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Activity: HEAF – PRA Report - Resolution of Public Comments

Comment No.	Document Number Section / Paragraph	Review Comments (Print)/Basis for Comment	Disposition
1	General	The document does not specifically indicate if it is superseding prior guidance, or is provided as a guidance for refinement of prior modeling. Superseding prior guidance would require fire model revisions during the next scheduled update.	This new method provides significant advances to modeling approaches over the previous methodologies. Consistent with other methodological advancements and data improvements, licensees should evaluate this new information as part of their periodic update process as committed to per the PRA standard. In general, NUREG documents are not compulsory methodologies, and licensees can choose to implement these methods per their normal procedures. Further clarification will be provided as needed during a planned workshop activity in the Spring of 2023.
2	General	All references to Thermoplastic cable or Thermoset cable should specify if referencing the jacket or insulation material. Recommend consistently using "thermoplastic jacketed cable", as an example.	Revised as suggested.
3	General	Although the guidance is comprehensive, it provides a detailed analysis methodology which will require significant man-hours to research and implement. Besides the simple summary in the Abstract (page vii lines 27-35), is there any guidance for a utility to partially implement the guidance as necessary for high risk HEAF scenarios, allowing current modeling per NUREG/CR-6850 & Supp 1 to remain bounding for other scenarios? Could the guidance provide very specific instances where NUREG/CR-6850 & Supp 1 are non-bounding? Must the guidance on application of revised ZOIs, IGFs, and NSPs be implemented together?	The new methodology was developed to be implemented as a replacement to the current tools rather than to supplement pieces of a current analysis on an as needed basis. The aspects of the new methodology should be applied together and not partially implemented, as HEAF likelihoods, durations, definitions and ZOIs are tied together. The methodology relies upon a level of detail not developed in the NUREG/CR-6850 approach. The new HEAF PRA methodology has aspects which may produce a larger increase in risk than 6850, as well as aspects which can reduce risk. For example, larger ZOIs, particularly for longer FCTs for bus ducts, can result in more extensive cable damage and increased risk; however, credit for ERFBS can lead to reductions in risk. Thus, the overall impact of risk from the new HEAF PRA methodology will depend upon the plant configuration and be plant specific. The guidance provides the tools for the analysist to determine if their current model is non-bounding, but the determination will be plant specific and

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			application specific. For high-risk scenarios, the FCT for the HEAF scenarios should be analyzed to determine if the energetic ZOI is larger/smaller than currently analyzed. Section 10.3 provides a starting point where the original NSBD/MV switchgear ZOIs may be challenged.
4	General	Throughout document, equation values should not have an apparent space before and after the "-" in the exponent. E.g., Page G-12, Lines 5-14. This may be a result of the selected italic font.	Revised to tighten up the text for the numbers displayed in scientific notation for Appendix G.
5	General	Regarding: "15 MJ/m2 target fragility" & "30 MJ/m2 target fragility" Throughout the document, "15 MJ/m2 target fragility" & "30 MJ/m2 target fragility" should be changed to use the more common terms "Thermoplastic" and "Thermoset".	The 15 & 30 MJ/m^2 criteria apply beyond the thermoplastic and thermoset cabling. See Section 6.2 which discusses additional targets such as junction boxes, electrical equipment, bus ducts, and instrument air. No changes are made globally since the fragility thresholds apply to more than just TS and TP-jacketed cabling.
6	General	Rotate wide pages in PDF for ease of reading electronically	This is a publication issue.
7	X Lines 13 & 14 Exec Summary	Regarding: Section 6 provides general guidance on the energetic portion of the HEAF ZOI, how to determine fault clearing times, and characteristics of the post-HEAF ensuing fire. State that the energetic portion of the HEAF ZOI discussed in Chapter 6 is specific to switchgear and load centers.	Section 6 provides general guidance for switchgear/load centers and NSBDs. For example, Section 6.1.2 is the damage footprint for NSBD (describes the waterfall). Section 6.5 (Post-HEAF ensuing fire) is only applicable to switchgear and load centers, so added the following bolded text to the executive summary. • Section 6 provides general guidance on the energetic portion of the HEAF ZOI, how to determine fault clearing times (FCTs), and characteristics of the post-HEAF ensuing fire **(for switchgear and load centers).**

