High Energy Arcing Faults Involving Aluminum Informational Update

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Division Director
Office of Nuclear Regulatory Research
March 20, 2019

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Welcome

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- High energy arcing faults (HEAF) involving aluminum (PRE-GI-018)
  - Follow on meeting from January 23, 2019 public meeting
    - Focus on NRC Testing
- Public meeting
  - Meeting transcribed
  - Remote participation via telephone
- Thank you for your interest and participation
  - Short presentations by NRC staff
  - Open discussion with public input on the next phase of testing

High Energy Arcing Fault (HEAF) Large-Scale Test Plan Comment Resolution

Public Meeting – Rockville, MD

Mark Henry Salley P.E.
Office of Nuclear Regulatory Research
Division of Risk Analysis

March 20, 2019

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Previous Industry Comments

Summary

- Official Public Comment Period
  - Federal Register notice (82 FR 36006) published on August 2, 2017
  - Public comment period closed September 1, 2017
    - 5 comments from NEI
    - 32 comments from OECD member countries
  - 29 additional comments received from EPRI on January 12, 2018
  - 4 additional comments received from industry technical expert (Beaver Valley) on April 12, 2018
  - 28 additional comments received from NEI on May 17, 2018
- 98 comments received in total
  - International and U.S. Industry
- All comments dispositioned and publicly released
  - ML18233A469
- Public Meeting
  - January 23, 2019 – ML19046A388
- Follow on Public Meeting- NEI/Industry Comments
  - March 20, 2019

HEAF Operating Experience Root Causes

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- Human Error
- Breaker Failure
- Over Current
- High Resistance Connections
- Manufacturer Design Defects
- Aging Degradation
- Foreign Material

Industry Comments

Duration Realism

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- Research and test durations are based on operating experience
- Millisecond fault occurrences are <u>not</u> part of the HEAF frequency bins

Plant	Event	Event classification	Event Duration
Palo Verde (M Voltage)	7/6/1988	Arc Blast	**0.7 sec** (actual duration)
DC Cook (M Voltage)	7/13/1990	HEAF	Likely **≤0.5 sec**
Waterford (M Voltage)	6/10/1995	HEAF	**4-8 sec** (estimated: generator fed)
SONGS (M Voltage)	2/3/2001	HEAF	**4-8 sec** (estimated: generator fed)
Prairie Island (M Voltage)	8/3/2001	HEAF	**4-8 sec** (estimated: generator fed)
Robinson (M Voltage)	3/28/2010	HEAF	1st Event: **20 sec** (actual HEAF duration)
Robinson (M Voltage)	3/28/2010	HEAF	2nd Event: 3 Min high impedance fault followed by unknown duration HEAF event
Palo Verde(M Voltage)	7/3/2013	HEAF	Estimated < **2 seconds** (however, photo evidence that protection may have operated much faster)
Brunswick (M Voltage)	2/7/2016	Arc Blast	0.15 sec (estimated duration)
Yankee Rowe (L Voltage)	8/2/1984	HEAF	Unknown
Fort Calhoun (L Voltage)	6/7/2011	HEAF	**42 sec** (actual duration)
River Bend (L Voltage)	2/12/2011	HEAF	**12 Sec**

Updated HEAF Frequency

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- The frequency will be updated to comport HEAF events from operating experience
- This analysis work is ongoing and will be a collaborative effort through the NRC/RES MOU
  - Expected Spring/Summer 2019

NUREG – 2169 Bin	Ignition Source	Fire Frequency
15	Electrical cabinets (non-HEAF)	3.00E-02
16.a	HEAF for low-voltage electrical cabinet (<1000 V)	1.52E-04
16.b	HEAF for medium-voltage electrical cabinet (>1000 V)	2.13E-03
16.1	HEAF for segmented bus duct	1.10E-03
16.2	HEAF for iso-phase bus duct	5.91E-04

Industry Comments
Realism of Testing

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Internal Cabinet Damage

SONGS, 2001

Testing

Enclosure Breach

Robinson, 2010

Testing

Industry Comments
Realism of Testing

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Diablo Canyon Bus Duct (OpE) 2000

Columbia Bus Duct (OpE) 2009

Zion Bus Duct (testing) 2016

NRC/EPRI Interaction

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- Working with EPRI under the MOU to quantify risk
  - EPRI witnessed the recent series of testing
  - Initiated EPRI/NRC working group to evaluate test results & determine risk
  - Working group conducted meeting February 19-22, 2019
- EPRI Technical Update #3002015459
  - "Critical Maintenance Insights on Preventing High-Energy Arcing Faults " – March 15, 2019

