EPRI/NRC-RES FIRE PRA METHODOLOGY

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Fire PRA – Long History

• Prior to IPEEE (1979-1990) early development and application of methods, tools and data
– Relatively simple by comparison to today
– Basic framework developed at UCLA (e.g., NUREG/CR-2258) remains largely unchanged. Applied in many early fire PRAs.

• EPRI FIVE (1992)
– A "vulnerability evaluation" methodology developed in response to IPEEE program

• EPRI Fire PRA Implementation Guide (1995)
– Developed as a complement to FIVE for detailed evaluation of unscreened
fire areas/compartments
– More robust methods (compared to FIVE) for:
• Development and evaluation of fire risk model, including human actions
• Assessment of fire growth and damage, detection and suppression
• Control room and multi-compartment fire risk

NUREG 6850/NRC Structure

- The objective here is to provide an understanding, from a regulatory perspective, the need for a fire Perspective probabilistic risk assessment (PRA) methodology document, and therefore, its role in the regulatory Structure.

- A major aspect of this objective is understanding what is meant by regulatory structure.

NRC Regulatory Structure

- Congressional Mandate

– Atomic Energy Actt indicates that the mission of the NRC is to ensure that commercial nuclear power plants are operated in a manner that provides adequate protection of public health and safety and is consistent with the common defense and security.

- NRC provides for public health and safety via a licensing, oversight and enforcement process.

- Licensing, oversight and enforcement all involve establishing regulations and developing the necessary supporting structure (e.g., regulatory guides).

EPRI/RES PRA Methodology

- The methodology is presented in the form technical task procedures within an overall process
- The process is intended as a guide and should fit most cases
- User may adjust process based on plant-specific information, efficiency, economy and desired applications

NRC Relationship with PRA

• Example relevant regulations:
– 10 CFR §50.48(c), Fire Protection, National Fire Protection Association Standard NFPA 805
– 10 CFR §50.69, Risk-informed categorization and treatment of structures, systems and components for nuclear power reactors
– 10 CFR §50.90, Application for amendment of license, construction permit, or early site permit
– 10 CFR §50.36, Technical Specifications

• What is the common element among these regulations?
– The use of risk information, and therefore, the need to have confidence in the risk analyses (or PRAs) being used to generate the information
– Risk contributors to be addressed include internal fires.

How is Confidence Achieved?

• The approach provided in RG 1.200 defines the attributes and characteristics of a technically acceptable PRA.
– The defined attributes and characteristics are very high level.

• For example, characteristics and attributes provided in RG1.200 for Fire Ignition Frequencies:
– Frequencies are established for ignition sources and consequently for physical analysis units.
– Transient fires should be postulated for all physical analysis units regardless of administrative controls.
– Appropriate justification must be provided to use nonnuclear experience to determine fire ignition frequency.

How is Confidence Achieved?

- RG 1.200 allows the use of a consensus standard (as endorsed by the NRC) with a peer review to demonstrate conformance with the defined attributes and characteristics.
  - RG 1.200 endorses and provides a position on the ASME/ANS PRA Standard (ASME/ANS RA-Sa-2009).
  - Part 4 of this standard provides the requirements for fires at-power PRA.

- The PRA Standard, however, only defines what is required for a technically acceptable PRA and an acceptable peer review.

NRC Confidence Summary

- NUREG/CR-6850 is a methodology document and, while not required to be met, plays a major role in defining a technically acceptable Fire PRA to support NRC activities where a Fire PRA model is needed and the results of the Fire PRA model are used to meet a regulation.

General

- Based on MOU between NRC-RES and EPRI on fire risk
- Needed to provide more realistic methods f risk-informed, performance-based fire protection activities
- Core Damage Frequency (CDF) and Large Early Release Frequency (LERF)

- Procedures cover the following technical areas

– Plant analysis boundary and partitioning

– Fire PRA component selection and risk model

– Circuit/cable selection, routing and failure modes analysis

– Screening, qualitative and quantitative

– Fire ignition frequency

– Fire modeling; fire growth, damage and detection/suppression

– Post-fire human reliability analysis (HRA)

– Seismic-fire interactions, and

– Fire risk quantification, including uncertainties, and documentation

New to the Fire PRA Scope

- Addition of fire human reliability analysis (HRA)
- The link between the methods and the PRA Standard

Related Activities

EPRI 1011989/NUREG/CR-6850

Publication - 2005

General Workshops - 2005

Detailed Work Shops - 2006

Detailed courses – 2007 – 2009

- EPRI 1011999/NUREG-1824 – Dec 2010
- Fire HRA Methodology Development – March 2011
- Fire Modeling Application Guide – Dec 2011
- Fire Events Database - On-going
- FAQ Support - On-going
- Fire Modeling Training - On-going
- Low Power/Shutdown Fire PRA Methods - NRC

Human Reliability Analysis

- 6850/1011989 did not address detailed HRA quantification methods
- A joint EPRI/NRC RES development project is underway to fill this gap
- Draft guidance published November 2009:
  - EPRI/NRC-RES Fire Human Reliability Analysis Guidelines – Draft Report for Comment, EPRI 1019196, NUREG-1921
- Final publication pending

Task 1: Plant Partitioning

- Objectives:
  - Define the global analysis boundary of the FPRA
  - Divide the areas within the global analysis boundary into fire compartments

- The fire compartments become the “basic units” of analysis
  - Generally we screen based on fire compartments
  - Risk results are often rolled up to a fire compartment level

