Taylor, Gabriel

From: Lindeman, Ashley <alindeman@epri.com>
Sent: Friday, May 04, 2018 8:27 AM
To: Taylor, Gabriel
Cc: Salley, MarkHenry; Cheok, Michael; Voelsing, Kelli
Subject: [External_Sender] EPRI Comments on Aluminum HEAF Particle Size
Attachments: PT-050418-145 Comments on HEAF Test Plan.pdf

Gabe,

EPRI has reviewed the *Aluminum High Energy Arc Fault (HEAF) Particles Size Characterization Test Plan – Draft.* Letter PT-05418-145 documents the EPRI comments on the public test plan. Please let me know if the NRC requires any additional detail or follow up on the comments provided by EPRI.

Best Regards,
Ashley

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EPRI | ELECTRIC POWER RESEARCH INSTITUTE

May 4, 2018
PT-050418-145

Mike Cheok
Director
U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Division of Risk Analysis
Washington, D.C. 20555-0001

Subject:Comments on “Aluminum High Energy Arc Fault (HEAF) Particle Size Characterization Test Plan - DRAFT” (Docket ID NRC–2018–0040)

Dear Mr. Cheok:

As an independent, not-for-profit organization for the benefit of the public, the Electric Power Research Institute (EPRI) appreciates the opportunity to comment on the test plan entitled “Aluminum High Energy Arc Fault (HEAF) Particle Size Characterization Test Plan - DRAFT”. Please find comments in Attachment A.

We believe that the attached comments and recommendations will lead to a more technically sound test plan and associated results.

If you have questions about any of these comments or would like to discuss resolution, please contact Ashley Lindeman at 704-595-2538 or at alindeman@epri.com.

Sincerely,

Kelli Voelsing

Kelli Voelsing
Program Manager
Risk and Safety Management

Cc. M. Salley, NRC-RES
G. Taylor, NRC-RES
M. Thaggard, NRC-RES
T. Taylor, EPRI
A. Lindeman, EPRI

PT-0050418-145

Attachment A – EPRI Comments on “Aluminum High Energy Arc Fault (HEAF) Particle Size Characterization Test Plan - DRAFT”

Attachment A:

EPRI comments on
"Aluminum High Energy Arc Fault (HEAF) Particle Size Characterization Test Plan - DRAFT"

Section / Page	Comment	Recommendation
General	The test plan repeated discusses "particle" characterization. However, based on the various historic tests and analysis documents, the major concern appears to be the vapor cloud of aluminum that forms through high-temperature arcing and oxidation. It is not evident in the test plan how the intended instrumentation will support characterization of the vapor cloud.	If the term "particle" – as used in the test plan – is intended to include vapor particles, this fact should be clarified. If the instrumentation is not geared toward characterizing the vaporized material while in the vapor phase, it is not clear how the test plan aligns with the identified concern.
General	Since the test plan objective is to better characterize the aluminum particle size, production, and morphology during a HEAF, the general reference to the IEEE Standard C37.20.7 is not relevant as the testing, setup, conduct deviates more than follows the IEEE guide. <u>Examples include:</u> • General/global reference: o Example: Section 2.2 "Experimental Setup", first paragraph. "*Twenty tests will be performed per IEEE C37.20.7*". • Shorting wire gauge does not follow IEEE C37.20.7: o Section 2.3, second paragraph states "wire per IEEE C37.20.7…"; however, o Sections 1.3 and 24 states shorting wire will be #6 AWG, which is a deviation from IEEE C37.20.7 (and cited by Section 2.4.3): ▪ 10 AWG for low-voltage gear ▪ 24 AWG for medium-voltage gear o Test plan provides no basis or reason from shorting wire size deviation.	Recommend stating up front that the proposed test plan is of a research and experimental nature regarding the behavioral characteristics of extreme/severe aluminum HEAF events and not intended to follow or meet the IEEE Standard C37.20.7 which is for the design and production of metal-enclosed switchgear.