ELECTRIC POWER RESEARCH INSTITUTE

High Energy Arcing Fault (HEAF)

Status of EPRI Comment Resolution

Marko Randelovic
Senior Technical Leader

NRC Public Meeting
March 20, 2019

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Resolution of EPRI's comments

- EPRI initially had 29 comments on the NRC's Phase II test plan
  - Most comments were addressed and resolved (25 out of 29)
  - Open comments were the more "difficult" ones
    - Scope, purpose, intended application
    - Significant effort or cost to change
- Since the initial review, EPRI has continued to research HEAF events
  - Additional technical information obtained and more detailed evaluations performed of HEAF events in the US.
  - Additional comments and suggestions for the upcoming HEAF tests provided to and discussed with NRC-RES under MOU
- NRC-RES, EPRI, Industry Experts, and Sandia was held a 4-day technical workshop to discuss open comments in February 2019

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Progress on EPRI's Initial Written Comments

- Out of 29, 25 comments were already resolved
- Significant collaborative discussion on on remaining items:
  1. *Need for the dynamic conductivity measurement of the combustion cloud*
     Continuing discussion and technical exchange to understand the performance of the conductivity probes and how results should be interpreted and applied
  2. *Methodology for the evaluation of the zone of influence and components/cables fragility assessment*.
     Feb 2019 workshop included detailed discussion of the proposed Sandia model. General understanding of the NRC-RES plan to utilize HEAF testing results to evaluate the Sandia model and to then use Sandia model to develop relevant ZOI's for the various sub-bins of Bin 16 was discussed.
  3. *Extrapolation of the low voltage test results to medium voltage switchgear testing*
     Significant discussion topic during the Feb 2019 workshop. Consensus is that more detailed review of data and test results will be required before concluding that any extrapolation of the data is practical
  4. *Value of the current for the low voltage test does not correspond to the values from the HEAF events in the US.*
     Discussed in Feb 2019 workshop and NRC-RES plans to amend future test plans to utilize currents representative of OE

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Progress on Additional EPRI Evaluation of the US OE

- EPRI's continued assessment of the Operating Experience (OE) related to HEAF events resulted in additional comments and suggestions for the upcoming testing
- Technical basis for recommendations have been discussed between EPRI and NRC-RES
  1. Proposed changes, based on the OE, are related to:
     - Medium voltage tests configuration and fault location
     - Low voltage load center test design
  2. Use of representative energized mock switchgear to evaluate ZOI for realistic equipment
     - Due to the lack of experience with the conductivity probes and risks associated with the interpretation of the results, EPRI suggests the use of an energized mock switchgear for a more representative evaluation of potential impact and ZOI
     - General consensus to evaluate the modification of the test plan to use a mock switchgear
     - EPRI is providing support under the MOU to help specify the necessary design of the mock switchgear

