U.S.NRC RIC 2016

# TH 32 - Improving Realism in Fire Probabilistic Risk Assessments

## Post-Fire Safe Shutdown Circuit Analysis
[Scope & Results of JACQUE-FIRE III; NUREG/CR 7150 Volume 3]

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## Discussion Topics

- Initial Circuit Failure Guidance [10CFR50.48 Appendix R]
- Efforts to Refine or Define Guidance
- Cable Fire - Circuit Failure Testing
- Gross Application of Test Results
- Detailed Analysis of Test Results
- Application of Detailed Analysis

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## Initial Circuit Failure Guidance [10CFR50.48 Appendix R]

- Put in place over 35 years ago as a part of the response to the Browns Ferry Fire
- Contained wording such as:
  - One train of systems – free of fire damage
  - Protection is to be provided for:
    - Cables or equipment of redundant trains, including associated non-safety circuits
    - From the effects of hot shorts, open circuits, shorts to ground

## Efforts to Refine or Define Guidance

- Dozens of Generic Letters, Information Notices & Memoranda were issued in the 1980s and 1990s to clarify and define Appendix R.
- Time was of the essence for complying with the new requirements.
- Numerous detailed approaches were used by various AE's in meeting the requirements.
- A detailed consensus means of meeting the requirements did not exist.

## Efforts to Refine or Define Guidance

- In the late 1990s, the BWROG developed the first consensus approach to performing post-fire safe shutdown circuit analysis for Appendix R.
- During this period, NFPA 805 developed the first consensus approach to performing a performance based plant fire analysis.

## Efforts to Refine or Define Guidance

- Each of these approaches, however, still relied upon many of the fire-induced circuit failure assumptions postulated throughout the 1980s and 1990s.
  - There were no cable fire tests available to determine the actual behavior of circuits in fire-induced failure conditions.
  - As a result, adequate justification for the assumptions postulated was not available.
    - Many of these assumptions related to fire-induced hot shorts and spurious operations.

## Cable Fire - Circuit Failure Testing

- In early 2000 through 2012, cable fire testing using cables configured to be representative of actual plant circuits was performed.
  - NEI/EPRI Testing [EPRI 1003326; Dec 2002]
  - NRC/EPRI Testing
    - CAROLFIRE [NRC NUREG/CR-6931, Vol. 1, 2 & 3; April 2008]
      - AC circuits; Cable thermal thresholds for fire modeling
    - DESIREE-FIRE [NRC NUREG/CR-7100; April 2012]
      - DC circuits

## Gross Application of Test Results

- This testing unequivocally confirmed that;
  - fire-induced hot shorts with the potential to cause spurious operation of plant equipment do occur when cables are subjected to specific threshold temperatures.
  - These hot shorts, however, take some time to develop and they quickly go to ground.
- These test results, however, although immensely useful, did not provide specific criteria for performing a post-fire safe shutdown circuit analysis.
  - They did, however, highlight the need for additional examination and analysis of the post-fire safe shutdown circuit analysis criteria.

## Detailed Analysis of Test Results

- JACQUE-FIRE – An informed, formal and critical review of the cable fire testing data and results
  - An NRC Research coordinated effort:
    - Involving Experts from Nuclear Reactor Regulation, NRC Research, the National Laboratories and Industry (both Licensees and Technical Consultants).
    - Employing rigorous and established processes, e.g., PIRT Process, expert elicitation process.
    - Lead by individuals with detailed knowledge of each of the processes used.

## Detailed Analysis of Test Results

- JACQUE-FIRE Volumes 1, 2 & 3 [NUREG/CR-7150; Oct 2012, May 2014, Planned for 2016] in combination with ELECTRA-FIRE [NUREG 2128; Sept 2013] performed the analysis of the fire test data, in combination with the plant specific circuit configurations, necessary to convert the cable fire tests results into detailed post-fire safe shutdown circuit analysis criteria.
  - Volume 1 – developed the critical characteristics important to the occurrence of fire-induced hot shorts and spurious operations in circuits representative of those used throughout the Nuclear Power Industry.
  - Volume 2 – developed probability of occurrence numbers for each of the circuit failure types identified in Volume 1. [Used to revise probability values in NUREG-CR 6850].
  - Volume 3 is developing post-fire safe shutdown criteria for specific issues requiring clarification within the current guidance documents based on insights from Volumes 1 & 2.

## Detailed Analysis of Test Results

- Specific Criteria Documents will be issued under JACQUE-FIRE Volume 3 [NUREG/CR-7150 Volume 3; Planned for 2016]:
  - Application of PIRT Results (Appendix J to NEI 00-01)
  - Shorting Switches (Appendix I to NEI 00-01)
  - Duration of Hot Shorts
  - Rules for Developing and Combining Multiple Spurious Operations
  - Proper Polarity Considerations
  - Impact of fire-induced open circuits on secondary fires for current transformers

## Application of Detailed Analysis

- Draft versions of the JACQUE-FIRE III documents have been reviewed by NRR and Industry
- When finalized by the NRC Research and EPRI Working Group, the JACQUE-FIRE III papers will be issued to NRR and Industry
  - Industry plans to include the criteria from these papers in a revision to NEI 00-01
  - The revision to NEI 00-01 is planned to be submitted to NRR for their review and endorsement in a future revision to Regulatory Guide 1.189
- When endorsed by NRR, the revision to NEI 00-01 will represent a detailed consensus approach to performing post-fire safe shutdown circuit analysis.
  - It will be available for use by Licensees whose fire protection programs comply with either Appendix R or NFPA 805.
  - When combined with the new probability values and other recent refinements to fire PRA methodology beyond NUREG-CR 6850, it will help to significantly improve the realism in the probabilistic risk assessments (PRAs) performed by Licensees.