Final ASP Program Analysis – Reject

Accident Sequence Precursor Program – Office of Nuclear Regulatory Research			
Oconee Nuclear Station	Loss of both Keowee Hydroelectric Units due to Human Error		
Event Date: 6/16/2017	**LER:** 269-2017-001 **IRs:** TBD		**ΔCDP =** 6×10^{-7}
Plant Type: Babcock & Wilcox Lowered Loop Pressurized-Water Reactor 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:** 12/07/2017

EVENT DETAILS

Event Description. On June 16, 2017, at approximately 7:40 a.m., workers were implementing a modification to governor actuator cabinets 1 and 2 located within the Keowee Hydroelectric Station. At approximately 9:07 a.m., alarm indications for a breaker on Keowee Hydroelectric Unit (KHU) 1 were received on the operator aid computer (OAC) alarm screens located in the Keowee control room (KCR). At 10:20 a.m., similar OAC alarm indications were received in the KCR associated with a breaker on KHU 2. However, the Keowee operator was performing his rounds and was not in the KCR to acknowledge these alarms.

Critical alarms associated with the KHUs are typically received in both the KCR and the Oconee main control rooms. In addition, critical alarms trigger an emergency lockout of the affected KHU. However, in this instance, alarms in the Oconee main control rooms were not generated and no emergency lockout condition on the KHUs was triggered due to the failure mode design of the repositioned breakers.

At 1:21 p.m. of the same day, while attempting to start KHU 2 for commercial generation, an "incomplete start" alarm was received in the KCR. Subsequent investigation revealed that both KHUs would not have been able to fulfil their safety function due to the breakers being out of position. As required by technical specifications, the standby buses were energized from a dedicated Lee Station combustion turbine generator (CTG) from an isolated power path at 5:15 p.m. Subsequent troubleshooting efforts concluded that the two KHU breakers were fully functional and had likely been inadvertently repositioned during work being performed in the area. Both breakers were returned to the closed position and the KHUs were successfully tested with KHU 1 declared operable at 9:50 p.m. and KHU 2 declared operable at 11:51 p.m. Additional information is provided in licensee event report (LER) 269-2017-001 (Ref. 1).

Cause. The direct cause of both KHUs being unable to fulfill their safety function is attributed to the two breakers being out of position due to human error.

MODELING

SDP Results/Basis for ASP Analysis. To date, no inspection reports have been released that provided additional information on this event. An independent ASP analysis was performed given the lack of an identified performance deficiency and the potential risk significance of this event.

Analysis Type. A test/limited use version of the Oconee standardized plant analysis risk (SPAR) model, created in November 2017, was used for this condition assessment. The key model changes in this test/limited used model included revised fault tree logic for the safety-related alternating current (AC) buses and credit for the Lee Station CTGs for certain station blackout (SBO) sequences.[1]

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

- In ASP analyses, recovery/repair credit for backup emergency power sources is limited to cases where event information supports its inclusion. For Oconee, the maximum time allowed for potential recovery/repair of the KHUs is 4 hours during a postulated loss of offsite power (LOOP) and subsequent SBO. During this event, it took Keowee operators approximately 13 hours to restore a KHU to operability; therefore, no recovery credit for the failure of the KHUs was provided in this analysis. The KEOWEE-4H (*Keowee recovered in 4 hours*) top event (including applicable event tree branching) was eliminated from the SBO event tree to remove this credit from the base SPAR model. The modified Oconee SBO event tree used in this analysis is shown in Figure A-2.
- The base test/limited SPAR model includes fault tree logic associated with a 100-kilovolt (kV) offsite electrical power source from the Lee Station Switchyard; however, credit for this alternate source of power is not provided because of the uncertainty associated with electrical power during different LOOP types. For plant- and switchyard-centered LOOPs, it is expected that the 100 kV electrical power from the Lee Station Switchyard would be available, allowing operators to manual align this source to the safety-related AC buses (if needed).[2] To provide this credit, the basic event ZV-TRUE (*logical true event*) was removed from the EPS-MFB1 (*emergency power main feeder bus 1*) and EPS-MFB2 (*emergency power main feeder bus 2*) fault trees.

Exposure Period. Both KHUs were unable to fulfil their safety function for approximately 12 hours.[3] In addition, KHUs 1 and 2 were unavailable individually for approximately 73 minutes and 121 minutes, respectively.[4] Calculations show the short-term unavailability of a single KHU has a negligible impact on risk. As such, this analysis focuses only on the concurrent unavailability of both KHUs.

