Enclosure 6 to AEP-NRC-2015-52

Risk Analysis to Support Response to Requests for Additional Information Regarding One Time Emergency License Amendment Request to revise Technical Specification Section 3.8.1 to permit extending the Completion Time. (RAI-APLA 1)

AEP AMERICAN ELECTRIC POWER

D. C. COOK NUCLEAR PLANT

CALCULATION/REPORT COVER SHEET

Document No. PRA-QNT-005	Rev No. 0	☒ Full Rev ☐ Addendum ☐ Status Change

Title: Additional Calculation of Regulatory Guide 1.177 Risk Parameters for Potential One-Time Emergency Technical Specification Completion Time Change for Unit 1 AB EDG

STATUS: ☒ Approved ☐ Superseded ☐ Voided ☐ Information Only

Document Type/Class: ☒ Calculation ☐ Report ☐ Class 1 ☐ Class 2 ☒ Class 3

QUALITY CLASSIFICATION:	SYSTEM CODE:	UNIT NO.:	COMPUTER MEDIA:	REVIEW METHOD:
☐ Safety-Related ☐ Non-Safety Related with Special Requirements ☒ Non-Safety Related	NAPL	1	☐ Yes ☒ No	☒ Detailed Review ☐ Alternate Calculation ☐ Other ☐ N/A – Status/Class Change **Only**

Do any assumptions require later verification? ☐ Yes ☒ No If yes, AI No.

Description: See Purpose

This non-design calculation is exempted by the approver from the configuration management requirements of 12-EHP-5040-DES-003 section 3.4.5.

If the Reviewer is the Preparer's supervisor, the supervisor review is needed and is approved: ☒ N/A

Supervisor's Manager's Name	Title	Signature	Date

Qualification Matrix Verification

* The responsible Engineering Supervisor/Manager approval signature also serves to signify that the qualifications of the individual(s) assigned as Preparer(s) and Reviewer(s) and Independent Design Verifier(s) were verified in the Plant Qualification Matrix.

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☐ **Sign-offs for additional Preparer(s) and Reviewer(s) on next page**

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List of Abbreviations

AFW	Auxiliary Feedwater
AMSAC	ATWS Mitigating System Actuation Circuitry
ATWS	Anticipated Transient Without Scram
CCP	Centrifugal Charging Pump
CDF	Core Damage Frequency
CST	Condensate Storage Tank
CRDM	Control Rod Drive Mechanism
CTS	Containment Spray system
CVCS	Chemical and Volume Control System
ECCS	Emergency Core Cooling System
EDG	Emergency Diesel Generator
EOP	Emergency Operating Procedure
ESFAS	Engineered Safety Features Actuation System
ESW	Essential Service Water
FW	Feedwater
F-V	Fussell-Vesely
HEP	Human Error Probability
HFE	Human Failure Event
HLR	High Level Requirement
HSS	High Safety Significant
ICCDP	Integrated Conditional Core Damage Probability
ICLERP	Integrated Conditional Large Early Release Probability
IE	Internal Events
LERF	Large Early Release Frequency
LOCA	Loss of Coolant Accident
LSS	Low Safety Significant
MAAP	Modular Accident Analysis Program
MDAFP	Motor-Driven Auxiliary Feedwater Pump
MOR or MORW	Model of Record
MTI	Maintenance Technical – Instrument and Control
NRC	Nuclear Regulatory Commission
OOS	Out of service or Unavailable
PAC	Plant Air Compressor
PORV	Power-Operated Relief Valve
PRA	Probabilistic Risk Assessment
PDS	Plant Damage State
PRM	Plant Response Model
RAW	Risk Achievement Worth
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RHR	Residual Heat Removal
RWST	Refueling Water Storage Tank
SDG	Supplemental Diesel Generator
SBO	Station Blackout
SG	Steam Generator
SR	Supporting Requirement
SSPS	Solid State Protection System
SI	Safety Injection
SIP	Safety Injection Pump
TDAFP	Turbine-Driven Auxiliary Feedwater Pump
TS	Technical Specification

1 Purpose

This calculation provides clarifications on changes made to the 2009 PRA Model of Record and the Fire PRA Model of record in support of the Unit 1 AB EDG one time completion time extension. This information is intended to provide a response to the NRC's Request for Additional Information regarding the updated, but not yet peer reviewed Internal Events PRA model. It also provides clarification on items that were updated following the preliminary risk assessment in both the updated Internal Events and Fire PRA model.

