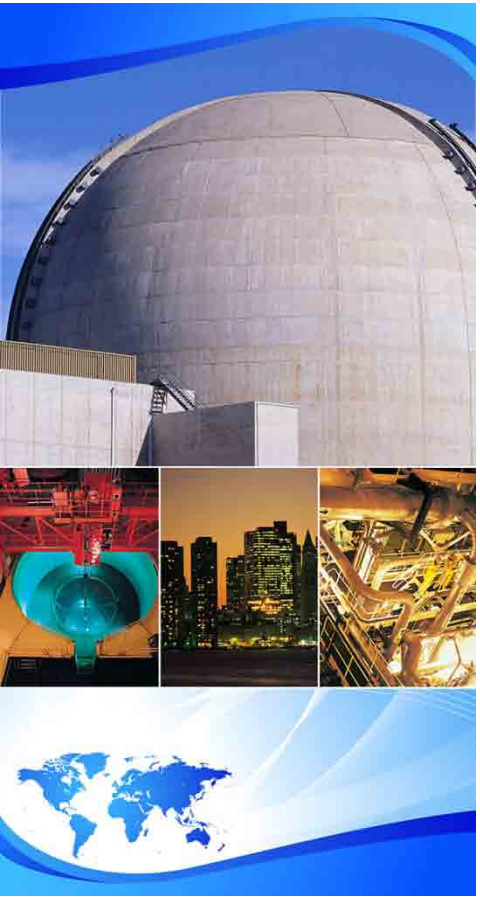

EPRI/NRC-RES FIRE PRA METHODOLOGY
Task 12 – Fire HRA

Screening Quantification

Joint NRC-RES/EPRI Fire PRA Workshop 2012
Bethesda, MD

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

Applicable HLRs (per the PRA Standard)
Quantitative Analysis

Internal Events PRA Standard (Ch. 2)

- HLR-HR-G: The assessment of the probabilities of the post-initiator HFEs shall be performed using a well-defined and self-consistent process that addresses the plant-specific and scenario-specific influences on human performance, and addresses potential dependencies between human failure events in the same accident sequence (8 SRs)

Fire PRA Standard (Ch. 4)

- HLR-HRA-C: The Fire PRA shall quantify HEPs associated with the incorrect responses accounting for the plant-specific and scenario-specific influences on human performance, particularly including the effects of fires (1 SR)

Outline of the Presentation

1. Overview of the EPRI/NRC-RES Fire HRA Guidelines
2. Identification and definition of fire human failure events
3. Qualitative analysis
4. Quantitative analysis
   a) **Screening**
   b) Scoping
   c) EPRI approach (detailed)
   d) ATHEANA (detailed)
5. Recovery analysis
6. Dependency analysis
7. Uncertainty analysis

HRA Screening - Fire HRA Objectives

- To verify that reasonable and feasible human actions and associated fire human failure events (HFEs) are
  - Identified and evaluated for fire effects
  - Included in Fire PRA

- To simplify PRA fire model by appropriately assigning screening HEPs for fire induced accident scenarios
  - Establish HEP screening values for developing Fire PRA model
  - Help focus analysis resources on the higher risk sequences

PRA Standard Definitions

- Screening – “a process that eliminates items from further consideration based on their negligible contribution to the probability of an accident or its consequences.”

- Screening criteria – “the values and conditions used to determine whether an item is a negligible contributor to the probability of an accident sequence or its consequences.”

- Corresponding PRA Standard SRs:
  - Part 2, HR-G1 and
  - Part 4, HRA-C1

Fire HRA Screening Analysis

- Method similar to that presented in NUREG/CR-6850 (EPRI 1011989)
- Supports assignment of screening values by:
  - addressing the key conditions that can influence crew performance during fires,
  - ensuring that the time available to perform the necessary action is appropriately considered (given the other on-going activities in the accident sequence), and
  - evaluating potential dependencies among HFEs modeled in a given accident sequence
- To facilitate simplified level of analysis, HFEs are sorted into “screening sets”

Fire HRA Screening - Inputs

- Mitigating equipment and diagnostic indications

  from Task 2 (Fire PRA Component Selection)

- Human actions carried over from Internal Events PRA

  from Task 5 (Fire-Induced Risk Model development)

- EOPs and fire procedures - to identify new potentially risk important human actions that support Appendix R assumptions

- Equipment failures, spurious operations and indications; timing and fire location information for feasibility assessment – if available when screening is performed:
  - Task 3 (Fire PRA Cable Selection),
  - Tasks 9 (Detailed Circuit Failure Analysis) & 10 (Circuit Failure Mode Likelihood Analysis)
  - Tasks 8 (Scoping Fire Modeling) and 11 (Detailed Fire Modeling)

Fire HRA Screening - Outputs

- May identify other equipment and indications that are needed to carry out a human action for Task 2 (Fire PRA Component Selection)
- May identify HFE modeling additions needed in Task 5 (Fire-Induced Risk Model) to account for pre-emptive procedure-driven actions to avoid fire-induced spurious equipment actuations
- Provide screening HEPs for Task 7 (Quantitative Screening)
- Identify HFEs requiring additional analysis (scoping or detailed)

Fire HRA Screening - Screening Criteria Sets

- NUREG/CR-6850 (EPRI 1011989) screening criteria produced HEPs for longer term actions (>1 hour after fire initiation and plant trip) that were overly conservative, even for screening, so this has been modified
- Criteria summary:
  - Set 1: Internal events PRA HFEs that are only indirectly affected by the fire scenario
  - Set 2: Internal events HFEs that have added complications from spurious actuations
  - Set 3:
    - new fire-related HFEs
    - HFEs modeled in internal events PRA that need to be significantly revised to reflect fire effects
  - Set 4: HFEs associated with Alternative Shutdown (including MCR Abandonment)

