UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 16, 2018

Mr. Mano Nazar
President and Chief Nuclear Officer
Nuclear Division
Florida Power & Light Company
Mail Stop: EX/JB
700 Universe Blvd.
Juno Beach, FL 33408

SUBJECT: TRANSMITTAL OF FINAL TURKEY POINT NUCLEAR GENERATING UNIT NO. 3 ACCIDENT SEQUENCE PRECURSOR REPORT (LICENSEE EVENT REPORT 250-2017-001)

Dear Mr. Nazar:

By letter dated May 16, 2017 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17136A372), Florida Power & Light Company Submitted Licensee Event Report (LER) 250-2017-001, "Reactor Trip, Auxiliary Feed Water and Emergency Diesel Generator 3A Actuations, Loss of Safety Injection Function," to the U.S. Nuclear Regulatory Commission (NRC) staff pursuant to Title 10 of the *Code of Federal Regulations* Section 50.73. As part of the Accident Sequence Precursor (ASP) Program, the NRC staff reviewed the event to identify potential precursors and to determine the probability of the event leading to a core damage state. The results of the analysis are provided in the enclosure to this letter.

The NRC staff does not request a formal analysis review, in accordance with Regulatory Issue Summary 2006-24, "Revised Review and Transmittal Process for Accident Sequence Precursor Analyses" (ADAMS Accession No. ML060900007), because the analysis resulted in a conditional core damage probability (CCDP) of less than 1×10^{-4}.

Final ASP Analysis Summary. A brief summary of the final ASP analysis, including the results, is provided below.

Loss of 3A 4kV Vital Bus Results in Reactor Trip, Safety System Actuations, and Loss of Safety Injection Function. This event is documented in LER 250-2017-001 and Inspection Reports 05000250/2017008 and 05000250/2017002.

Executive Summary. On March 18, 2017, at approximately 11:07 a.m., the Turkey Point Nuclear Generating Unit No. 3 reactor tripped due to a trip of the reactor coolant pumps (RCPs) caused by a high-energy arc fault (HEAF) on the 4.16 kilovolt (kV) safety-related alternating current (AC) bus 3A. The site declared an Alert because of smoke in switchgear room 3A. Auxiliary feedwater (AFW) actuated as expected due to low steam generator (SG) level. Operators closed the main steam isolation valves, per emergency operating procedures, and used SG atmospheric dump valves for decay heat removal. Each unit has two high-head safety injection (HHSI) pumps, which are shared between the two units. Both Unit 4 HHSI pumps were out of service for maintenance at the time of event. This maintenance combined with the

failure of bus 3A resulted in three of the four HHSI pumps being unavailable. Both Unit 4 HHSI pumps were restored at 1:36 p.m. on the 18th of March.

This event was modeled as a loss of 4.16 kV bus 3A initiating event with the Unit 4 HHSI pumps unavailable due to maintenance. Given the modeling assumptions used in this analysis, the CCDP was calculated to be 3×10^{-6}. For most Westinghouse pressurized-water reactors, a similar event often results in a CCDP greater than 10^{-5}, with the results dominated by the loss of AFW and feed-and-bleed cooling from (postulated) random failures of the opposite train(s) or loss of RCP seal cooling scenarios with a subsequent seal failure resulting in a loss-of-coolant accident. However, Turkey Point has some unique plant design features that mitigate the risk of this event. The most notable is that each unit's safety-related direct current buses have battery-charging capability from both units. This is important because the three turbine-driven AFW pumps (also unique to Turkey Point), remain available during a postulated loss of all safety-related AC power. In addition, SG level indication could be maintained throughout the most severe postulated event. Turkey Point also has a nonsafety-related standby SG feedwater system available to provide inventory makeup to the SGs. Another key plant feature is the installation of N9000 Flowserve RCP seals, which substantially decrease the risk of RCP seal failures given a loss of all seal cooling/injection.

On the other hand, some plant design features increase the risk for this event. The most notable is that the main generator powers the safety-related AC buses, which renders these buses vulnerable to failure of the feeder circuit breakers to open. These postulated breaker failures result in the applicable safety-related bus(es) being deenergized, with the operators unable to align alternate power sources [e.g., emergency diesel generator, alternate transformer]. Another negative feature is that the safety- and nonsafety-related buses share the same cubicle for the respective trains. Therefore, a fault (such as a HEAF) results in a loss of all safety- and nonsafety-related power for the affected train. These negative design features are mitigated by the positive elements previously noted.

Subsequent inspections by the NRC staff identified two licensee performance deficiencies and two unresolved issues. The performance deficiencies were due to the licensee failure to (1) implement adequate fire watches following a HEAF on 4.16 kV safety related bus 3A, which resulted in inadequate fire detection capability in switchgear room 3B for approximately 28 hours, and (2) incorporate appropriate instructions to prevent foreign material from entering nearby electrical equipment when installing Thermo-Lag insulation. Both findings were determined to be *Green* (i.e., very low safety significance).

Summary of Analysis Results. This operational event resulted in a best estimate CCDP of 3×10^{-6}. The detailed ASP analysis can be found in the enclosure.

If you have any questions, please contact me at 301-415-6459 or Michael.Wentzel@nrc.gov.