2 Methodology

The PRA risk impact of operation with Unit 1 AB EDG unavailable was estimated using an application specific updated WinNUPRA PRA Model (Input 3.1) and an updated Fire PRA model (Input 3.2), modified for this application as described in Reference 7.17. Since the updated Internal Events model has not yet been peer reviewed, this calculation provides results from the 2009 Internal Events PRA Model of Record, for comparison purpose with the updated model. Regulatory Guide 1.177 (Reference 7.12) risk parameters are calculated using the following general equations:

$$\Delta CDF = CDF_{inst} - CDF_{base}$$

where

CDF_{inst} = the Unit 1 CDF value when only the Unit 1 AB EDG is unavailable, with appropriate allowances for the Unit 2-PAC & 1W-MDAFP OOS time and the operation and maintenance restrictions described below (Assumption 4.1) are in place

CDF_{base} = the Unit 1 "base case" zero maintenance CDF value (with the exceptions shown in Assumption 4.1).

$$\Delta LERF = LERF_{new} - LERF_{base}$$

where

$LERF_{inst}$ = the Unit 1 LERF value when only the Unit 1 AB EDG is unavailable, with an appropriate allowance for the Unit 2-PAC & 1W-MDAFP OOS time, and the operation and maintenance restrictions described below (Assumption 4.1) are in place

$LERF_{ave}$ = the Unit 1 "base case" zero maintenance LERF value (with the exceptions shown in Assumption 4.1).

ICCDP = (ΔCDF)*(Duration (days) / 365 days/year)

ICLERP = (ΔLERF)*(Duration (days) /365 days/year)

Consistent with the cases developed in Section 2 of Reference 7.17, two quantification cases are provided for the 2009 Internal Events model.

1. A baseline CDF and LERF value with zero maintenance other than the exceptions listed in Assumption 4.1, without credit for the SDS.
2. CDF and LERF values with the Unit 1 AB EDG failed, with zero maintenance other than the exceptions listed in Assumption 4.1, without credit for the SDS

3 Inputs

3.1 The 2009 WinNUPRA model of record (Reference 7.1) is currently undergoing a full model update. Results are provided from the 2009 model in this calculation, and are provided for comparison to the updated model documented in Reference 7.17.

3.2 The Fire PRA model of record (Reference 7.2) was changed for this application as described in Reference 7.17. The results from Reference 7.17 are used in this calculation.

4 Assumptions

4.1 The average PRA model test and maintenance factors for the following equipment are adjusted to match the out of service durations during the Unit 1 AB EDG unavailability:

- The Unit 1 West MDAFP was unavailable for approximately 28 hours. The test and maintenance term is therefore adjusted to 28 hrs/ (14 days * 24 hrs). This conservatively accounts for 28 hours of unavailability during the onetime extended EDG unavailability window.
- The Unit 2 PAC was unavailable for approximately 14 hours. The test and maintenance term is therefore adjusted to 14 hours/(14 days * 24 hours). This conservatively accounts for 14 hours of unavailability during the onetime extended EDG unavailability window.
- The Unit 1 Middle Heater Drain Pump remained out of service for the majority of the EDG unavailability. This pump is not modeled in the Internal Events or Fire PRA.
- Required surveillance runs with short-duration (~15 mins) unavailabilities are not considered. This includes surveillance tests on other EDGs to prove that they remain operable. For EDG runs, multiple equipment operators are stationed at the EDG being tested, such that the EDG can be restored in short order.

4.2 All previous assumptions listed in Reference 7.17 are used in this analysis, with the exception of the ESW crosstie configuration, since no flag settings exist in the 2009 Internal Events model to account for this configuration. This is judged to have an insignificant impact on the overall results, for the same reasons as Assumption 4.7 in Reference 7.17 for the Fire PRA.

5 Calculations

5.1 2009 Internal Events & Internal Flooding Model Items Addressed in Updated Model Pertinent to Unit 1 AB EDG CT Extension

The 2009 Internal Events & Internal Flooding PRA Model contains shortcomings that have the potential to impact the Unit 1 AB EDG Completion Time extension. The shortcomings, their resolution, and their impact to the assessment is provided in the table below.

