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EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Module II – Circuit Analysis

Task 3: Fire PRA Cable Selection

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FIRE PRA CABLE SELECTION

Purpose & Scope (per NUREG/CR-6850, EPRI 1011989)

- Identify circuits/cables associated with Fire PRA components
- Determine routing/location of the identified cables
- Use component-to-cable-to-location relationships to determine what components could be affected for postulated Fire Scenarios

  Note: A Fire Scenario can involve a Fire Area, Room/Compartment, Raceway, or Other Specific Location

- Identify Fire PRA power supplies
- Screen for Associated Circuits

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Corresponding PRA Standard Element

- What Standard?
  - ASME/ANS RA-Sb-2009, “Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications,” Addendum A to RA-S-2008, ASME, February 2009
  - Because the number and name rather impractical and non-intuitive, the common reference is “The PRA Standard”

- Primary match is to element CS – Cable Selection
  - CS Objectives (as stated in the PRA standard):

    “[T]o ensure that

    (a) all cables needed to support proper operation of equipment selected per technical element ES (see 4-2.2) are identified and assessed for relevance to the Fire PRA plant response model

    (b) the plant location information for selected cables is sufficient to support the Fire PRA and its intended applications.”

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HLRs (per the PRA Standard)

- HLR-CS-A: The Fire PRA shall identify *and* locate the plant cables whose failure could adversely affect credited equipment or functions included in the Fire PRA plant response model, as determined by the equipment selection process (HLR-ES-A, HLR-ES-B, and HLR-ES-C). (11 SRs)
- HLR-CS-B: The Fire PRA shall

  (a) perform a review for additional circuits that are either required to support a credited circuit (i.e., per HLR-CS-A) or whose failure could adversely affect a credited circuit

  (b) identify any additional equipment and cables related to these additional circuits in a manner consistent with the other equipment and cable selection requirements of this Standard. (1 SR)
- HLR-CS-C: The Fire PRA shall document the cable selection and location process and results in a manner that facilitates Fire PRA applications, upgrades, and peer review. (4 SRs)

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NEI 00-01, Rev. 2, Section 3.3 – Safe Shutdown Cable Selection and Location

- NEI 00-01, Rev. 2, “Guidance for Post-Fire Safe Shutdown Circuit Analysis,” May 2009
- Generally follows the Task 3/9 methodology of NUREG/CR-6850, EPRI 1011989
- Updated Guidance in NEI 00-01, Rev. 4
  - Number of hot-shorts that must be postulated
  - Perspective on “Proper Polarity”
  - Latching vs Non-Latching
  - High Impact Components
  - Updates to Failure Mode Classification
  - Shorting Switches
  - Hot Short Duration – Deterministic Analysis
  - CT Open Circuit Secondary Fires

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NEI 00-01, Rev. 2, Section 3.3 – Safe Shutdown Cable Selection and Location (cont.)

Figure 3-4 in NEI 00-01 provides a flowchart illustrating the steps involved in selecting the cables necessary for performing a post-fire safe shutdown analysis:

- Step 1 – Define safe shutdown equipment.
- Step 2 – Identify circuits (power, control, instrumentation) required for the operation of each safe shutdown equipment.
- Step 3 – Identify equipment whose spurious operation or mal-operation could affect safe shutdown.
- Step 4 – Identify interlocked circuits and cables whose failure may cause spurious actuations
- Step 5 – Decision: Is power required for equipment operation?
- Step 6 – If power is required, identify closest upstream power supply and verify that it is on the safe shutdown list
- Step 7 – Assign cables to equipment
- Step 8 – Identify routing of cables
- Step 9 – Identify location of cables by fire area

FIRE PRA CABLE SELECTION

Introduction (per NUREG/CR-6850, EPRI 1011989)

- Conducted for all Fire PRA Components

  Note: Exceptions do exist

- Cable selection is a **Deterministic** process

- Selected cables are associated to components based on <u>specified functionality</u>

  – Basic circuit analysis (Task 9A) incorporated into Task 3 work to prevent overwhelming the PRA model with inconsequential cable failures during cutset reviews and quantification runs

  – Final output is a listing of defined Basic Events (component and credited function) that could be impacted by a fire in a given location (Fire Area, Compartment, etc.) or for a specific Fire Scenario

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Introduction (cont.)