Sincerely,

Michael J. Wentzel, Project Manager
Plant Licensing Branch II-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-250

Enclosure:
Final Accident Sequence Precursor Analysis

cc: Listserv

ENCLOSURE

Final Accident Sequence Precursor Analysis - Turkey Point Nuclear Generating Station (Unit 3), Loss of 3A 4kV Vital Bus Results in Reactor Trip, Safety System Actuations, and Loss of Safety Injection Function (LER 250-2017-001) - Precursor

Final ASP Program Analysis – Precursor

Accident Sequence Precursor Program – Office of Nuclear Regulatory Research			
Turkey Point Nuclear Generating Station, Unit 3	Loss of 3A 4kV Vital Bus Results in Reactor Trip, Safety System Actuations, and Loss of Safety Injection Function		
Event Date: 3/18/2017	**LER:** 250-2017-001 **IRs:** 05000250/2017008 and 05000250/2017002	**CCDP** = 3×10^{-6}	
Plant Type: Westinghouse 3-Loop Pressurized-Water Reactor (PWR) with Dry, Ambient Pressure Containment			
Plant Operating Mode (Reactor Power Level): Mode 1 (100% Reactor Power)			
Analyst: Chris Hunter	**Reviewer:** Ian Gifford	**Contributors:** N/A	**Approval Date:** 02/12/2018

EXECUTIVE SUMMARY

On March 18, 2017, at approximately 11:07 a.m., the Turkey Point, Unit 3 reactor tripped due to a trip of the reactor coolant pumps (RCPs) caused by a high-energy arc fault (HEAF) on the 4.16 kilovolt (kV) safety-related alternating current (AC) bus 3A. The site declared an Alert because of smoke in switchgear room 3A. Auxiliary feedwater (AFW) actuated as expected due to low steam generator (SG) level. Operators closed the main steam isolation valves, per emergency operating procedures, and used SG atmospheric dump valves for decay heat removal. Each unit has two high-head safety injection (HHSI) pumps, which are shared between the two units. Both Unit 4 HHSI pumps were out of service for maintenance at the time of event. This maintenance combined with the failure of bus 3A resulted in three of the four HHSI pumps being unavailable.[1] Both Unit 4 HHSI pumps were restored at 1:36 p.m. on March 18th.

This event was modeled as a loss of 4.16 kV bus 3A initiating event with the Unit 4 HHSI pumps unavailable due to maintenance. Given the modeling assumptions used in this analysis, the conditional core damage probability (CCDP) was calculated to be 3×10^{-6}. For most Westinghouse PWRs, a similar event often results in a CCDP greater than 10^{-5}, with the results dominated by the loss of AFW and feed-and-bleed cooling from (postulated) random failures of the opposite train(s) or loss of RCP seal cooling scenarios with a subsequent seal failure resulting in a loss-of-coolant accident (LOCA).[2] However, Turkey Point has some unique plant design features that mitigate the risk of this event. The most notable is that each units' safety-related direct current (DC) buses have battery-charging capability from both units. This is important because the three turbine-driven AFW pumps (also unique to Turkey Point), remain available during a postulated loss of all safety-related AC power.[3,4] In addition, SG level

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1 The high-pressure injection safety function can be fulfilled by one HHSI pump.

2 Results are based on calculations using the SPAR models of other Westinghouse 3- and 4-loop plants that include a loss of safety-related AC bus initiating event.

3 Turkey Point is the only PWR that has a three turbine-driven AFW pump configuration. All other plants have a combination of motor- and turbine/diesel-driven pumps.

4 For most PWRs, operators have the capability for continued operation of turbine-driven AFW pump(s) after battery depletion, and this action is often credited in PRAs (including some SPAR models). However, there is variance among risk analysts on the likelihood of success for "blind" feeding the SGs and reaching a safe/stable end state given the potential for underfill/overfill.

indication could be maintained throughout the most severe postulated event. Turkey Point also has a nonsafety-related standby SG feedwater system available to provide inventory makeup to the SGs. Another key plant feature is the installation of N9000 Flowserve RCP seals, which substantially decrease the risk of RCP seal failures given a loss of all seal cooling/injection.

On the other hand, some plant design features increase the risk for this event. The most notable is that the main generator powers the safety-related AC buses, which renders these buses vulnerable to failure of the feeder circuit breakers to open. These postulated breaker failures result in the applicable safety-related bus(es) being deenergized, with the operators unable to align alternate power sources [e.g., emergency diesel generator (EDG), alternate transformer]. Another negative feature is that the safety- and nonsafety-related buses share the same cubicle for the respective trains. Therefore, a fault (such as a HEAF) results in a loss of all safety- and nonsafety-related power for the affected train. These negative design features are mitigated by the positive elements previously noted.

Subsequent inspections by the NRC identified two licensee performance deficiencies and two unresolved issues (URIs). The performance deficiencies were due to the licensee failure to (1) implement adequate fire watches following a HEAF on 4.16 kV safety related bus 3A, which resulted in inadequate fire detection capability in switchgear room 3B for approximately 28 hours, and (2) incorporate appropriate instructions to prevent foreign material from entering nearby electrical equipment when installing Thermo-Lag insulation. Both findings were determined to be *Green* (i.e., very low safety significance).