Table 5.1-1 – Internal Events & Internal Flooding PRA Model Issues and Resolutions for Unit 1 AB EDG CT Extension

2009 Model of Record Identified Issue	Impact to 1 AB EDG CT Extension	Resolution in Updated Model
Average test and maintenance values were incorrectly squared due to a misunderstanding of the conditional probabilities involved with support system initiating events.	None. The test and maintenance configuration of the plant is known for the risk analysis.	Test and Maintenance values were adjusted back to their original values, and updated with the latest plant specific data.
ESW and CCW pump recovery terms were applied in internal flooding and dual unit SBO sequences in which pump repair was unlikely.	Small. Dual Unit SBO sequences are low probability and have a small impact on the assessment	Pump repair/recovery is no longer credited for Internal Flooding or Dual Unit SBO

2009 Model of Record Identified Issue	Impact to 1 AB EDG CT Extension	Resolution in Updated Model
No safety train alignment was considered for the SDGs. The SDGs are procedurally directed to be aligned to a single safety train on one unit. Although crews would be expected to re-align them to the alternate train if the first train incurred random equipment failures, no direct procedural guidance exists to direct this consideration.	Small. Dual Unit SBO sequences are low probability and have a small impact on the assessment	Safety Train alignment for the SDGs was added. This makes the updated model SBO contributions higher for the SDGs.
A reduction factor was incorrectly used for support system initiating events to reduce the contribution of common cause terms. This reduction factor was used to ensure the common cause failure only occurred during the technical specification allowed outage times during the year. Since common cause failure factors already include the consideration of the failures occurring within a short time period of each other, this reduction factor is unnecessary.	Significant Impact to the total Internal Events CDF, but not a significant impact to this assessment. Support system initiating events do not challenge offsite power availability and thus the unavailability of a single EDG does not significantly impact the assessment.	Reduction factor was removed. This significantly raises the CDF and LERF contribution from Loss of CCW and ESW in the updated model.
The WOG 2000 RCP Seal LOCA model was not fully incorporated. SBO offsite power recovery times were combined with Core Not Uncovered (CNU) probabilities rather than being justified by MAAP analyses.	Moderate. Plant Specific MAAP analysis provides a better realistic estimate of offsite power recovery times.	MAAP analyses have been performed for SBO and updated offsite power recovery times were used. This generally reduces the SBO contributions in the updated model.
The amount of sequences on event trees and the total number of event trees were unnecessarily complicated leading to quantification issues.	None. The quantification issues only impacted processing time and had no impact on results.	Event trees were simplified. No overall effect on the updated model.
Initiating event and component data is sourced from older data sources and out of date.	Moderate. Newer data is more representative of the current operating plant.	A full data update was performed for the model update. Component data generally improved, so this will reduce the contributions across the model.
Internal Flooding initiating events contained simplified HFEs for isolation of the break which require updating.	Very Small. Internal Flooding does not challenge offsite power availability and thus the unavailability of a single EDG has a minor impact on internal flooding.	Internal Events HFEs were updated to reflect correct HEPs. Minor change in overall flood contribution.

5.2 Clarification of Sources of Reduced Risk – Internal Events Model

Several HFEs related to offsite power were reviewed in the updated Internal Events model as part of the risk assessment. The HFEs which resulted in the majority of the CDF reduction from the preliminary assessment to the final assessment are discussed below:

Table 5.2-1 - Internal Events Model HFE Review Summary

HFE	Description	Original Assessed HEP value	Updated HEP value	Basis for change
1-----EXE-RCCHE	Operator Fails to perform RCS cooldown after SBO	2.8E-2	2.96E-04	Execution stress should not be high as assumed in the HRA due to large time to perform actions and ease of action. Added a recovery step in the execution. Procedure step requires operators to check SG pressure. This can be used as recovery in the HRA analysis.
0A-EP-TBUS---HE	Operator fails to align SDGs to Safety Bus	4.14E-2	1.39E-02	Changed time window to 1.62 hrs based on core uncovery time from MAAP Case L1-2-33d (Reference 7.7). Reduced stress level to low because of high SPAR-H ratio.
COMBO_41	Dependent HFE Combination of 1----- EXE-RCCHE and 0A-EP-TBUS---HE	4.14E-2	1.24E-04	The listed actions to not have a common cognitive event (different cues). They are sequential actions.
1C------ALIGNHE	Operator fails to fully open CCW to RHR Heat Exchanger valves after ECCS recirculation switchover	5.2E-3	2.60E-03	Decreased level of dependency to low due to high available time for action.

5.3 Fire PRA Model Items Addressed in Analysis Model Pertinent to Unit 1 AB EDG CT Extension

The Fire PRA Model of Record contains shortcomings that have the potential to impact the Unit 1 AB EDG Completion Time extension. The shortcomings, their resolution, and their impact to the assessment is provided in the table below.