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8	X Exec Summary	Regarding: The overall discussion on Section 8 regarding fragility. Use of "and" for defining the 15 and 30 MJ/m2 target types may be misleading in lines 38-47. For example, as written it reads that 15 MJ/m2 should be used when you have thermoplastic targets AND aluminum enclosed bus ducts. One solution here would be to use commas separated values in the parenthesis with an "etc." at the end since there are more than 2 criteria to apply each fragility level.	Agree. Comment incorporated
9	Ix General	The scope of the overall report seems to ignore a design configuration wherein an additional transformer exists between Zone 1 and Zone 2. In such configurations the size of the associated transformer (e.g., 13kv – 4kv) can be relatively small and consequently the maximum available fault current can be well below the designed capability of the switchgear. It is unclear whether such a configuration was considered or addressed within the framework of this NUREG. It would be beneficial if some discussion for such a configuration could be provided.	Added discussion of configurations where ESF transformers exists between Zone 1 and Zone 2. Added in definition (Section 3), Zone 1 and Zone 2 switchgear (Section 3) and a new section 6.4.3.
10	Section 1.2	Section 1.2 Approach indicates the guidance is a methodology "update". Is this to be interpreted as the methodology is not an "upgrade" which would require peer-review?	Removed the word "update" from the sentence. Not in the scope to determine if the report is considered an update or an upgrade.
11	Section 2	"Target Fragility" should be a defined term in Section 2 Terminology.	In Section 2, terminology – the definition of target fragility is added as: **Target Fragility**: The condition when targets external to the HEAF are likely to be damaged.

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12	Section 3.6.3	The discussion of switchgear main bus bar faults does not address the design configuration wherein a bus differential is applied. The discussion in the report should acknowledge that if such a design exists and the breaker(s) actuated by such a differential relay successfully opens (trips), then a HEAF event would not occur. This conceptual approach should apply to all instances where an 87 device is applied.	Added definition (in Section 2) and discussion of bus differential protection in Section 3.6.3. If bus differential works, there is no HEAF-level consequences. The treatment of bus differential is similar to the treatment of the SAT differential protection (assumed failed). Footnote added in Section 8.2.2 to address.
13	Page 3-32 Section 3.6.5 Figure 3-14	The 9th branch down (Supply side of supply breaker, fails/stuck, SAT, with zone of differential (87), one switchyard breaker fails/sticks) should be light grey text since the duration is less than or equal to 0.2s, and therefore wouldn't be expected to cause a HEAF.	Updated Figure 3-14
14	Page 3-34 Section 3.7.1 Figure 3-16	The last branch should have a duration of 0.4 to 5.2s instead of 0.4 to 5s.	Figure 3-16 updated with 0.4 to 5.2 s

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Comment No.	Document Number Section / Paragraph	Review Comments (Print)/Basis for Comment	Disposition
15	Section 5.2.3	Regarding statement: It is possible to use both the known transition point and the unknown transition point method in the same analysis if the frequency is conserved within the respective NSBD bin. Section 5.2.3 discusses the development of the ignition frequency weighting factors applied to Zone 1 and Zone 2 MV switchgear. These are based on OE, and thus appear to implicitly include the breaker protection failure likelihood for the Zone 2 events. It is not exactly clear that modeling a Zone 2 event should not (or should) multiply the Zone 2 HEAF ignition frequency by the probability of upstream supply breaker failures (as illustrated in Figure 6-5). A statement could be added to clarify the intent.	Regarding the second comment, the analyst should not multiply by the upstream breaker failure probability. Revised the text near Figure 6-6 (old figure 6-5) to remove the word “end state” to eliminate confusion. Also added in the footnote to clarify the working group’s intentions: The three independent failures are not explicitly modeled in the PRA method. However, through the use of the Zone 1/Zone 2 weighting factor (Section 5.2.2.3) and the apportionment of split fractions in the Zone 2 event trees (Figure 8-7 [5%] and Figure 8-10 [1%]), scenarios depicted in Figure 6-6 are expected to be of low likelihood.