EVENT DETAILS

Event Description. On March 18, 2017, at approximately 11:07 a.m., the Turkey Point, Unit 3 reactor tripped due to a trip of the RCPs caused by a HEAF on the 4.16 kV safety-related AC bus 3A. The site declared an Alert because of smoke in switchgear room 3A. Operators closed the main steam isolation valves, per emergency operating procedures. AFW actuated as expected due to low SG level. In conjunction with AFW, the SG atmospheric dump valves were used for decay heat removal. EDG 3A automatically started; however, it did not load onto bus 3A due to the bus lockout caused by the HEAF. Operators secured EDG 3A at 1:32 p.m. on March 18th. The reactor was stabilized in Mode 3, while Unit 4 remained operating at 100 percent power. The loss of the 3A 4kV bus required a plant shutdown to Mode 5 (cold shutdown) in accordance with technical specifications (TS). The plant entered Mode 5 at 12:50 p.m. on March 19th.

The Unit 4 HHSI pumps were out of service for maintenance at the time of event. As result of this maintenance and the unavailability of 4.16 kV bus 3A, three of the four HHSI pumps were unavailable (i.e., only the Unit 3 train B pump remained available). Both Unit 4 HHSI pumps were restored at 1:36 p.m. on March 18th.

Additional information is provided in licensee event report (LER) 250-2017-001 (Ref. 1) and inspection report (IR) 05000250/2017008 (Ref. 2).

Cause. The direct cause of the HEAF in 4.16 kV safety-related bus 3A was foreign material in the reactor coil cubicle. The root cause was determined to be an inadequate Thermo-Lag insulation installation procedure, which did not address control of foreign material nor provide precautions for controlling airborne debris fibers generated during installation of insulation.

MODELING

SDP Results/Basis for ASP Analysis. The ASP Program performs independent analyses for initiating events. ASP analyses of initiating events account for all failures/degraded conditions and unavailabilities (e.g., equipment out for test/maintenance) that occurred during the event, regardless of licensee performance.[5] Additional LERs were reviewed to determine if concurrent unavailabilities existed during the March 18, 2017, event. No windowed events or concurrent degraded operating conditions were identified.

In response to this event, the NRC performed a special inspection per Management Directive 8.3, "NRC Incident Investigation Program." The special inspection (as documented in IR 05000250/2017008) revealed four URIs. Specifically, inspectors identified issues concerning the following:

- The establishment of fire watches for the 4.16 kV switchgear rooms following the event (URI 05000250/2017008-01).
- The licensee's procedures and practices for accounting for risk on the opposite unit with equipment removed from service (URI 05000250/2017008-02).
- The potential failure of the licensee to properly control the spread of airborne particulates generated from the installation of Thermo-Lag insulation material on cable trays and conduits inside the 4.16 kV switchgear room 3A (URI 05000250/2017008-03).
- Potential discrepancies between the licensee's design documentation and the installed configuration of busses inside the reactor coil cabinet (URI 05000250/2017008-04).

Subsequent inspections [as documented in IR 05000250/2017002 (Ref. 3)] revealed two licensee performance deficiencies associated with URIs 05000250/2017008-01 and 05000250/2017008-03. Specifically, the licensee failed to (1) implement adequate fire watches following a HEAF on 4.16 kV safety-related bus 3A, which resulted in inadequate fire detection capability in switchgear room 3B for approximately 28 hours, and (2) incorporate appropriate instructions to prevent foreign material from entering nearby electrical equipment when installing Thermo-Lag insulation. Both findings were determined to be *Green* (i.e., very low safety significance). The other two URIs remain open. LER 250-2017-001 was closed in IR 05000250/2017002.

Analysis Type. A test/limited use version of the Turkey Point Nuclear Generating Station standardized plant analysis risk (SPAR) model, created on January 18, 2018, was used for this initiating event analysis. The key model changes in this test/limited used model include the following:

- Revised RCP seal modeling given the installation of N9000 Flowserve RCP seals,
- Modification of HHSI pump success criterion requiring only one-of-four pumps (instead of two) to mitigate small and medium LOCAs, and
- Crediting turbine-driven AFW pumps or the standby SG feedwater pumps to achieve a safe/stable end state for loss of all safety-related AC power scenarios (assuming no LOCA) with available safety-related DC power, which either unit can supply.

[5] ASP analyses also account for any degraded condition(s) identified after the initiating event occurred, if the failure/degradation exposure period(s) overlapped the initiating event date.

SPAR Model Modifications. The following modifications were required for this initiating event assessment:

- In ASP analyses, recovery credit for EDG failures is limited to cases where event information supports credit for EDG recovery. Therefore, the DGR-02H (*diesel generator recovery in 2 hours*) top event (including applicable event tree branching) was eliminated from the station blackout (SBO) event tree. The modified SBO event tree is shown in Figure A-3.
- To prevent risk contributions from certain anticipated transient without scram (ATWS) cut sets that do not apply to this assessment, the complement basic event OEP-VCF-LP-CLOPT (*consequential loss of offsite power—transient*) was inserted under gate RPS-1 (*electrical failures*) in the RPS (*reactor protection system fault tree*). An ATWS is only possible during a consequential loss of offsite power (LOOP) if the rods fail to insert into the reactor (i.e., they are mechanically stuck). The modified RPS fault tree is shown in Figure B-1.
- During the event, nonsafety-related AC bus 3C remained energized and, therefore, the motor-driven standby SG feedwater pump was available to provide inventory makeup to the SGs. This pump would also be available for the dominant (postulated) scenarios in this analysis (i.e., loss of all safety-related 4.16 kV power). To ensure that credit for this pump is provided in this analysis, basic events HE-LOOP (*house event—loss of offsite power initiating event has occurred*) and HE-LOSP-3C (*loss of division 3C offsite power flag*) were deleted from the ACP-3C-AC (*Turkey Point 3 and 4 PWR B division 3C AC power system*) fault tree. The modified ACP-3C-AC fault tree is shown in Figure B-2.