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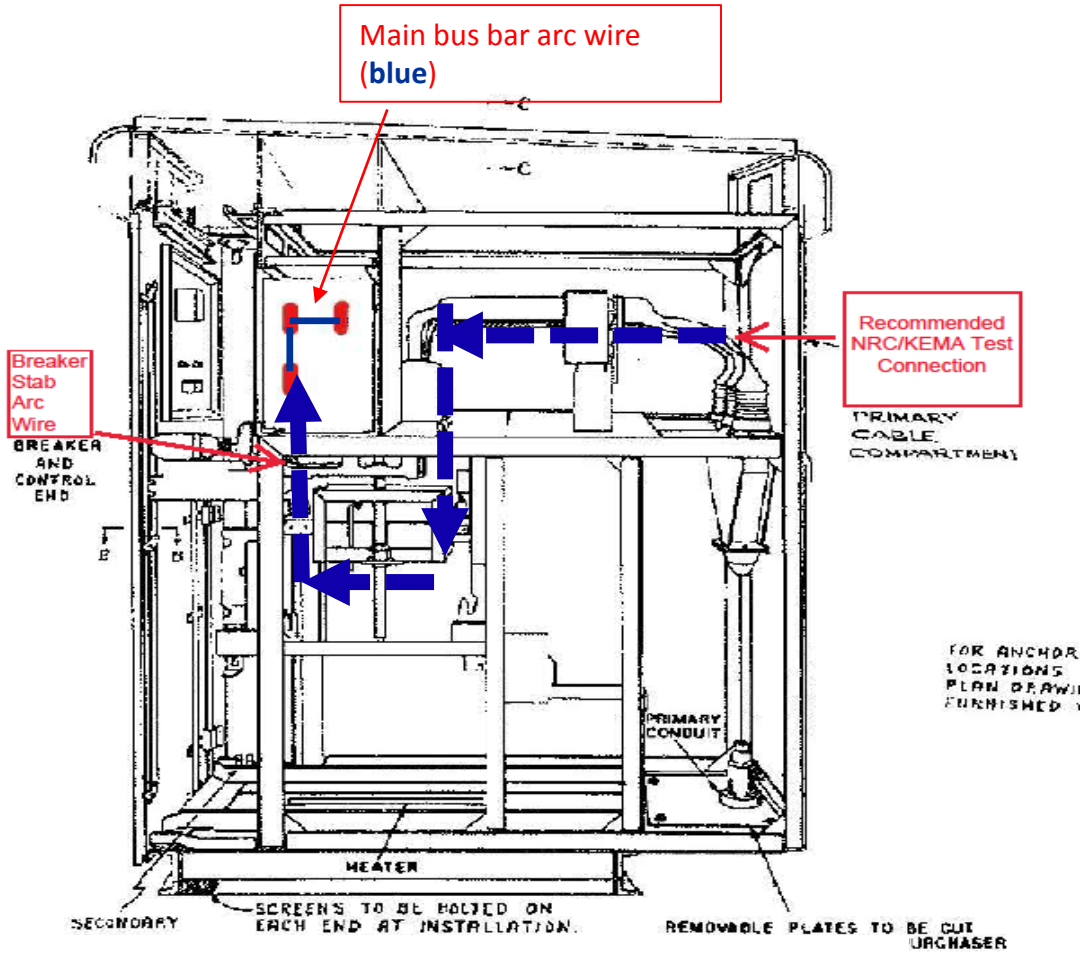
1a) Evaluation of the US OE – Medium Voltage

- OE on medium voltage switchgear HEAF events:
  - Majority of the medium voltage switchgear events occurred in the supply switchgear configuration
  - Majority of the faults occurred at the supply breaker stabs and main bus bars

- Medium voltage tests may require reconfiguration
  - Planned test setup
  - Locations of the arc wire

HEAF working group working to address



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1b) Evaluation of the US OE – Low Voltage

- OE on low voltage HEAF events:
  - All low voltage events occurred in the load center supply cubicle
  - All faults initiated at the supply breaker stabs

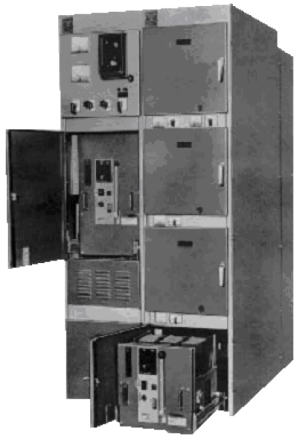

Figure 1 – Switchgear Cell

- OE and working group recommendations are currently being considered during the procurement activities