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16	Page 5-10 Lines 3-6 and Page 5-15 Lines 11-13	Regarding: In addition to the transition points, fire PRA targets in locations with a propensity to allow for degradation of the bus bar insulation – vents, hatches, or wall penetrations – should be captured and included with scenarios structured around the nearest transition points. Page 5-10 Lines 3-6 and Page 5-15 Lines 11-13; Inclusion of bus duct vent/drain/pens/hatch targets with the closest transition point could result in capturing targets from both Engineered Safety Feature trains in one scenario, even though the train targets are well separated and farther apart than the bus duct ZOI. Did the OE indicate that events related to vents/drains/pens/hatch occur at that location or at the nearest transition point? (Page 5-9 Lines 36-39) If at the vent/... location, then recommend including the vents/drains/pens/hatches in the count, and mapping targets exclusive to those locations. Inclusion of the additional targets at the nearest transition is more conservative than the method provided for unknown transition points, which does not address vents/drains/pens/hatches (Page 5-16, Example 2).	The OPEX has shown a propensity for vents, hatches, and wall penetrations to be the initiation point for arcing faults, however, this is typically associated with outdoor events. After reviewing the operating experience, the working group decided to remove the requirement to consider vents, hatches and wall penetrations inside (but still consider outside if these features exist). The revised text is as follows: Reviewing operating experience also highlighted the potential for a HEAF to occur in outdoor locations where environmental access to the bus bar insulation—such as ventilation openings, mechanical hatches, or external wall penetrations (e.g., yard-to-turbine-building penetration)—occurs and could allow accelerated degradation of the bus bar insulation. For known transition points, the analysis should look for fire PRA targets (i.e., fire PRA equipment and cables) within the ZOI at the transition points and postulate scenarios consistent with Supplement 1 to NUREG/CR-6850 [2]. For outdoor locations with features that may allow degradation of the bus bar insulation (e.g., vents, hatches, and wall penetrations), fire PRA targets near these features should be captured and included with scenarios structured around the nearest transition points or alternatively considered as transition points**.** Openings, such as vents, drains, or hatches located inside buildings (protected from weather elements) are not expected to increase the likelihood that the bus bar will degrade and do not need to be included in a scenario. Locations outdoors with a propensity to allow degradation of the bus bar insulation do not need to be counted as transition points for the purposes of counting segmented bus ducts, but the fire PRA targets located in the ZOI of one of these locations should be included in a scenario involving the closest transition point.