Key Modeling Assumptions. The following modeling assumptions were determined to be significant to the modeling of this event analysis:

- This analysis models the March 18, 2017, reactor trip at Turkey Point Nuclear Generating Station, Unit 3 as a loss of bus 3A initiating event (IE-LOACB-3A) due to the HEAF on the 4.16 kV safety-related bus 3A.[6] Therefore, the probability for IE-LOACB-3A was set to 1.0; all other initiating event probabilities were set to zero.
- Basic events HPI-MDP-TM-4P2154A (*HHSI MDP 4-P215A unavailable due to maintenance*) and HPI-MDP-TM-4P215B (*HHSI MDP 4-P215B unavailable due to maintenance*) were set to TRUE because both pumps were unavailable due to maintenance at the time of the event. Note that the Unit 4 HHSI pumps were restored in approximately 2.5 hours. Therefore, recovery credit for these pumps may be warranted for certain accident sequences (i.e., scenarios in which sufficient time is available to operators for recovery). However, the applicable accident sequences [e.g., stuck-open power-operated relief valve (PORV)] for this analysis have a core uncovery time of less than 2 hours; therefore, no recovery credit for the Unit 4 HHSI pumps is provided.
- Basic events BAT-MDP-TM-P3B (*boric acid pump 3B out due to test or maintenance*) and HPI-MDP-TM-3P215B (*HPI MDP 3-P215B unavailable due to test or maintenance*) were set to FALSE because the TS prohibit rendering these pumps unavailable due to testing/maintenance while the Unit 4 HHSI pumps were undergoing maintenance.
- Basic event ACP-XHE-XM-CLRBKR (*operator fails to clear breaker*) was set to TRUE because if breaker 3AB02 had failed open, operators would have been unable to align

[6] The event tree associated with the loss of 4.16 kV safety-related bus 3A was not used in this analysis because this event tree assumes that feedwater and the condenser heat sink are available. Feedwater and the condenser heat sink were unavailable during the March 18th event.

alternate power sources to supply safety-related bus 3B.[7] Given the short time period for the dominant scenarios in this analysis (i.e., 1–2 hours), there would likely not be sufficient time for maintenance/troubleshooting activities to repair the failure. In addition, repair/troubleshooting activities are not typically credited in ASP analyses.

ANALYSIS RESULTS

CCDP. The CCDP for this analysis is calculated to be 3.22×10^{-6}. The ASP Program acceptance threshold is a CCDP of 1×10^{-6} or the CCDP equivalent of an uncomplicated reactor trip with a non-recoverable loss of feedwater or loss of condenser heat sink, whichever is greater. This CCDP equivalent for Turkey Point, Unit 3 is 6.0×10^{-7}. Therefore, this event is a precursor.

Dominant Sequence. The dominant accident sequence is LAC3A sequence 13-16-22 (CCDP = 2.30×10^{-6}), which contributes approximately 71 percent of the total internal events CCDP. The dominant sequences that contribute at least 1.0 percent to the total internal events CCDP are provided in the following table. The dominant sequence is shown graphically in Figures A-1 through A-4 in Appendix A.

Sequence	CCDP	Percentage	Description
LAC3A 13-16-22	2.30E-6	71.4%	Loss of safety-related bus 3A initiating event; successful reactor trip; subsequent loss of bus 3B results in a loss of all safety-related AC power; AFW succeeds; a PORV fails to reclose resulting in a LOCA; all HHSI pumps are unavailable due to no electrical power (Unit 3) or maintenance (Unit 4), which results in core damage
LAC3A 13-16-20	2.68E-7	8.3%	Loss of safety-related bus 3A initiating event; successful reactor trip; subsequent loss of bus 3B results in a loss of all safety-related AC power; AFW succeeds; RCP seal injection/cooling is lost and a subsequent RCP seal LOCA occurs; all HHSI pumps are unavailable due to no electrical power (Unit 3) or maintenance (Unit 4), which results in core damage
LAC3A 02-9-05	1.21E-7	3.8%	Loss of safety-related bus 3A initiating event; successful reactor trip; AFW succeeds; RCP seal injection/cooling is lost and a subsequent RCP seal LOCA occurs due operators failing to trip the RCPs; high-pressure injection succeeds; accumulators successfully inject in the reactor coolant system; secondary-side cooldown fails, and high-pressure recirculation fails resulting in core damage
LAC3A 08	1.18E-7	3.7%	Loss of safety-related bus 3A initiating event; successful reactor trip; AFW succeeds; a PORV fails to reclose resulting in a LOCA; high-pressure injection fails resulting in core damage
LAC3A 13-16-24	1.04E-7	3.2%	Loss of safety-related bus 3A initiating event; successful reactor trip; subsequent loss of bus 3B results in a loss of all safety-related AC power; AFW and standby SG feedwater fail resulting in core damage

[7] The SPAR model has a placeholder probability in the base model.