Section / Page	Comment	Recommendation
viii & Section 1.3	It is recommended that clarification be added to the "Overview of Test Plan" and Section 1.3 "General Approach" to describe how the results of this experimentation will be used.	Consider adding the following clarifications: • The small scale tests are not representative of actual installed equipment and thus test results are not intended to predict overall equipment performance during a HEAF event for actual electrical distribution system (EDS) equipment • The purpose of these small scale tests is to better characterize at a micro-level the phenomena of aluminum arcing (particle size, distribution, production, and morphology) so that instrumentation and test design for the OECD Phase 2 testing is optimized • The small scale test results should be used only for the intended purpose and should not be extrapolated to predict performance of actual equipment with respect to HEAF response or full-scale damage
viii	The word "configurations" is not the correct terminology in the following sentence: "The experimental setup was developed based on prior work by KEMA and SNL[1] for phase-to ground and phase-to-phase electrical circuit configurations".	Revise sentence to read: "The experimental setup was developed based on prior work by KEMA and SNL[1] for phase-to ground and phase-to-phase electrical faults."
Section 1.2 [Page 1]	First paragraph: This paragraph implies that rate of HEAF events are increasing as a result of aging; however, there have been other non-aging causes have been attributed to failed barriers, human errors, and design errors (i.e., the HEAF would have occurred regardless of the age of equipment).	Recommend acknowledging other HEAFs initiators such as multiple failed barriers, design errors, human errors, etc.
Section 1.2 [Page 1]	The meaning of "holding rack" is not clear. Does "holding rack" refer to the breaker compartment or to the breaker stabs and fingers?	Clarify the term "holding rack" according to standard electrical terminology.
Section 1.2 [Page 1]	Nuclear power plants contain primarily medium-voltage gear. There are not many, if any, greater than 35kV pieces of equipment within the plant.	Revise sentence to state "NPPs within the United States (US) widely use medium-voltage bus bars which are typically housed within a bus duct or rated cabinet"
Section 1.2 [Page 2]	Second paragraph, 5th sentence: What is meant by "*non-mechanical destructive forms as well"* as it relates to expanding the zone of influence (ZOI)?	Recommend providing a non-mechanical destructive example.
Page 2	There is typically not high-voltage equipment within the plant.	"High–voltage equipment" should be replaced with "medium-voltage equipment"

PT-010518-145
Attachment A

Section / Page	Comment	Recommendation
Section 1.2 [Page 3]	The fourth to last sentence in Section 1.2 discusses the use of the small scale test results to predict fundamental equipment failure criteria, specifically both ignition and functionality.	This statement should be removed – the test configuration does not represent real equipment (either mechanically or electrically) and thus the small-scale test results should not be extrapolated to predict equipment performance. The small-scale tests should be used only for the intended purpose, i.e., characterize arc behavior and product formation for aluminum.
Section 2.2 [Page 5]	The test plan provides detailed information about instrumentation but is general with respect to the actual test configuration/equipment. While it is understood that the primary purpose of the test is not to characterize the system response (electrically), the full electrical test configuration should be specified, including the power source, connecting cables, grounding, etc. The test plan does not address the extent to which the voltage, current, X/R ratio, system reactance, voltage and current wave shape, harmonics, DC offset, and electrical transients affect the outcome of HEAF events involving aluminum.	The standard parameters associated with the electrical system analysis should be characterized to determine short circuit behavior and performance. This information should be readily available for the ACD Lab equipment (e.g., MacroAmp power supplies, HILO V & I sources, trek amplifiers, and Glassman power supplies).
Figure 2 [Page 6]	Dimensions provided for the test mock-up have no units.	Recommend identifying somewhere the units of measurement.
Section 2.4 [Page 7]	Are the bus bar dimensions 3 mm x 1 mm? This is not much larger than a rectangular metal rod.	Verify bus bar dimensions in Section 4 and Table 1. Stated size in test plan is extremely small.