17	Section 5.2.3.3	As written, the guidance does not allow a mixed treatment within a bus duct type bin. For example, assume a plant has 500 feet of non-segregated bus duct and the location of transition points are not readily apparent. Therefore, the approach described in 5.2.3.2 is used. However, during analysis development and/or refinement it is discovered that a key critical target is within the ZOI for a 'short length' of bus duct. If it can be determined there are no transition points or features described in Section 5.2.3.1 within that 'short length', the guidance would not allow the HEAF event to be precluded using the guidance in Section 5.2.3.1. Section 5.2.3.3 should be modified to allow a mixed treatment within a bin – i.e., the HEAF event can be excluded provided the frequency for the 'short length' is re-apportioned to the remaining lengths of bus duct.	The method of mixing counting with in a bin, appears to allow an analyst to selectively assign risk as desired based on targets. This does not appear to meet the original treatment of bus duct counting, based on the following sentences in supplement 1 of NUREG/CR-6850: *As noted above, arc faults generally occur at the transition points. When the actual location of the transition points is not known, the approach assumes that a fault might occur at any point along the duct length. point. By the same token, the approach partitions fire frequency equally along the length of the bus duct, whereas in reality faults would be more frequent at the actual (but unknown) transition points* However, the following sentences allow for the removal of targets from consideration based on a more detailed look at the bus duct: *It is recommended that in assessing analysis results, these observations be treated as a part of the uncertainty and sensitivity analyses, and that the analysis be refined for cases where risk-significant fire scenarios develop (i.e., by examining the bus duct to determine if any transition points are actually present in the segment of bus duct associated with a significant scenario). This is discussed further below. Note that in either approach, the analysis can always be refined by examining the bus duct to determine if one or more transition points actually lie within the applicable bus duct segment. If no transition points are identified within that particular duct section, then a fault scenario need not be postulated and the scenario "goes away."* *Revised text in in 5.2.3.3 to state:* In summary, the analyst may choose different apportioning strategies for Bins 16.1-1 and 16.1-2. Supplement 1 to NUREG/CR-6850 [2] identifies the following refinement which may still be utilized if the unknown transition point method is used for one of the bins: *Note that in either approach, the analysis can always be refined by examining the bus duct to determine if one or more transition points actually lie within the applicable bus duct segment. If no transition points are identified within that particular duct section, then a fault scenario need not be postulated and the scenario "goes away." If one or more transition points are identified within a particular duct section, then the analysis can be refined based on the known locations (i.e., both the fire frequency and the impacted target set may be refined once transition points are identified).*

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18	Table 5-8	It would be beneficial to include the frequency previously assigned for a quick assessment of increases or decreases in the generic frequency.	Listing the old numbers creates a chance for the wrong number. Change in values can be compared by referencing NUREG-2169. Added discussion below Table 5-8 that discusses the frequency changes. The text includes: The mean frequencies for bin 16.a (HEAF for low-voltage electrical cabinets) and *bin 16.2 (HEAF for* iso-phase bus ducts*)* increased from the mean values in NUREG-2169 [38]. The mean frequencies for bins 16.a and 16.2 have increased by 250% and 71%, respectively. The significant increase in bin 16.a is driven by the limited number of fire events in the industry experience in NUREG-2169 and an event that occurred post NUREG-2169 (the impact of adding or removing a single event is more apparent). However, the frequency for bin 16.a is the low *(second lowest following Bin 1 – batteries)*. The frequency for bin 16.b has decreased by 7%. Splitting the segmented bus duct frequency results in an increase in frequency by 137% for bin 16.1-1 and a decrease of 18% for bin 16.1-2 from the previous combined bin 16.1 *mean*.
19	Table 5-8	Bin 16.a 95th percent is missing “-“, should read 1.69E-03.	Corrected.
20	Table 5-8	it would be helpful to provide the uncertainty values for the distribution (Mu, Sigma, EF) similar to NUREG-2169 Table 4-4, and/or indicate the distribution function [assume log-normal per NUREG-2169].	Updated Table 5-8. This now includes the Mu, Sigma, and EFs for each HEAF bin.

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21	Page 5-21 Section 5.3.1	Regarding: The value of 3.5E-05 associated with the air-blast type GCB bounds the failure results for the three different GCB technologies. Credit for the GCB interrupting the faulted conditions can be applied when the fault is within the GCB zone of differential protection. This credit can be applied to the following fault zones: Application of 1-GCB factor is not discussed here. The other frequency modifiers in this document function like split fractions, where applicable, and add up to 1.0. The difference here should be clarified to avoid issues where it will appear frequency is not conserved. Additional “number events” should read “number of events”	Agree that the draft report was not clear on what to do when the GCB operates. Added the following text after Table 5-9: If the GCB operates as designed (1 - 3.5E-05), the GCB prevents the main generator coast-down energy from feeding a fault within the GCB zone of protection. The working group determined that plants with installed GCBs are expected to have a better than average performance as compared to plants without GCBs. Therefore, for an end state where the GCB is credited, the scenario frequency is not conserved, since the 1 – 3.5E-05 when applied to the branch end state does not result in HEAF-type consequences. Editorial issue corrected *Also added text in Section 8.5 (Zone 1) for the 1-GCB reliability and in Section 9.2.1 (IPBD), and 9.2.2 (BDUAT)
22	Page 5-23 Section 5.4	Regarding: The primary difference is the number events counted for the determination of the suppression rate results from the inability to count events with no suppression time (self-extinguish), automatic suppression, or unknown suppression times. If there are known fire events where self-extinguishment occurred, this could be developed into a split fraction where no ensuing fire occurs. This would benefit the overall results given that the HEAF suppression curve has historically been one of the most challenging.	Table A-2 – Fire Event Data provided details on the suppression time. Reviewing the events in this table, three events are excluded due to suppression discharge (old 434, 50935, and 51765). Old 678 is self-extinguished and the remainder of the events with no suppression time are bus duct events (which do not always necessitate manual suppression efforts). There are no load center or switchgear HEAFs that are self-extinguished (and by definition HEAFs in load centers and switchgear have an ensuing fire). No changes to the HEAF suppression approach are made.