Sequence	CCDP	Percentage	Description
LAC3A 14-08	8.45E-8	2.6%	Loss of safety-related bus 3A initiating event; reactor trip fails resulting in an ATWS; AFW succeeds; emergency boration fails resulting in core damage
LAC3A 05	8.09E-8	2.5%	Loss of safety-related bus 3A initiating event; successful reactor trip; AFW succeeds; a PORV fails to reclose resulting in a LOCA; high-pressure injection succeeds; secondary-side cooldown succeeds, residual heat removal fails, and high-pressure recirculation fails resulting in core damage
LAC3A 14-10	5.25E-8	1.6%	Loss of safety-related bus 3A initiating event; reactor trip fails resulting in ATWS; AFW succeeds; emergency boration fails resulting in core damage
Total	**3.22E-6**	**100.0%**	

REFERENCES

1. Turkey Point Nuclear Generating Station, "LER 250-2017-001 – Reactor Trip, Auxiliary Feed Water and Emergency Diesel Generator 3A Actuations, Loss of Safety Injection Function, and Completion of Technical Specification Required Shutdown," dated May 16, 2017 (ADAMS Accession No. ML17136A372).

2. U.S. Nuclear Regulatory Commission, "Turkey Point Nuclear Generating Station – NRC Reactive Inspection Report 05000250/2017008 and 05000251/2017008," dated May 12, 2017 (ADAMS Accession No. ML17132A258).

3. U.S. Nuclear Regulatory Commission, "Turkey Point Nuclear Generating Station – NRC Integrated Inspection Report 05000250/2017002, 05000251/2017002," dated August 11, 2017 (ADAMS Accession No. ML17223A012).

