TENNESSEE VALLEY AUTHORITY

Browns Ferry Nuclear Plant (BFN) Subsequent License Renewal Application (SLRA) – Severe Accident Mitigation Alternatives (SAMA) Analysis

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Introduction

Pete Donahue – Director, Subsequent License Renewal (SLR)

Bill Baker – Senior Program Manager, SLR Plant Operations

Ashley Michael – Senior Program Manager, SLR Mechanical Systems

Dan Kearnaghan – Manager Nuclear Power Group Probabilistic Risk Assessment (PRA) Projects

Gerry Kindred – Senior Program Manager, PRA

Bill Victor – Senior Program Manager, Corporate Nuclear Licensing

Beau Eckermann – Program Manager, Fleet Licensing

Joe Bashore – SLR Environmental Lead

Dan Green – SLR Licensing Manager

Nick Lovelace – Jensen Hughes - PRA

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Background

Purpose of Analysis of Severe Accident Mitigation Alternatives (SAMAs)

- Identify design alternatives, procedural modifications, or training activities that are cost-beneficial and further reduce risks of severe accidents

Analysis of SAMAs includes identification and evaluation of alternatives that reduce risk from severe accident by

- Preventing substantial core damage (preventing a severe accident) or
- Limiting releases from containment in event substantial core damage occurs (mitigating impacts of a severe accident)

In accordance with 10 Code of Federal Regulations (CFR) 51.53(c)(3)(ii)(L) and Table B-1 of Appendix B to 10 CFR Part 51, Subpart A

- License Renewal Environmental Reports (ERs) must provide consideration of alternatives to mitigate severe accidents
  - If NRC staff has not previously considered such alternatives for applicant's plant in an Environment Impact Statement (EIS) or related supplement or in an Environmental Assessment (EA)

Background (continued)

Nuclear Regulatory Commission (NRC) staff previously considered alternatives to mitigate severe accidents for BFN in Supplemental EIS for License Renewal

- Supplement 21 Regarding Browns Ferry Nuclear Plant Units 1, 2, and 3, to Generic EIS for License Renewal of Nuclear Plants (NUREG-1437) dated June 2005

Since that time, BFN Units 1, 2 and 3 and associated PRA models have undergone many modifications/changes

Because of extent of changes to BFN Units 1, 2 and 3 and associated PRA models, TVA has determined that it would be more efficient to perform a full SAMA analysis rather than using Nuclear Energy Institute (NEI) 17-04, Model SLR New and Significant Assessment Approach for SAMA

Background (continued)

BFN Modifications

For example:

- Numerous modifications to Unit 1 to support recovery to operating status
- Extended Power Uprate (EPU) and Maximum Extended Load Line Limit Analysis Plus (MELLLA+) for Units 1, 2, and 3
- Numerous modifications for compliance with BFN National Fire Protection Association (NFPA) 805 analyses
- Diverse and Flexible Coping Strategies (FLEX) modifications

Background (continued)

PRA Model

Note: Previously submitted SAMA evaluation performed with RISKMAN model

PRA model completely re-built using CAFTA software to meet Regulatory Guide 1.200

- Substantial update to PRA internal events and internal flooding model

Modeling changes

- PRA updated to model current as-built, as-operated plant

Extended Power Uprate

- Several different analyses conducted to reflect EPU

Fire PRA and seismic PRA models developed for BFN

Modeling Updates from Internal and Industry Peer Reviews

- PRA model refined by incorporation of latest state of knowledge and recommendations from Internal and Industry Peer Reviews
- All Finding Level Facts & Observations (F&Os) have been closed using applicable NEI guidance

Creation of One-Top Multi-Hazard Model (OTMHM)

- Internal events, internal flood, fire and seismic PRA models integrated to create one-top model

Model Development

Level 1, 2, and 3 Models

Level 1 PRA model: One-Top Multi-Hazard Model (OTMHM)

- Includes internal events, internal flood, fire, and seismic

Level 2 analysis uses Containment Event Tree (CET) to analyze all core damage sequences identified in Level 1 analysis

- Results include each sequence's release frequency, magnitude, and timing
- Level 2 bins:
  - High-Early Release (H-E), High-Intermediate Release (H-I), High-Late Release (H-L),
  - Medium-Early Release (M-E), Medium-Intermediate Release (M-I),
  - Low-Intermediate Release (L-I), Low Low-Intermediate Release (LL-I),
  - Containment Intact (Intact)

Model Development (continued)