- A note on terminology:
  - The PRA standard uses “physical analysis units” rather than “fire compartments”
  - Definitions are quite similar, overall role in analysis is identical

Task 2: Equipment Selection

• Objective: To decide what subset of the plant equipment will be modeled in the FPRA

• FPRA equipment will be drawn from:
– Equipment from the internal events PRA
– Equipment from the Post-Fire Safe Shutdown analysis

• e.g., the Appendix R analysis or the Nuclear Safety Analysis under
NFPA-805
– Other "new" equipment not in either of these analyses

Task 3: Cable Selection

• Objectives:

– Identify/select cables whose fire-induced failure could adversely affect the operation of selected equipment (from Task 2)
– Locate selected cables

• Cables may include Power, Control/Indication, and Instrumentation

Task 3: Cable Selection

• Cable routing can be a major commitment of FPRA resources
– Depends a *lot* on status of existing plant cable if a lot of information

• Scope, quality, vintage, method of documentation
– Tracing cables is a time consuming activity
– Intent is to allow for "work smart" approaches

• Iteration to identify and route more cables as needed to support FPRA

• Allowances are made for making "conservative" assumptions about a cable's routing if unknown

– e.g., exclusionary approach

Task 4: Qualitative Screening

• Objective: To identify fire compartments that can be screened out as insignificant risk contributors without quantitative analysis

• This is an Optional task
– You can choose to bypass this task which means that all fire compartments will be treated quantitatively to some level of analysis (level may vary)

• Qualitative screening criteria consider:
– Trip initiators,
– Presence of selected equipment
– Presence of selected cables

Task 5: Fire Induced Risk Model

• Objective: Construct the FPRA plant response model reflecting:
– Functional relationships among selected equipment and operator actions

• Covers both CDF and LERF

• Begins with internal events model but more than just a "tweak"
– Adds fire unique equipment – various reasons/sources
– May delete equipment not to be credited for fire
– Adds fire-specific equipment failure modes
• e.g., spurious actuations (Task 9)
– Adds fire-specific human failure events (Task 12)

Task 6: Fire Ignition Frequency

• Objective: To define fire frequencies suitable to the analysis of fire scenarios at various stages of the FPRA

• Fire frequencies will be needed at various resolutions:

- An entire fire area
- A fire compartment (or physical analysis unit)
- A group of fire ignition sources (e.g., a bank of electrical cabinets)
- A single ignition source (e.g., one electrical panel)

Task 7: Quantitative Screening

• Objective: To identify compartments that can be shown to be insignificant contributors to fire risk based on limited quantitative considerations

• This task is Optional
– Analyst may choose to retain all compartments for more detailed Analysis

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Task 8: Scoping Fire Modeling

- Objective: To identify (and screen out) fire ignition sources that are non-threatening and need not be considered in detailed fire modeling

- Non-threatening means they cannot:
  – Spread fire to other combustibles, or
  – Damage any FPRA equipment item or cable

Task 9: Detailed Circuit Failure

• Objectives:
– To identify circuit responses (failure modes) to fire-induced cable failures
– To screen out cables that do not impact the ability of a component to complete its credited function

• This is about defining the effects that cable failure can (or cannot have) on selected equipment
– e.g., what cables can, or cannot, cause spurious actuations?

Task 10: Circuit Failure Modes

• Objective: To establish first order estimates of the conditional probability, given failure of a specific cable, that the circuit will respond in a specific way

• This one is about the likelihood that certain equipment failure modes will be observed given fire-induced cable failure
– Will the equipment spuriously actuate, or
– Will it be a loss of function failure?
– What is the relative likelihood of each failure mode of interest?

Task 11: Detailed Fire Modeling

- Objective: To identify and analyze specific fire scenarios

- Divided into three sub tasks:

– 11a: General fire compartments (as individual risk contributors)
– 11b: Main Control Room analysis
– 11c: Multi-Compartment fire scenarios

Task 12: Post-Fire Human Reliability Analysis

- Objective: Identify human failure events (HFEs) to be included in the FPRA plant response model and assess corresponding human error probabilities (HEPs)
  - Some HFEs derive from internal events PRA
  - Some are unique to fire

- HRA module based on the ongoing RES/EPRI collaboration

- Substantial expansion compared to 6850/1011989:
  - Updated rules-based screening approach
  - New intermediate “scoping” approach
  - Detailed quantification guidance for fire HEPs

Task 13: Seismic/Fire Interactions

- Objective: A qualitative assessment of potential fire/seismic interactions

- IPEEE guidance (e.g., the Fire PRA Implementation Guide)

Task 14: Fire Risk Quantification

- Objective: To quantify fire-induced CDF and LERF

- Relatively straight-forward roll-up for fire scenarios considering

- Ignition frequency
- Scenario-specific equipment and cable damage
- Equipment failure modes and likelihoods
- Credit for fire mitigation (detection and suppression)
- Fire-specific HEPs
- Quantification of the FPRA plant response model

Task 15: Uncertainty/Sensitivity

- Objective: Provide a process for identifying and quantifying uncertainties in the FPRA and for identifying sensitivity analysis cases
- Covered in limited detail
- Guidance is based on potential strategies that might be taken, but choices are largely left to the analyst
  – e.g., what uncertainties will be characterized as distributions and propagated through the model?

Tsunami

http://www.youtube.com/watch_popup?v=c3rqPPJPwLg