Appendix A: Key Event Trees

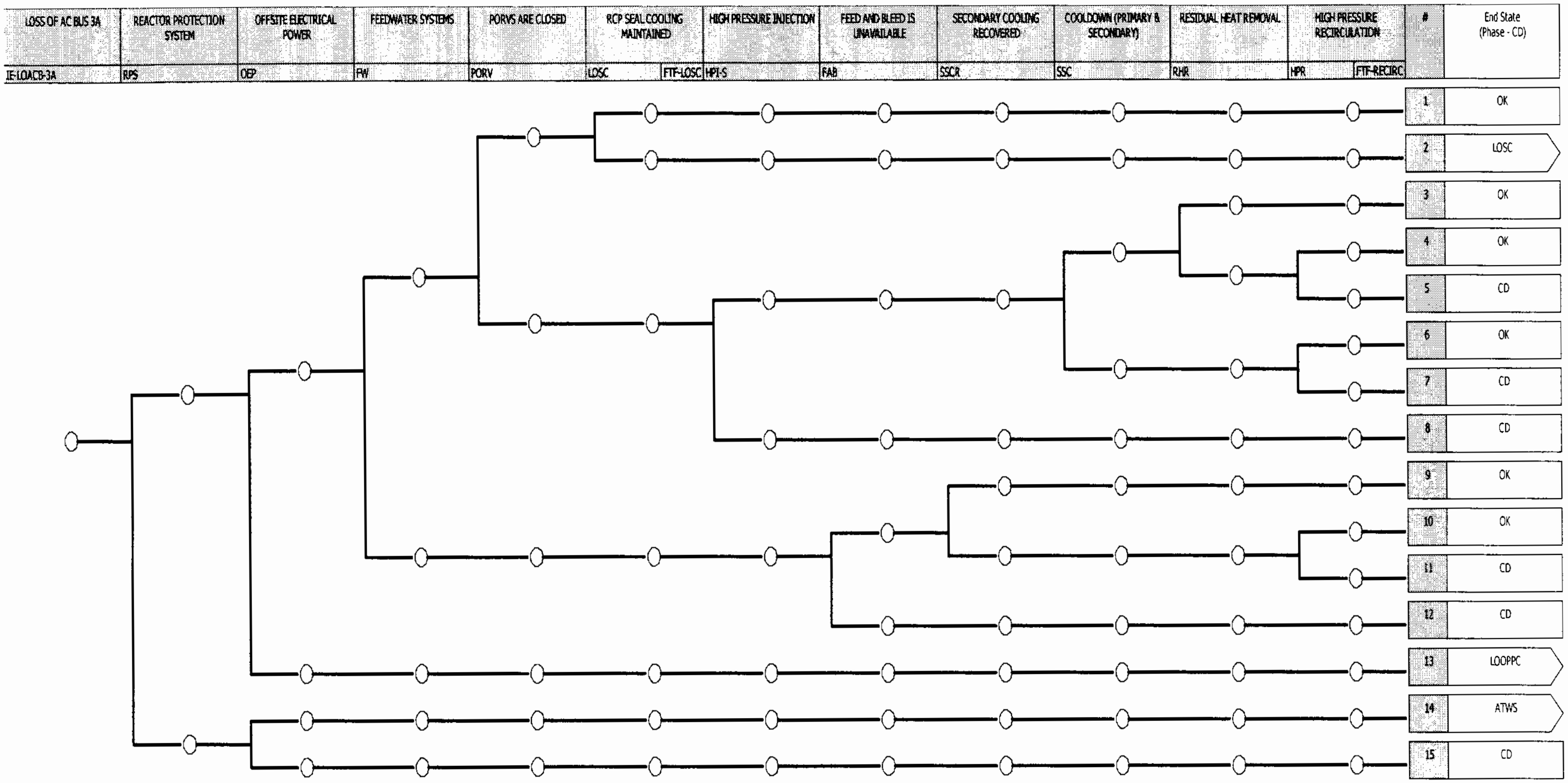

Figure A-1. Turkey Point Loss of 4.16kV Safety-Related Bus 3A Event Tree

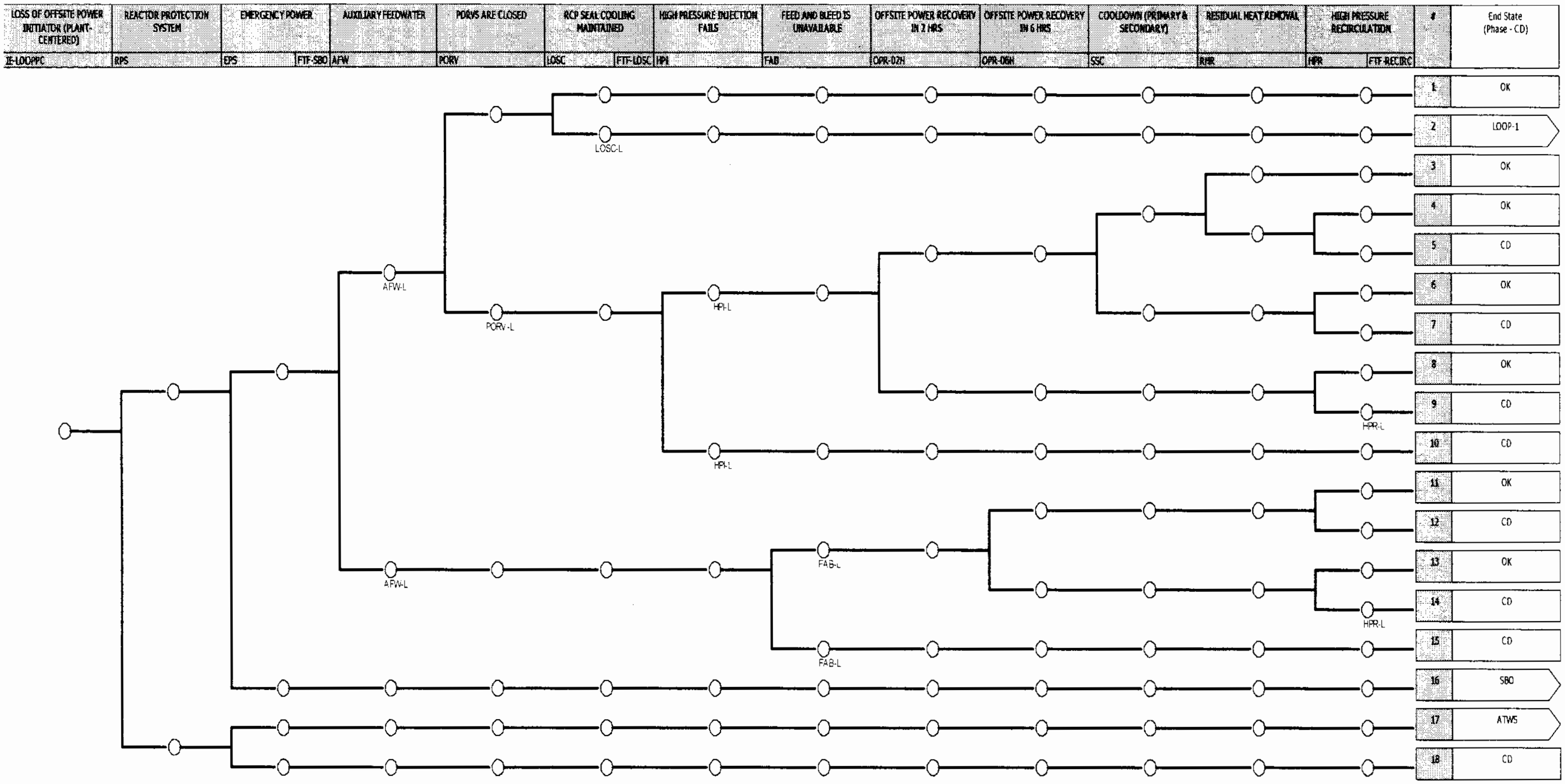

Figure A-2. Turkey Point Plant-Centered LOOP Event Tree