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1 Credit for aligning the Lee Station CTGs is only provided for 4-hour SBO sequences. Credit for the CTGs for the 1-hour SBO sequences is not provided because of the uncertainty associated with the time required to start the CTGs and align them to the Oconee safety-related buses. The lack of credit for the CTGs for the 1-hour SBO sequences is potentially conservative. Consideration for crediting the CTGs for the 1-hour SBO sequences will be evaluated as part of future SPAR model changes.

2 Note that the base test/limited use SPAR model has the necessary fault tree logic (EPS-LEE) to prevent any credit for the Lee Station Switchyard during grid- and weather-related LOOPs.

3 Both KHUs were concurrently unavailable from 10:20 a.m. to 9:50 p.m. on June 16th.

4 KHU 1 was unavailable by itself from 9:07 a.m. to 10:20 a.m. on June 16th. KHU 2 was unavailable by itself from 9:50 p.m. to 11:51 p.m. on June 16th.

Key Modeling Assumptions. The following modeling assumptions were determined to be significant to the modeling of this bounding condition assessment:

- Basic event EPS-HTG-CF-KEOS (*common cause failure of Keowee hydro units to start*) was set to TRUE because the out of position breakers would have prevented both KHUs from starting during a postulated LOOP.

ANALYSIS RESULTS

ΔCDP. The increase in core damage probability (ΔCDP) for this analysis is calculated to be 6.0×10^{-7}. The ASP Program acceptance threshold is a ΔCDP of 1×10^{-6} for degraded conditions; therefore, this event is not a precursor. The dominant initiating events for this analysis are provided in the following table:

Event Tree	ΔCDP	Percentage	Description
LOOPGR	3.00×10^{-7}	49.8%	Loss of Offsite Power (Grid-Related)
LOOPWR	2.99×10^{-7}	49.6%	Loss of Offsite Power (Weather-Related)

Dominant Sequence. The dominant accident sequence is grid-related LOOP/SBO sequence 16-22 (ΔCDP = 2.6×10^{-7}), which contributes approximately 42 percent of the total internal events ΔCDP. The dominant sequences that contribute at least 1.0 percent to the total internal events ΔCDP are provided in the following table. The dominant sequence is shown graphically in Figure A-1 and Figure A-2 in Appendix A.

Sequence	ΔCDP	Percentage	Description
LOOPGR 16-22	2.56×10^{-7}	42.4%	Grid-related LOOP initiating event; successful reactor trip; emergency power system failure results in SBO; auxiliary feedwater (AFW) fails; and operators fail to restore offsite power within 1 hour
LOOPWR 16-22	1.45×10^{-7}	24.1%	Weather-related LOOP initiating event; successful reactor trip; emergency power system failure results in SBO; AFW fails; and operators fail to restore offsite power within 1 hour
LOOPWR 16-02-04	1.15×10^{-7}	18.9%	Weather-related LOOP initiating event; successful reactor trip; emergency power system failure results in SBO; AFW succeeds; safe shutdown facility (SSF) successfully provides reactor coolant pump (RCP) seal cooling; operators fail to restore offsite power within 4 hours; operators continue to feed the steam generators (SGs) via the SSF or the turbine-driven AFW pump; operators fail to restore offsite power within 24 hours
LOOPWR 16-08-04	2.16×10^{-8}	3.6%	Weather-related LOOP initiating event; successful reactor trip; emergency power system failure results in SBO; AFW succeeds; SSF fails to provide RCP seal cooling; RCP seal integrity is maintained; operators fail to restore offsite power within 4 hours; operators continue to feed the SGs using the turbine-driven AFW pump; operators fail to restore offsite power within 24 hours