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23	Page 6-1 Figure 6-1	Page 6-1; Figure 6-1 (as well as others) illustrates HEAF ZOIs and implies that no damage occurs in the areas extending from the corners between the front/back zones and the side/side zones or the top zone, as opposed to bus duct ZOI shape of "rounded corner square". Is this intentional? As an example, in Figure 11-19 (page G-8), imagine that cable A penetrates the floor at "u" in the title "Figure 11-19", and Cable C penetrates the floor at "y" in the title "supply", these cables would be outside the HEAF front or side ZOIs.	The ZOIs as depicted in Figures 6-1 through 6-4 are as intended. The ZOIs for electrical enclosures are squared and are extended from the corresponding enclosure faces. These are the regions around the enclosure where an arc plasma jet could be located due to ventilation openings, access doors, or breaches. The space outside these regions would not be located within an arc plasma jet, and would the radiant view factor to the arc would be small given the arc is within the enclosure. The ZOI for bus ducts is rounded since breaches in the housing tend to occur on all sides resulting in minimal radiant obstruction between faces and potential exposure to the arc plasma jet. As the bus duct ZOIs are drawn and developed in this report they capture the 360° around the bus duct. For switchgear, the ZOI is intended to be squared based on the FDS results and the analyst should consider this difference in defining the energetic and ensuing fire ZOIs. Added additional text for the ZOIs in Section 7, 8, and 10 for loads centers and switchgear.
24	Page 6-2 Lines 11-13 Section 6.1	Regarding: Note that the ensuing fire ZOI may expand beyond the ZOI associated with the HEAF if secondary combustibles are involved, a damaging hot gas layer forms, or adjacent electrical enclosure sections are ignited. Per Section 6.5, the ensuing fire is required to utilize a 170kW fire. The ZOI from the 170kW fire is larger than the majority of the HEAF specific ZOIs when utilizing NUREG-1805 FDTs. The statement in question implies that the ensuing fire ZOI will only be larger than the HEAF ZOI if the ensuing fire involves secondary combustibles, creates a HGL, or ignites adjacent sections. If this is true, Section 6.5 should be revised to be consistent with this statement in Section 6.1.	Text on Page 6-2 already eludes that the ensuing fire may be larger than the energetic phase (for short FCTs). Additional it could get larger if additional combustibles are involved, HGL, or additional sections are ignited. Revised text to state: Note that the ensuing fire ZOI may **also** expand beyond the initial HEAF ZOI if secondary combustibles are involved, if a damaging hot gas layer forms, or if adjacent electrical enclosure sections are ignited.