Table 5.3-1 – Fire PRA Model Issues and Resolutions for Unit 1 AB EDG CT Extension

Fire PRA Model Identified Issue	Impact to 1 AB EDG CT Extension	Resolution for Risk Assessment
The Fire PRA reduced the success criteria for AFW from supplying 2 of 4 SGs to 1 of 4 SGs. This reduction requires containment spray to be available (References 7.6 and 7.7) to prevent containment failure since insufficient containment heat removal is provided by one SG. This is corrected in the Fire PRA model used for this application.	Non-conservative success criteria for AFW would have a moderate and non-conservative impact on the risk assessment.	This is corrected in the Fire PRA model used for this application.

Fire PRA Model Identified Issue	Impact to 1 AB EDG CT Extension	Resolution for Risk Assessment
An HFE was credited in the Fire PRA to re-power the Hydrogen Igniters after fires which left all the busses faulted on the fire affected unit. This action takes 3.5 hours to complete and it was identified late in the transition period that the time to core damage could be as little as 2 hours in some sequences (such as AFW failure). The HEP was averaged in the final model to account for this.	The value of the frequency weighted average HEP changes when the model configuration does, particularly if fire-induced SBO becomes more significant.	For this application, there is increased potential for this action to be required since the Unit 1 AB EDG is not available. Therefore, a risk mitigating action is taken to stage the alternate power supply such that the action can be completed within the 2 hour time window. No adjustment is made to the HEP on the basis of this action
The fire-induced SBO fault tree (1SBOINIT.LGC) was noted to contain an error. Successful operation of the TDAFP constituted success of the top gate, despite the fact that an RCP Seal LOCA would occur due to the blackout.	Since this application increases the likelihood of an SBO, this results in an increase in both the base model and the application results.	RCS inventory makeup via the CVCS crosstie was added to this event. Alternate success path based on MAAP analysis included a RCS cooldown.

5.4 Clarification of Sources of Reduced Risk – Fire PRA Model

In the Fire PRA model of record, the 480 gpm/pump Seal LOCA could not be mitigated by the CVCS crosstie based on MAAP analyses (Reference 7.7). This placed a significant emphasis on the HFE to trip the RCPs within 8 minutes (1-----CCW-RCPHEF). No RCS cooldown was credited in the model of record analysis, even though a cooldown is directed in the Emergency Remote Shutdown procedure (Reference 7.14) and in the Post-LOCA cooldown and depressurization procedure (Reference 7.16). For this risk assessment it was desired to show that there was significant conservatism in the importance of tripping the RCPs. The MAAP analysis was performed in Reference 7.17, Section 5.2, and shows successful mitigation of the 480 gpm/pump RCP seal LOCA with the cooldown credited. This significantly reduced the risk associated with tripping the RCPs.

In addition to the credit for performing an RCS cooldown, the HFEs in the table below were reviewed. In particular, 1ASD-SBONOTDPOMA was reviewed because it contributed the majority of the preliminary delta risk. After review and operator interview, this HFEs were re-evaluated in the HRA calculator at a reduced stress level, resulting in a reduction of the HEP. These changes, in combination with the credited cooldown provided the risk decrease from the preliminary delta risk values discussed with NRC.

Table 5.4-1 – Fire PRA HFE Review Summary

HFE	Description	Original Assessed HEP value	Updated HEP Value	Basis for Change
1ASD-SBONOTDPOMA	Operator Fails to Crosstie AFW and CVCS per Emergency Remote Shutdown (Reference 7.14) for fires that occur in the Main Control Room	4.9E-2	4.9E-2	HFE will retain the value of 4.9E-2 and be used ONLY for scenarios in which the fire occurs inside the main control room, and stress is expected to be high. Although, the HEP value in the HRA Calculator is 1.33E-02. This value was left at 4.9E-2 for conservatism in the final NFPA 805 model of record.