Sequence	ΔCDP	Percentage	Description
LOOPGR 16-02-04	1.94×10^{-8}	3.2%	Grid-related LOOP initiating event; successful reactor trip; emergency power system failure results in SBO; AFW succeeds; SSF successfully provides RCP seal cooling, operators fail to restore offsite power within 4 hours, operators continue to feed the SGs via the SSF or the turbine-driven AFW pump, operators fail to restore offsite power within 24 hours
LOOPGR 16-08-10	1.20×10^{-8}	2.0%	Grid-related LOOP initiating event; successful reactor trip; emergency power system failure results in SBO; AFW succeeds; SSF fails to provide RCP seal cooling; RCP seal integrity is maintained; operators fail to restore offsite power within 4 hours; operators fail to manually to feed the SGs using the turbine-driven AFW pump
LOOPWR 16-08-10	1.16×10^{-8}	1.9%	Weather-related LOOP initiating event; successful reactor trip; emergency power system failure results in SBO; AFW succeeds; SSF fails to provide RCP seal cooling; RCP seal integrity is maintained; operators fail to restore offsite power within 4 hours; operators fail to manually to feed the SGs using the turbine-driven AFW pump
LOOPGR 16-20	6.14×10^{-9}	1.0%	Grid-related LOOP initiating event; successful reactor trip; emergency power system failure results in SBO; AFW fails; power-operated relief valve fail to close resulting in a loss-of-coolant accident; and operators fail to restore offsite power within 1 hour

REFERENCES

1. Oconee Nuclear Station, "LER 269/17-001 – Loss of both Keowee Hydroelectric Units Due to Human Error," dated August 9, 2017 (ML17256A516).