Level 1, 2, and 3 Models

Level 3 PRA model created for BFN using Windows MELCOR Accident Consequences Code System (WinMACCS)

- Site-specific meteorological, population, and economic data to estimate each accident consequence's population dose and offsite economic costs
  - Used to estimate accident consequences in terms of population dose and offsite economic costs for 50 miles around BFN
- Risks in terms of population dose risk and offsite economic cost risk also estimated in this analysis
  - Calculated as product of WinMACCS consequence and frequency of different postulated accidental releases based on Level 2 analysis

Overview of SAMA Process

NEI 05-01 Methodology

NEI 05-01, Severe, Accident Mitigation Alternatives (SAMA) Analysis Guidance Document, guidance used for all three BFN units

- Guidance in NEI 17-04, Model SLR New and Significant Assessment Approach for SAMA, not used since full SAMA analysis performed
  - except for SAMA candidate identification

Analytical Steps Involved:

1. Identification of Potential SAMA Candidates
   - Potential SAMA candidates were identified from following sources, based on NEI 05-01 and NEI 17-04 in relation to potentially cost beneficial SAMAs from other BWR plants
     - SAMA analyses for other BWR plants;

       (NEI 17-04 includes review of SAMAs identified as potentially cost beneficial for other industry plants that have been determined to be applicable, but not already implemented at the analyzed plant)
     - NRC and industry documentation discussing potential plant improvements; and
     - BFN updated PRA model lists of risk significant contributors

       (Including internal flood, fire, and seismic hazards)

Overview of SAMA Process (continued)

NEI 05-01 Methodology

2. Preliminary Screening (Phase I)
   - Potential SAMA candidate was screened out if:
     - It modified features not applicable to BFN;
     - It had already been implemented at BFN; or
     - It was similar and could be combined with another SAMA candidates

3. Final Screening and Cost-Benefit Evaluation (Phase II)
   - Cost-benefit analysis was performed for each SAMA candidate remaining after preliminary screening
   - Benefit of implementing a SAMA candidate was estimated in terms of averted consequences

4. Sensitivity Analyses
   - Two sensitivity cases
     - Instead of using a 20-year license renewal period, the full period is used (31 years for Unit 1, 32 years for Unit 2, and 34 years for Unit 3)
     - Conservative discount rate (3% instead of 7%)

Overview of SAMA Process (continued)

Phase II Analysis

Result of implementation of each SAMA candidate would be change in severe accident risk (change in frequency of severe accidents or change in frequency of subsequent release to environment)

- Calculate baseline risk and cost
- Calculate each SAMA's risk and cost
- Calculate each SAMA's benefit

Overview of SAMA Process (continued)

Phase II Analysis: Severe Accident Risk

After baseline risk is calculated, severe accident risk after implementation of each SAMA candidate is calculated

- Level 2 PRA model was modified to reflect maximum benefit of each improvement
- Generally, maximum benefit of a SAMA candidate was determined with bounding modeling assumption
  - For example, if objective of SAMA candidate was to reduce the likelihood of a certain failure mode, then eliminating the failure mode from PRA would bound the benefit, even though SAMA candidate would not be expected to be 100% effective in eliminating the failure
- Severe accident impacts were calculated based on:
  - Offsite exposure costs (monetary value of dose consequences to offsite population);
  - Offsite economic costs (monetary value of damage to offsite property);
  - Onsite exposure costs (monetary value of dose to workers); and
  - Onsite economic costs (monetary value of damage to onsite property)
- Results of Level 2 model were combined with Level 3 model to calculate post-SAMA costs
  - These values are subtracted to calculate SAMA benefit

Overview of SAMA Process (continued)

Phase II Analysis: Cost/Benefit Analysis

Cost/Benefit Analysis of each SAMA performed

- Estimate each SAMA's cost
  - Expected cost of enhancement to implement each SAMA established from existing estimates of similar modifications combined with engineering judgment
- Compare each SAMA's cost estimate to benefit calculations
  - To assess viability of each SAMA considered for final cost-benefit evaluation, cost of implementing that SAMA was estimated and compared with estimated benefit
  - If cost of implementation was greater than attainable benefit of a particular SAMA, then modification was not considered economically viable and was eliminated from further consideration

SAMA Results

Overall Results

Identification of Potential SAMA Candidates: 298 SAMA candidates

- Evaluation addressed 298 SAMA candidates for mitigating severe accident impacts

Preliminary Screening (Phase I): 229 screened, 69 remain

- Eliminated 229 SAMA candidates from further consideration
  - Based on either inapplicability to BFN's design, or features that had already been incorporated into BFN's current design, procedures, or programs