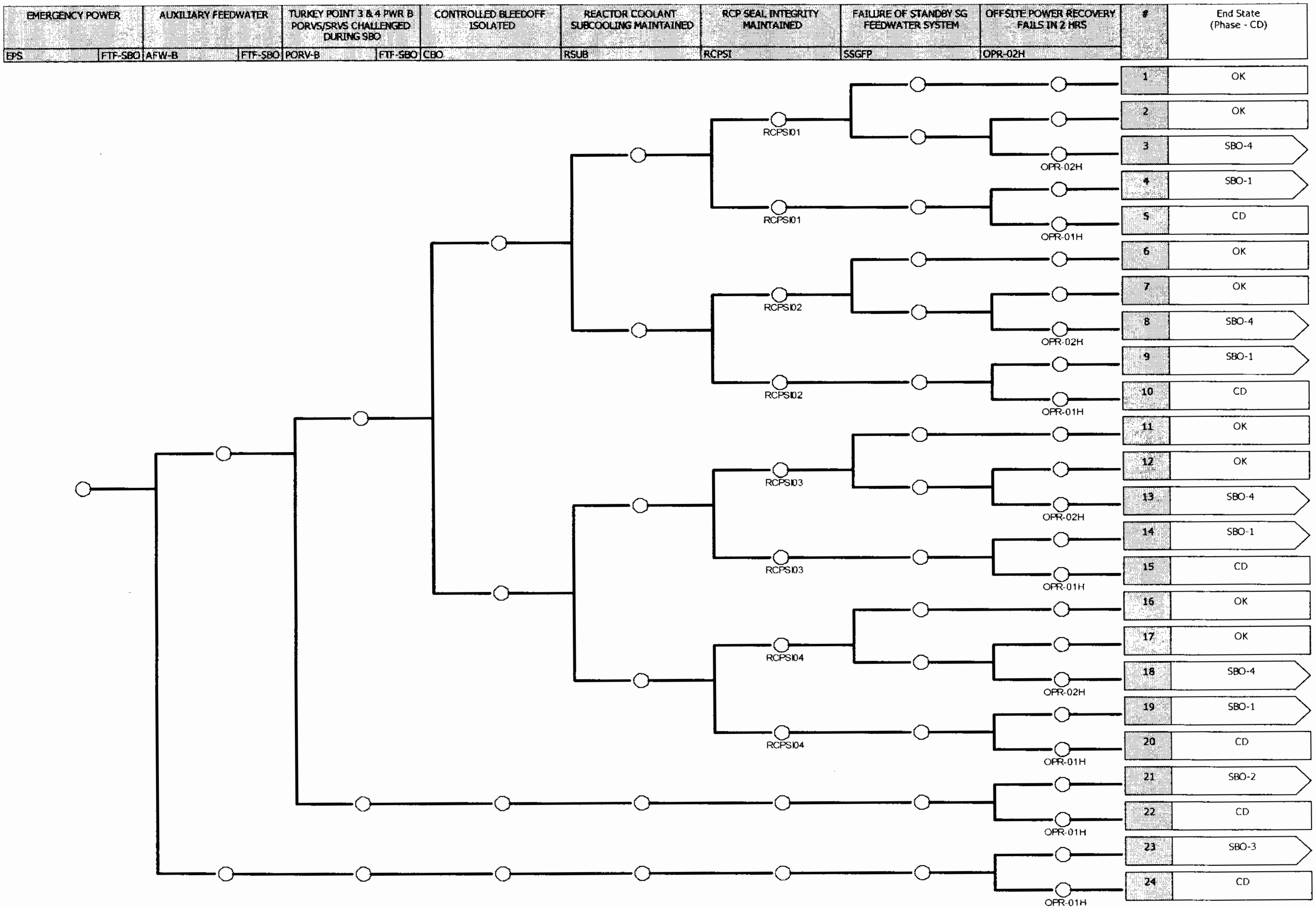

Figure A-3. Modified Turkey Point SBO Event Tree

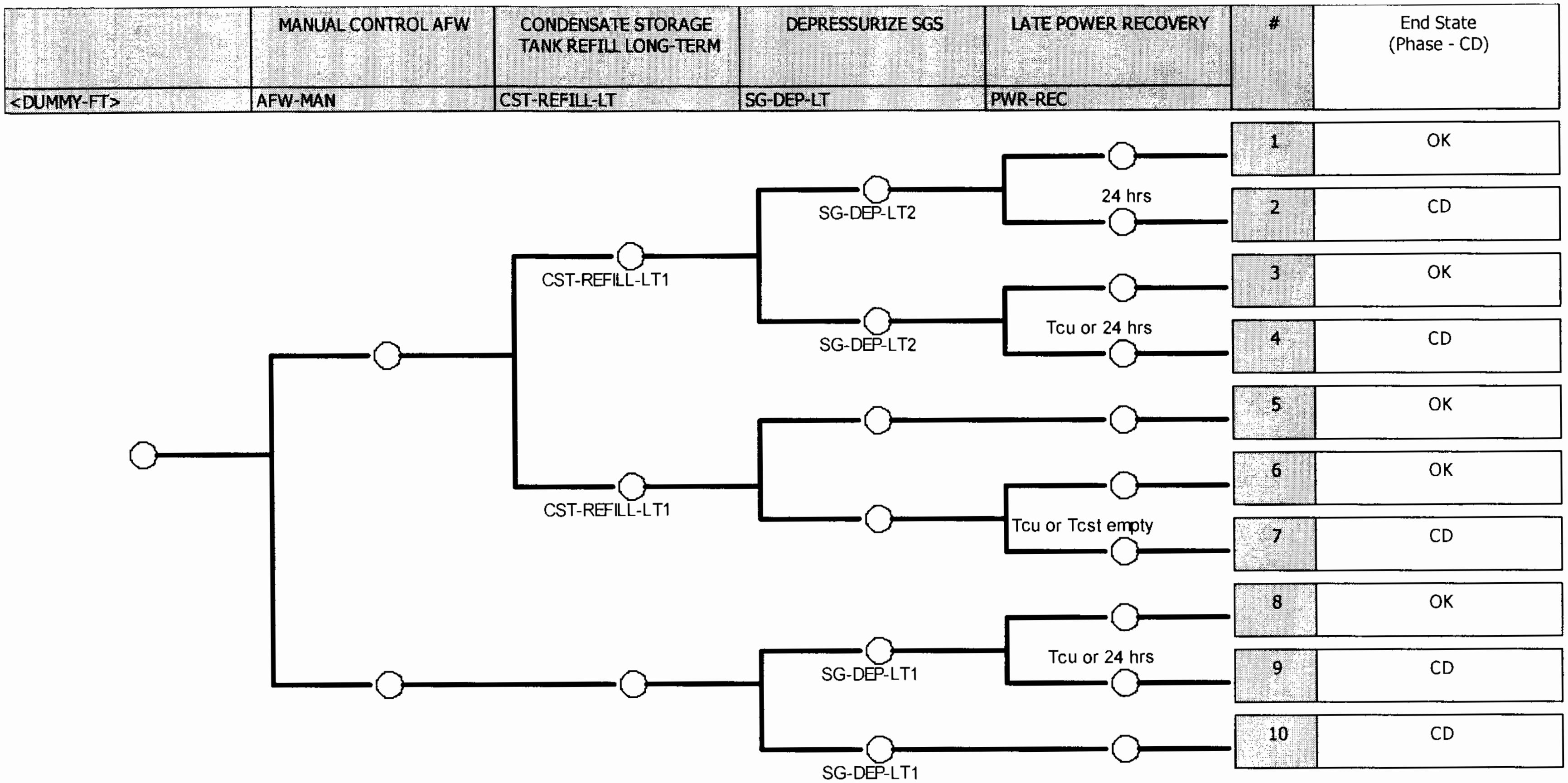

Figure A-4. Turkey Point SBO-4 Event Tree

Appendix B: Modified Fault Tree