HFE	Description	Original Assessed HEP value	Updated HEP Value	Basis for Change
1FSBO--XTIE-OMA	Operator Fails to Crosstie AFW and CVCS per Emergency Remote Shutdown (Reference 7.14), for fires that do not occur in the Main Control Room	4.9E-2	5.3E-03	New HFE. HFE will model what 1ASD-SBONOTDPOMA used to for scenarios in which the fire occurs outside the main control room, and stress is expected to be moderate. The original HEP assessment for 1ASD-SBONOTDPOMA is very conservative in that a High Operator stress level has been assigned by default generating a high HEP value. However, since the action is practiced every two years, the plant should respond as expected (i.e., operators have the plant under control and are familiar and comfortable with the actions and procedures required, workload might be high, but PSFs should be optimal. This was confirmed by operators on phone interview (5/26/2015), therefore a moderate stress level is selected.
1FSBO---RCC-OMA	Operator Fails to initiate RCS Cooldown after success of CVCS and AFW crosstie per Emergency Remote Shutdown (Reference 7.14)	N/A	6.58E-04	New HFE. HFE will model a 14F/hr cooldown per OHP-4025-001-001, step 25 given success of 1FSBO--XTIE-OMA using the same time window, based on new MAAP analysis. Execution Time for operator action is 15 minutes, confirmed by operators. Moderate stress level assumed based on operator phone Interview discussed above.
1E-RV--MRV2X3HEF	Operator fails to manually open SG PORVs.	1.3E-2	N/A	Removed from the model and superseded by 1FSBO---RCC-OMA, since the cooldown is credited for fire-induced SBO only, where CVCS and AFW crosstie must first be successful.
1-----CCW-RCPHEF	Operator Fails to Locally Trip RCPs	4.80E-03	4.80E-03	HEP agreed upon between DC Cook and the NRC and cannot be changed. If stress reduced, HEP = ~2E-03

5.5 Risk Analysis Using the 2009 Internal Events PRA Model of Record

Two cases of the 2009 Internal Events PRA Model of Record are run consistent with the cases developed in Section 2, and Reference 7.17. The Unit 1 West MDAFP and Unit 2 Plant Air Compressor unavailability is taken from Assumption 4.1. These cases are:

1. A baseline CDF and LERF value with zero maintenance other than the exceptions listed in Assumption 4.1, without credit for the SDS. For this case, the following basic event modifications are made:

Table 5.5-1 – Basic Event Settings for Baseline CDF and LERF

Component	Basic Event	Probability
Unit 1 West MDAFP	1DBPM----PP3WTM	8.333E-2
Unit 2 Plant Air Compressor	2X-CM---OME41TM	4.167E-2
All other Test or Maintenance Events	Basic Events ending in "TM"	0

2. CDF and LERF values with the Unit 1 AB EDG failed, with zero maintenance other than the exceptions listed in Assumption 4.1, without credit for the SDS. For this case, the following basic event modifications are made:

Table 5.5-2 – Basic Event Settings for Unit 1 AB EDG Failed CDF and LERF

Component	Basic Event	Probability
Unit 1 AB EDG	1SBDG----DGABFR	1
Unit 1 West MDAFP	1DBPM----PP3WTM	8.333E-2
Unit 2 Plant Air Compressor	2X-CM---OME41TM	4.167E-2
All other Test or Maintenance Events	Basic Events ending in "TM"	0

5.6 CDF and LERF Results

The CDF and LERF results from each case are shown below in Table 5.6-1. The ICCDP and ICLERP calculations are shown below in Table 5.6-2. ICCDP and ICLERP are calculated assuming a 65 day completion time, using the equations in Section 2. Updated Internal Events and Fire PRA values are obtained from Reference 7.17.

Table 5.6-1 – 2009 Internal Events Model vs. Updated Internal Events Model Total CDF and LERF Results

Case	Internal Events CDF 2009 Model (/yr)	Internal Events LERF 2009 Model (/yr)	Internal Events CDF Updated Model (/yr)	Internal Events LERF Updated Model (/yr)
Basecase	1.412E-05	2.867E-06	1.268E-04	4.237E-06
1 AB EDG Failed	1.963E-05	3.454E-06	1.304E-04	5.119E-06

Table 5.6-2 – ICCDP and ICLERP Results for 65 Day Completion Time

Case	Delta CDF (/yr)	Delta LERF (/yr)	ICCDP	ICLERP
2009 Internal Events	5.51E-06	5.87E-07	9.81E-07	1.05E-07
Updated Internal Events	3.60E-06	8.82E-07	6.41E-07	1.57E-07
Fire PRA	1.96E-05	7.97E-07	3.49E-06	1.42E-07
Total (2009 Internal Events & Fire PRA)	2.51E-05	1.38E-06	4.47E-06	2.46E-07
Total (Updated Internal Events & Fire PRA)	2.32E-05	2.27E-06	4.13E-06	4.04E-07

6 Conclusions

The 2009 Internal Events PRA model provides a slightly larger estimate of ICCDP and a 50% smaller estimate of ICLERP than the updated Internal Events model. Using the 2009 Model of Record and the Fire PRA, the calculated values of 4.47E-06 ICCDP and 2.46E--7 ICLERP are within the Regulatory Guide 1.177 acceptance guidelines of less than 1E-5 ICCDP and 1E-6 ICLERP for one time TS completion time changes, given a total TS completion time of 65 days (Reference 7.12). This one-time TS completion time change is therefore considered acceptable.