Final Screening and Cost-Benefit Evaluation (Phase II): 63 screened, 6 remain

- Additional 63 SAMA candidates were eliminated because their cost was expected to exceed their benefit
- Six SAMAs found to be potentially cost-beneficial for mitigating consequences of severe accident at BFN

Sensitivity Analyses: No additional cost-beneficial SAMAs

- Sensitivity studies indicated results of analysis would not change for conditions analyzed

SAMA Results

Resulting Potentially Cost-Beneficial SAMAs
(based on conservative calculations)

SAMA 64: Enhance procedures for actions on loss of heating, ventilation and air conditioning (HVAC) (Units 1, 2, and 3)

SAMA 65: Add emergency diesel generator building high temperature alarm or redundant louver and thermostat (Unit 3)

SAMA 148: Install inter-unit control rod drive (CRD) system cross-tie as potential means of recovering from loss of CRD at a given unit (Unit 1)

SAMA 149: Diverse emergency diesel generator HVAC logic. (Units 1, 2, and 3)

SAMA 150: Provide diverse swing emergency diesel generator air start compressor (Units 1, 2, and 3)

SAMA 157: Add automatic fire suppression system (Fire Compartment 13 – Electrical Board Room 3A) (Unit 3)

Note: None of these SAMAs are related to adequately managing effects of aging during subsequent period of extended operation

Next Steps for Potentially Cost-Beneficial SAMAs

Potentially Cost-Beneficial SAMAs

SAMA analysis is conservative and is not a complete engineering project cost-benefit analysis - does not estimate all benefits or costs of a SAMA

For example:

- May not consider increases or decreases in maintenance or operation costs following SAMA implementation
- May not consider possible adverse consequences of the changes.

Although none of these potentially cost-beneficial SAMAs are related to adequately managing effects of aging during the subsequent period of extended operation, the following actions are being taken:

- Condition Report initiated within Corrective Action Program to investigate more detailed cost analysis and potentially implement these cost-beneficial SAMAs
- Knowledgeable AE for BFN currently working on more accurate minimum cost estimates for these SAMAs
  - Resulting SAMAs determined to be cost effective to be processed through BFN Plant Health Committee for further consideration

SLRA Environmental Report Contents – SAMA

SLRA ER Contents – SAMA

SLRA ER Section 4.15, Severe Accident Mitigation Alternatives

- Description of Methodology including:
  - Establishing Baseline Consequences of Severe Accidents
  - Identifying SAMA Candidates
  - Phase I Preliminary Screening
  - Phase II Final Screening and Cost Benefit Evaluation
  - Sensitivity Analyses
- Tables with Potentially Cost-Beneficial SAMAs and Bases for Conclusion

SLRA ER Appendix E.1, Evaluation of BFN PRA Model

- Description of BFN PRA Level 1, 2, and 3 analyses, uncertainty, and PRA model peer review

SLRA ER Appendix E.2, Evaluation of BFN SAMA Candidates

- Description of generation of initial list of potential SAMA candidates, screening methods, and analysis of remaining SAMA candidates

BFN SLRA currently scheduled for submittal by end of 2023

Note: Supporting Engineering Documents/Calculations available on BFN SLR online reference portal for NRC review/audit

Abbreviations List

BFN	Browns Ferry Nuclear Plant	L-I	Low-Intermediate Release
CET	Containment Event Tree	LL-I	Low Low-Intermediate Release
CFR	Code of Federal Regulations	M-E	Medium-Early Release
CRD	Control Rod Drive	M-I	Medium-Intermediate Release
EA	Environmental Assessment	MELLLA+	Maximum Extended Load Line Limit Analysis Plus
EIS	Environmental Impact Statement	NEI	Nuclear Energy Institute
EPU	Extended Power Uprate	NFPA	National Fire Protection Association
ER	Environmental Report	NRC	Nuclear Regulatory Commission
F&Os	Facts & Observations	OTMHM	One-Top Multi-Hazard Model
FLEX	Diverse and Flexible Coping Strategies	PRA	Probabilistic Risk Assessment
H-E	High-Early Release	SAMA	Severe Accident Mitigation Alternatives
H-I	High-Intermediate Release	SLR	SLR - Subsequent License Renewal
H-L	High-Late Release (H-L)	SLRA	Subsequent License Renewal Application
HVAC	Heating, Ventilation and Air Conditioning	WinMACCSS	Windows MELCOR Accident Consequences Code System

Questions/ Comments


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