Fig. 4 *Type DS-206 Breaker in Connected Position (392506)*

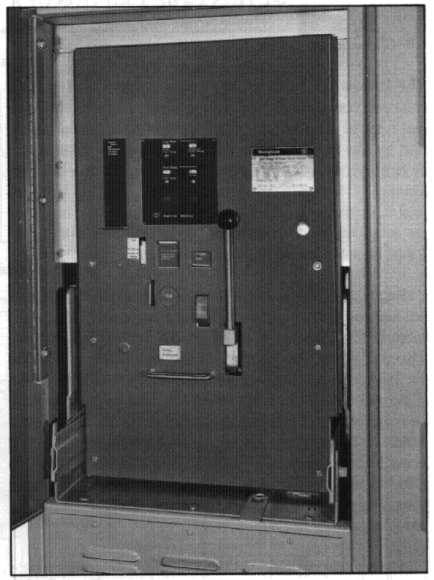

Fig. 6 *Type DS-632 Breaker in Connected Position (391179)*

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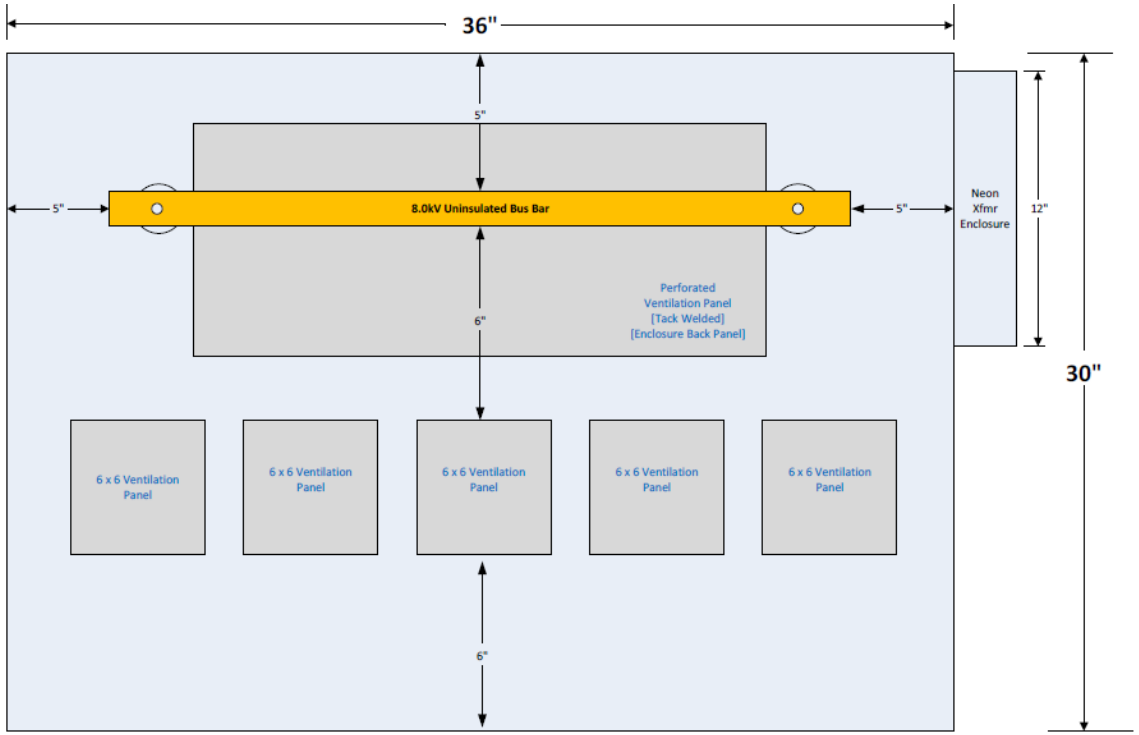
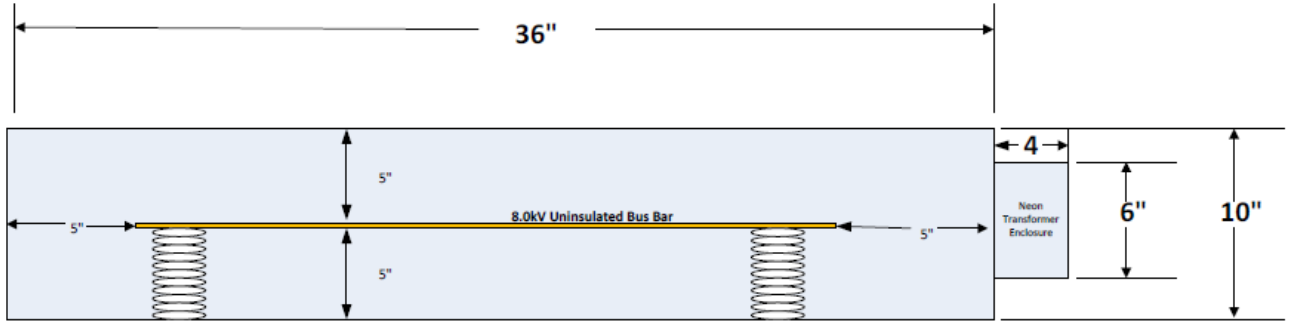
2) Use of Energized Mock Switchgear

- Purpose of the Mock Switchgear Test Unit (MSTU) is to verify if liberal amounts of aluminum combustion cloud byproduct/debris is sufficient to cause collateral damage (flashover) in nearby/adjacent medium voltage.
- Location of the MSTU will be based on the previous Medium Voltage test results (videos)





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