PT-010518-145
Attachment A

Section / Page	Comment	Recommendation
Table 1 [Page 8]	The proposed durations are too short to develop meaningful data and conclusions. HEAF events that have lasted for several seconds are the most challenging from a damage and aluminum oxidation concern. The short duration tests will not create the same thermal environment as a real HEAF event, so it will be difficult to extrapolate any conclusions related to rate of erosion, size of particles, or percentage of eroded aluminum that oxidizes. As a point of reference, Stanback (1) derived a model of the amount of aluminum eroded during an arcing event. Stanback found the following relationship: $Y = 1.519E\text{-}6 \times I_{arc}^{1.5}$ Where; Y = burn rate of bus work, in^3/sec (1 in^3/sec = 16.387 cm^3/sec) I_{arc} = rms arcing fault current, A For the nine Sandia tests planned with aluminum electrodes, the median predicted lost aluminum is 0.035 cm^3 (0.002 in^3). That is 1 cm of the planned electrode. The worst-case test has a predicted loss of 0.56 cm^3 (0.034 in^3). That is not much material. As a comparison, in the worst medium-voltage test of HEAFs performed at KEMA, 2000 cm^3 of aluminum was eroded. (1) Stanback, H. I. J., "Predicting Damage From 277-V Single Phase to Ground Arcing Faults," IEEE Transactions on Industry Applications, vol. IA-13, no. 4, pp. 307-14, July-August 1977.	Perform longer duration tests. Instead of 4- and 8- millisecond durations, aim for durations of several seconds.
Table 1 [Page 8]	Use the higher end currents to maximize erosion and match conditions of the most severe HEAF events.	Test at one higher end current (either 12, 20, or 29 kA) to maximize bus bar erosion.
Table 1 [Page 8]	In Table 1, the following rows are missing whether the test is AC or DC: • Row 8 • Row 12 • Row 16	Fill in the missing table elements regarding AC/DC testing in Table 1.

PT-010518-145
Attachment A

Section / Page	Comment	Recommendation
Table 1 [Page 8]	The durations of 4 ms and 8 ms are extremely short. These times are shorter than the fastest clearing time of any overcurrent protective device and hundreds of times shorter than the test durations of large-scale testing.	Provide a technical basis to demonstrate that the test durations of 4 ms and 8 ms are adequate to support the test objectives.
Section 2.4 [Page 8]	The last paragraph of this section indicates that data collection will occur at 20 ms or lower. However, the arc duration (4 ms or 8 ms) is much shorter that the stated upper limit of data sampling.	The data recording should be much faster than the test arc duration. This aspect of the test should be clarified, including the required sampling rate to meet test objectives. It is suggested that sampling should be at the micro-second level not millisecond level.
Section 2.4 [Page 8]	Last paragraph, what is meant by "…*which is consistent with personnel options from IEEE HEAF events*"?	This cannot be understood as written. Recommend rewording for clarity.
Table 1 [Page 9]	10,000 V is not standard voltage. Recommend selecting a voltage in the medium-voltage range and use throughout test.	Use standard medium-voltage range (either 4160V or 6900V) for test voltage.
Figure 4 [Page 11]	Figure 4 description: "…analyzed by collecting **as** from the arc flash region…" should be "analyzed by collecting **gas** from the arc flash region".	Recommend correcting typo.
Section 2.10 [Page 11]	Many "XXX"x are used. Was this intended to be filled in later?	Recommend updating when final test plan is issued.
Section 2.11/ [Page 11]	Item 2 states that the "*Full event can last 1-4 seconds.*"	Recommend updating the duration depending on the intended "*Target Arc-Duration*" in Table 1.
Section 2.11/ [Page 12]	2nd full paragraph (below the three bullets). "*agnostic*" appears to be a typo?	Recommend correcting.
Section 2.12 [Page 12]	Item 6: If applicable, consider expanding for specifics: • Melted slag • Ejected, non-melted fragments, shrapnel	If there is the possibility of performing oxidation calculations (of vaporized/consumed material); the testing will need to collect all available non-oxidized material to ensure volumetric calculations are as accurate as possible.