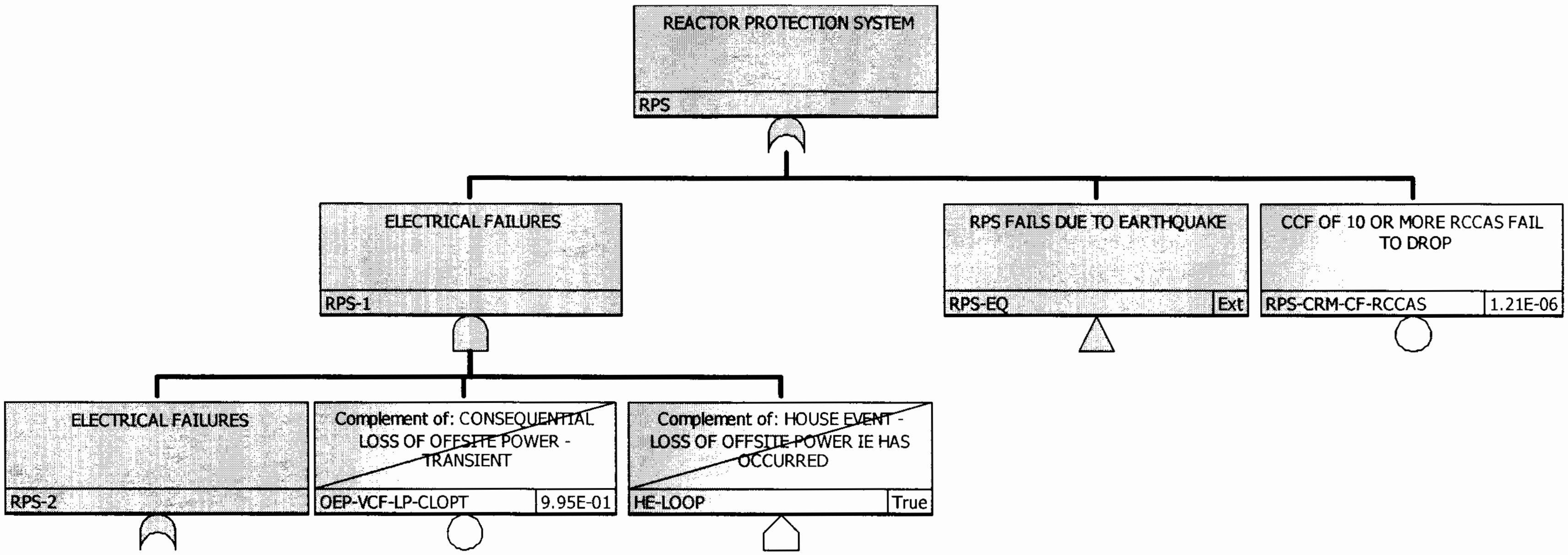

Figure B-1. Modified Turkey Point RPS Fault Tree

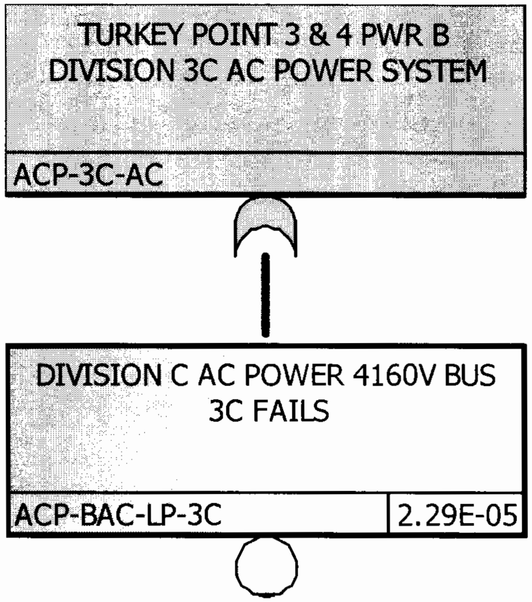

Figure B-2. Modified Turkey Point ACP-3C-AC Fault Tree

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