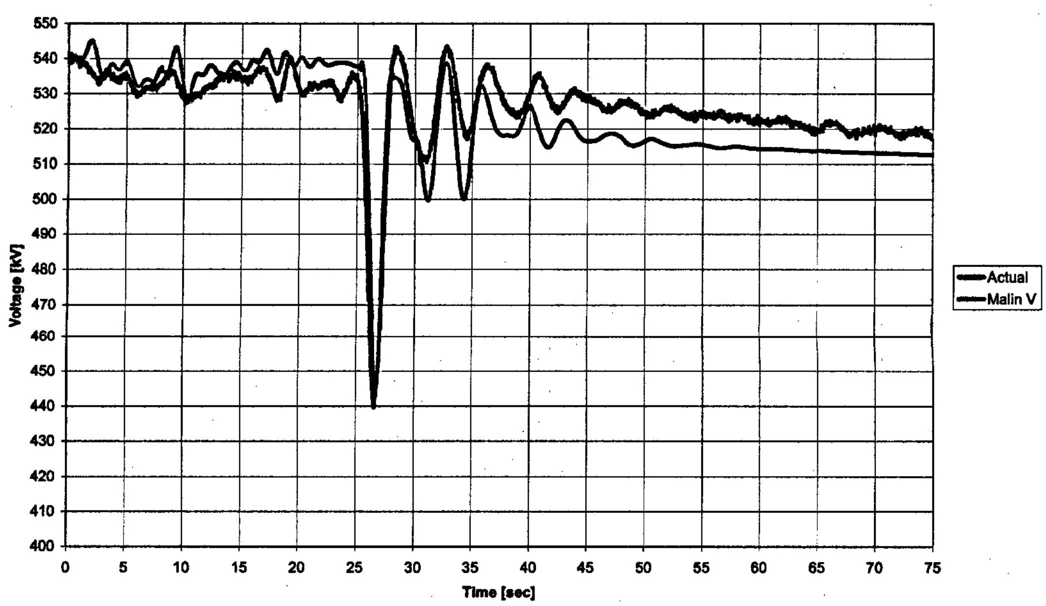

Figure 4b: Comparison of simulated and actual Malin 500 kV voltage after model adjustments

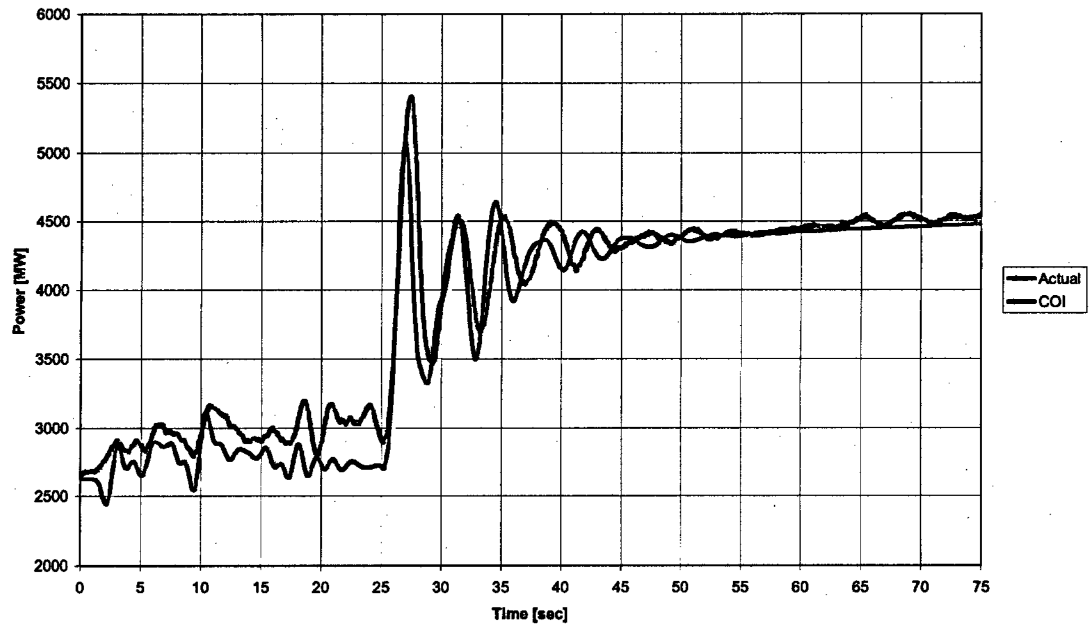

Figure 4c: Comparison of simulated and actual COI real power transfer after the model adjustments