- Cable Selection procedure is subdivided into six (6) distinct steps

  Step 1: Compile and Evaluate Prerequisite Information and Data

  Step 2: Select Fire PRA Circuits/Cables

  Step 3: Identify and Select Fire PRA Power Supplies

  Step 4: Perform Associated Circuits Review

  Step 5: Determine Cable Routing and Plant Locations

  Step 6: Generate Fire PRA Cable List and Target Equipment Location Reports

FIRE PRA CABLE SELECTION

Task Interfaces - Input

- Plant Boundary Partitions (Task 1)
- Fire PRA Component List (Task 2)
- Fire PRA Database (Support Task B)
- Appendix R Circuit Analysis
- Plant Cable & Raceway Database
- Plant Drawings

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Task Interfaces - Output

- Fire PRA Cable List
- Fire PRA Power Supply List
- Associated Circuits Review
- Component Analysis Packages
- Target Equipment Loss Reports
  - Potential equipment functional losses broken down by location or fire scenario
  - Generally managed by a database (e.g., FRANX)

FIRE PRA CABLE SELECTION

Step 1 – Prerequisite Information

- Confirm Plant Partitioning is compatible
  - Do partitions align with cable location data?
  - What data is available and what is missing?
  - Are routing assumptions used?
- Confirm PRA Equipment List is Stable
  - Easier said than done…
  - Input into a formal and controlled database
  - For NFPA-805 transition projects a joint “consistency” review of NSCA and PRA component lists is highly recommended

    NOTE: Critical that electrical analysts understand the functional requirements for the PRA Model Basic Events

    (Corresponds to NEI 00-01, Rev. 2, Step 1)
- Evaluate Database Requirements and Controls are in Place
  - How is data to be managed and controlled?
  - This is a BIG DEAL

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Step 2 – Select Fire PRA Cables

- Analysis Cases
  - Appendix R SSA / NSCA Component with *Same* Functional Requirements
    - Must consider which (if any) automatic features are included in the existing analysis
    - Aligning existing analyses to Fire PRA Basic Events is not straightforward
  - Appendix R Component with *Different* Functional Requirements
  - New Component (Non-Appendix R/NSCA)

  IMPORTANT: In Practice this Breakdown is Seldom Used – "Real World" cases are less well defined

- Analysis Sub-Steps
  - *Step 2.1:* Analysis Strategy
  - *Step 2.2:* Plant Specific Rules
  - *Step 2.3:* Select Cables
- Corresponding PRA Standard SRs: CS-A1, A3
- Corresponding NEI 00-01, Rev. 2, Steps: 2 & 4

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Step 2.1 – Analysis Strategy

- Coordinate with Systems Analysts to establish Functional Requirements and General Rules
  - MUST WORK OUT THE DETAILS OF HOW PRA BASIC EVENTS ARE TO BE CORRELATED TO CIRCUIT ANALYSIS
  - Consistent conventions for equipment functions & positions
  - Equipment-level dependencies and primary components – must understand what is beneficial to PRA and what is a waste of time
  - Multiple function components (Consider carefully how to treat instruments)
  - “Super” or “Pseudo” components
- Evaluate Appendix R Component & Circuit Data
  - Ensure equipment list comparison was conducted during Task 2
  - Review in detail the comparison list – ask questions!!!
  - Essential that comparison includes detailed review/assessment of “desired functional state(s)”

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Step 2.1 – Analysis Strategy (cont.)

- Goal – Efficient and accurate process to obtain required information
- Revisit past assumptions, conventions, and approach
- Potential trouble areas
  - How is off-site power going to be handled?
  - Instrument circuits – understand exactly what is credited
  - ESFAS, Load-Shed, EDG Sequencer, other automatic functions
  - Medium-voltage switchgear control power
  - Digital control system circuits
- Extent that Circuit Analysis (Task 9) is to be conducted concurrently

  Note: This will be discussed as part of the Task 9 presentation

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Step 2.2 – Plant Specific Cable Selection Rules

- Objective is Consistency and Accuracy
- Approach for Groups of Components
- Approach for Spurious Actuation Equipment
- Auxiliary Contacts – Critical Area for Completeness
- System-Wide Actuation Signals
- Digital Control System Conventions
- Bus or Breaker?
- Subcomponents & Primary Components
- Identification of Permanent Damage Scenarios
- Procedure - Develop Circuit Analysis Procedure/Guidelines

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Step 2.2 – Ready to Start?