Appendix A: Key Event Trees

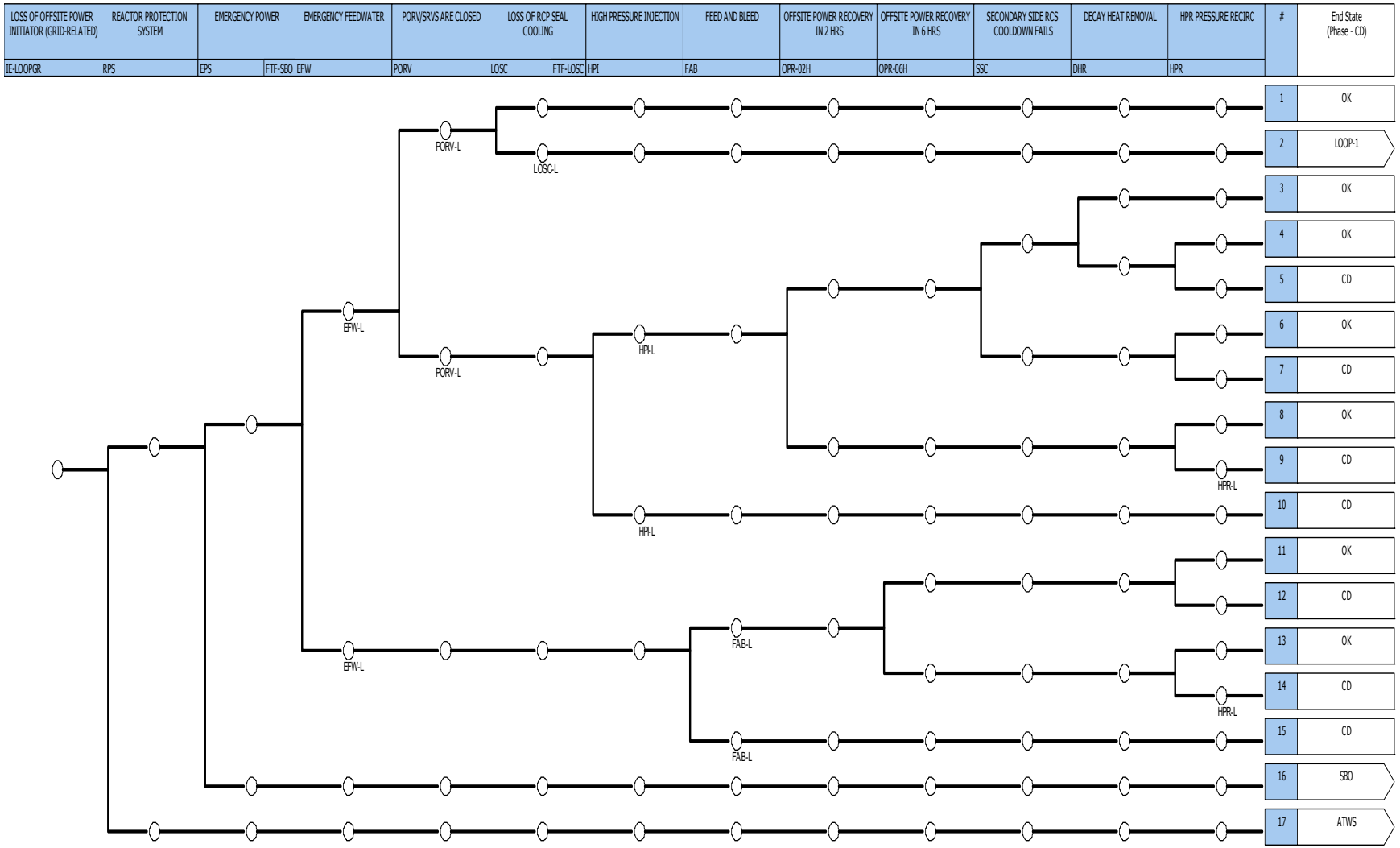

Figure A-1. Oconee Grid-Related LOOP Event Tree

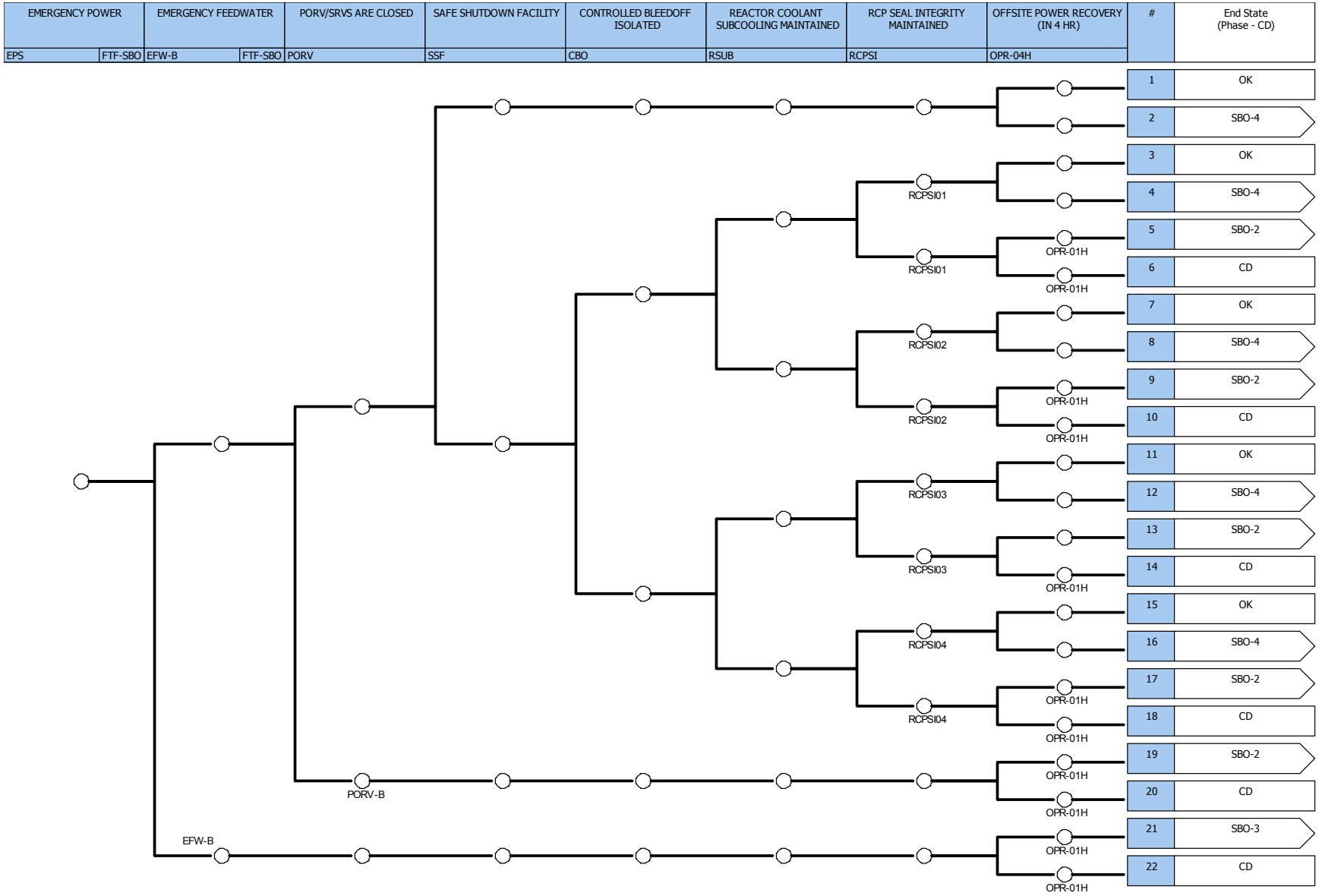

Figure A-2. Oconee SBO Event Tree (Modified)