Fire HRA Screening Criteria: Set 1
Existing Level 1 internal events PRA HFEs

- Plant trip with no significant damage to safe shutdown equipment or related instrumentation beyond internal events PRA
- No spurious cues or equipment actuations for safety-related equipment
- Necessary immediate responses are not attributed to fire
- One train/division of safe shutdown-related equipment and instrumentation is completely protected from fire
- MCR crew responsible for safe shutdown have no significant additional responsibilities

Fire HRA Screening Criteria: Set 1 (continued)

- No significant environmental impact or threat to MCR crew (e.g., smoke)
- Time available to diagnose and implement the action(s) is not significantly different than internal events PRA-related scenario(s) where HFE(s) apply
- Ex-MCR manual actions from internal events PRA are not significantly affected by smoke or toxic gases, loss of lighting, radiation threat
- Staff, special tools and communication capability are available to perform ex-MCR actions
- Dependency between multiple HFEs in internal events PRA sequences is still applicable to fire PRA

Fire HRA Screening Criteria: Set 2
Modification to existing HFEs for spurious effects

- Set 2 screening criteria same as Set 1, except when
  - Significant spurious electrical effects are likely occurring in one (and only one) safety-related train/division of equipment and/or instrumentation important to the critical safety functions
- Presumes that some corrective responses on the part of the crew may be needed
- In Set 2, the crew might have to attend and respond to the spurious activity in the affected train/division to make sure it does not affect their ability to reach safe shutdown (e.g., causing a diversion of all injection).
- However, the crew would likely detect the spurious activity quickly and not be confused by it
- The Set 2 screening adjustments are intended to conservatively bound the general fire effects on Set 1 internal events PRA actions. Set 2 adjustments do <u>not</u> address operator actions added to the PRA model to address additional fire scenario concerns.

Fire HRA Screening Criteria: Set 3
New or significantly modified HFEs

- These criteria address
  - new HFEs added to the fire PRA or
  - prior internal events PRA HFEs needing to be significantly altered or modified because of fire conditions
- In such cases, pre-existing internal events PRA HEPs either do not exist, or are not appropriate as a basis for the fire PRA
- If action is within 1st hour of fire initiation, set HEP to 1.0 for screening
- If action is long term, apply 0.1 or 10 times internal events PRA HEP, whichever is lower

Fire HRA Screening Criteria: Set 4 Alternative Shutdown HFEs

- All HFEs involved in reaching safe shutdown from outside the MCR, including HFEs representing the decision to abandon the MCR, should be assigned screening values of 1.0 since more detailed analysis is needed
- As discussed in Section 11.5.2.10 of NUREG/CR-6850 (EPRI 1011989), an overall probability value (often, 0.1) to represent the failure of reaching safe shutdown using alternate means can be used if the value is evaluated conservatively and a proper basis is provided
  - this approach was used in several IPEEE submittals
  - may be sufficient when MCR abandonment is proven to not be risk-significant
  - before crediting this approach, apply the criteria discussed in NUREG-1921
    - Section 4.3 for feasibility assessment
    - Section 4.8 for MCR abandonment qualitative analysis

Fire HRA Screening - Basis for Screening Values

- Conservative HEP values have no direct empirical basis
- Qualitative basis comes from experience with
  - Range of screening values used and accepted in HRA
  - Quantifying HEPs for events in nuclear power plant HRAs
  - Applying range of HRA methods and values associated with those methods
  - Performing HRA for fire PRAs, including pilots
- Other inputs
  - Peer review comments
  - Not so low so as to miss potential dependencies among HFEs

Fire HRA Screening - Quantification

- Assign screening HEPs on a fire scenario specific basis
- Four sets of screening criteria :
  - Set 1 (existing Level 1 HFEs): Multiply internal events HEP by 10 to account for effects of potential fire brigade interaction and other minor increased workload/distraction issues. Examine dependencies across scenario
  - Set 2 (modification to existing HFEs re: spurious events): Spurious events impact one critical safety-related train/division: increase internal events HEP to 0.1, or 10 times original value, whichever is greater. Examine dependencies across scenario
  - Set 3 (new or significantly modified HFEs): Applies to new HFEs and existing HFEs not meeting Set 1 or 2. Use 1.0 if action has to be performed within one hour of fire initiation. Use 0.1, or 10 times existing HEP, if > 1 hour, whichever is lower (relaxation of original screening guidance)
  - Set 4 (alternative shutdown HFEs): Use screening value of 1.0 or use overall value of 0.1 with documented justification (relaxation of original screening guidance)

Quantitative Screening Summary

Screening Criteria	Short-Term Human Actions		Long-Term Human Actions	
	Definition	Value	Definition	Value
Set 1: similar to internal events HFE but with some fire effects	Required within first hour of fire/trip	10x internal events HEP	Performed ~1 hour after fire/trip (fire effects no longer dynamic, equipment damage understood, and fire does not significantly affect ability of operators to perform action)	Same as internal events HEP
Set 2: similar to Set 1 but with spurious equipment or instrumentation effects in one safety-related train/division		0.1, or 10x internal events HEP, whichever is greater		0.1, or 10x internal events HEP, whichever is smaller
Set 3: new fire HFEs or prior internal events HFEs needing to be significantly modified as a result of fire conditions		1.0		0.1, or 10x internal events HEP, whichever is smaller
Set 4: alternate shutdown (including MCR abandonment)	1.0 for initial screening (per Section 5.1.1.4), or 0.1 following feasibility assessment (per Section 4.3) and qualitative analysis (per Section 4.8)			

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