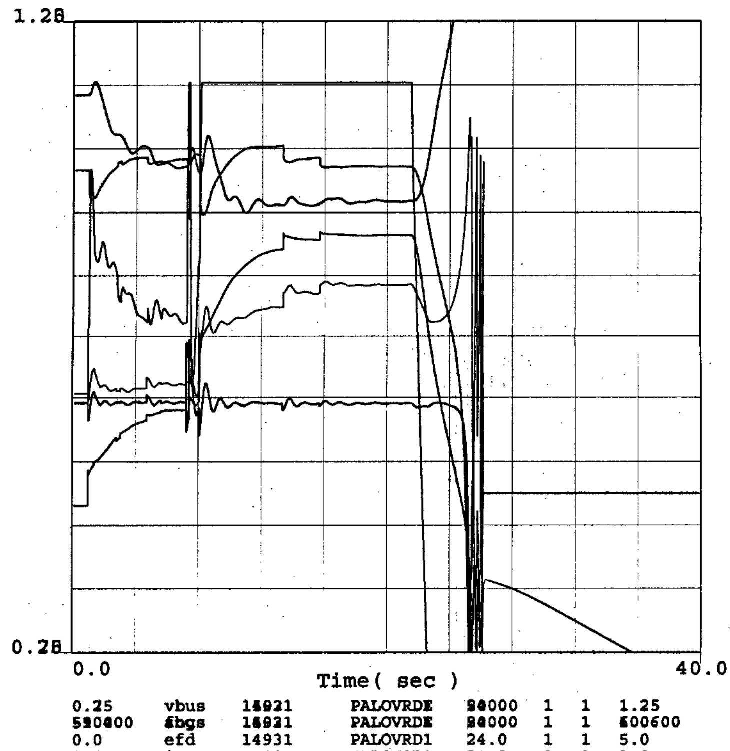

Figure 5a. Palo Verde voltage (blue) and system frequency (red) for Scenario 1. Palo Verde units trip at 20 seconds following OEL action

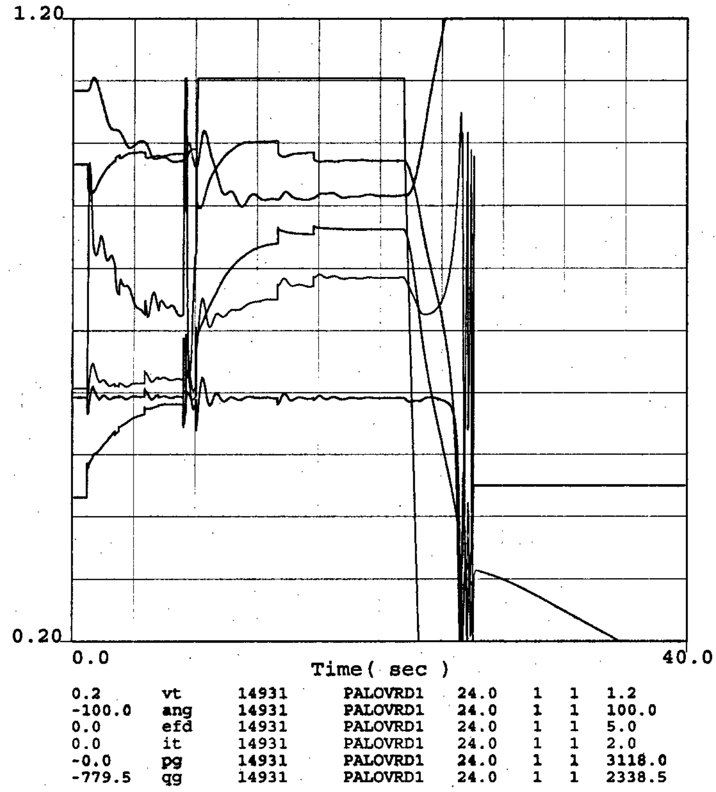

Figure 5b. Palo Verde Unit #1 quantities for Scenario 1, showing unit instability and trip at 20 seconds following OEL action. Results from Units #2 and #3 are similar.

Figure 6. Palo Verde 500 kV bus voltage for Scenario 2, showing that the system would have remained in a stable condition if the fault would have been cleared in 19 seconds. The Palo Verde units did not trip during this simulation.