- Develop Written Project Procedure/Guidelines
  - Consistency, Consistency, Consistency
  - Checking Process?
  - Data Entry
  - Problem Resolution
- Training for Analysts
  - Prior circuit analysis experience is a prerequisite for key team members or personnel that will work with minimal supervision
  - Familiarity with plant drawings and circuit types is a requirement
  - A junior engineer with no prior circuit analysis experience will not be able to work independently
- Consideration of Permanent Mechanical Damage

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Step 2.3 – Select Cables

- *Case 1:* Incorporate Existing Appendix R Analysis
  - Confirm adequacy of existing analyses IAW plan
  - Careful consideration of automatic functions
  - Exact alignment for credited functionality
- *Case 2A:* New Functional State / New Component
  - Collect drawings and/or past analysis information
  - Identify/select cables IAW plant specific procedure/guidelines
  - Conduct circuit analysis (Task 9A) to the extent decided upon
  - Formally document cable selection IAW established procedures/guidelines

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Step 2.3 – Select Cables (cont.)

- *Case 2B:* New Functional State / New Component (no cable routing information)
  - Same as Case 2A, plus…
  - Determine cable routing and associate with plant locations, including cable end points
- Analysis Work Packages
  - Retrieve from past Appendix R Analysis (if available)
  - Highly recommended for new components
  - Major time saver for future work

Note: More on Work Packages later in this presentation…

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Step 3 – Select Fire PRA Power Supplies

- Identify Power Supplies as integral part of Cable Selection
  - Make sure to differentiate between “Required” and “Not Required” power supplies
  - Switchgear and instrument power supplies can be tricky
  - Useful to identify the applicable breaker/fuse
  - Decide how to handle alternate sources
- Add New Power Supplies to Fire PRA Component List
- Make sure Fire PRA model, equipment list, and circuit analysis are consistent with respect to power supplies
- Does Fire PRA model consider spurious circuit breaker operations?
  - Must understand how this is modeled to correctly select cables
- Corresponding PRA Standard SRs: CS-B1
- Corresponding NEI 00-01, Rev. 2, Steps: 5 & 6

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Step 4 – Associated Circuits Review

- Objective is to confirm existing studies are adequate
- View the process as a “Gap Analysis”
- Common Power Supply Circuits - Assess Plant Coordination Studies
  - Be cautions of coordination studies that credit cable length
  - Understand implications of adding new non-vital equipment
- Common Enclosure Circuits - Assess Plant Electrical Protection
- Roll up results to Circuit Analysis or Model as appropriate
- Has emerged as difficult issue for Fire PRA – more discussion later

- Corresponding PRA Standard SRs: CS-A6, CS-B1
- Corresponding NEI 00-01, Rev. 2: Step 3
  and Sections 3.5.2.4 & 3.5.2.5 (circuit analysis and evaluation)

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Step 5 – Determine Cable Routing and Locations

- Correlate Cables-to-Raceways-to-Locations
- Conceptually Straightforward
- Logistically Challenging
  - Labor intensive
  - Manual review of layout drawings
  - Plant walkdowns often required
- Treatment and Documentation of “Assumed Locations”
- Determine Cable Protective Features
  - Fire wraps
  - Embedded conduit

- Corresponding PRA Standard SRs: CS-A10
- Corresponding NEI 00-01, Rev. 2, Steps: 7, 8, & 9

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Step 6 – Target Equipment Loss Reports

- Data Entered into Fire PRA Database
- Mapping of Circuit Analysis to Model Basic Events is CRITICAL to accurate results
- Sorts and Queries to Generate Target Equipment Loss Reports

Perspective – Cable selection process should be viewed as providing "Design Input" to the Fire PRA. It does not, however, provide any risk-based results. In its simplest form it provides a list of equipment that could be affected by a fire at a specified location or for a specific fire scenario.

- Corresponding PRA Standard SRs: CS-C1, C2, C4

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Work Packages

- A work package for each Fire PRA component consists of a compilation of drawings and documents that provide the basis of the circuit analysis results for that component
- Contents typically include
  - One-line diagram(s) (highlighted to show the component's power supply)
  - Elementary diagram(s) (marked up to show cable associations)
  - Block diagram(s) (highlighted)
  - Loop diagram(s) (if applicable)
  - Component circuit analysis worksheets
  - Other descriptive/supporting information

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Any Questions ??