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25	Page 6-5 Line 34	change “bents” to “vents”	Corrected.
26	Section 6.3.1 Page 6-6 Line 44	Section 6.3.1, page 6-6 line 44, introduces the term V_{L-L} which I interpret as a line-line (or phase-phase) short arc voltage. Was a phase to ground short also considered for developing the simulation of MV or LV HEAF scenarios?	Added a footnote to explain this, footnote reads: V_{L-L} represents phase-to-phase arc voltage. Phase-to-phase arc fault testing is the predominant industry standard (i.e., IEEE Std C37.20.7 [60]). In addition, NRC open box testing (RIL 2021-18 [53]) shows that phase-to-phase and phase-to-ground faults rapidly develop into three-phase faults. Due to the wide variability of reduced fault current in resistance grounded systems, phase-to-ground fault testing is not used.
27	Page 6-7 Equation 6-2	Equation 6-2, page 6-7, implies that power(W) * time(s) = Joules/m^2, rather than Joules. If intending to calculate radiant exposure or radiant fluence (MJ/m^2), then terms are missing from the equations, and the example on line 17 is inaccurate. By the context, it appears that the units on the Arc energy on line 11 should be Joules versus J/m^2, and on line 17 should be MJ versus MJ/m^2.	Corrected Equation 6-2 to Joules (rather than Joules/m^2). Also corrected 68 MJ/m^2 to 68 MJ.
28	Page 6-12 Lines 21-25	Page 6-12 lines 21-25, is there a reason that the Zone 1 load breaker feeding the faulted Zone 2 bus supply breaker is not being credited (refer to Figure 6-8)? Is there some basis for the settings of the load breaker being equivalent or less conservative than the Zone 1 supply breaker? Or, is the Zone 1 load breaker considered equivalent to the Zone 2 supply breaker, in which either could be credited to interrupt the fault as depicted in Figure 6-9? Could crediting the Zone 1 load breaker limit the fault duration to 2 seconds (versus 4 seconds) as discussed in lines 27-30.	See the comment response to comment #29. The analyst can credit the load breaker if it has overcurrent protection and use smaller energy end state if the time is less than the default. Added discussion in the supply breaker limited section and linked to Section 8.6.1 “Zone 2: Refinement Level 1” and Section 8.6.2 “Zone 2: Refinement Level 2” if the Zone 1 to Zone 2 load breaker has active protective relaying for credit. See also Section 3.2.3 and 3.8.

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29	Page 6-12 Figure 6-8	There is no stated justification for the non-credit for the Zone 1 load breaker feeding the faulted Zone 2 bus supply breaker (refer to Figure 6-8). This justification should be included, or the credit explicitly described.	The analyst can credit a load breaker interrupting the faulted Zone 2 bus supply breaker if the load breaker has overcurrent protection. See Section 8.6.1 “Zone 2: Refinement Level 1” and Section 8.6.2 “Zone 2: Refinement Level 2” if the Zone 1 to Zone 2 load breaker has active protective relaying for credit. See also Section 3.2.3 and 3.8. To be comprehensive, starting in the SBL discussion on Page 6-14, added a note about crediting the load breaker in the PRA method in Section 8 with the following text for SBL 3s and SBL2 end states: This refinement can also be used for Zone 2 if the Zone 1 switchgear has a load circuit breaker with overcurrent protection (see Section 8.6.1 and 8.6.2). Change: Added text to Figure 6-9 (old Figure 6-8) to show the Zone 1 load breaker feeding Zone 2 as a “No Relay Protection - Maintenance Switch”.
30	Page 6-12 Line 24	change “interpolated” to “interpolation is”.	
31	Page 6-18 Line 6	Page 6-18 Line 6. Should read: Fault Current: 1.043 Units * 40.276kA/Unit = 42kA (brown vertical line…)	Revised to: Fault current: 1.043 units × 40.276 kA/unit = 42 kA (brown vertical line on Figure 6-11)
32	Page 6-19 Line 30	I spotted one error on page 6-19 line 30 where it refers to figure 6-1. It really should be figure 6-10.	Agree. Corrected Figure 6-1 to Figure 6-11 (figures got moved by one place due to addition of Figure 6-4).

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33	Section 6.4	For fault clearing time (I had accounted for relay operating time and breaker operating time). The breaker operating time is small. Guidance should clarify if we need to account for both.	The order of magnitude where a HEAF becomes a concern is 2 seconds or greater. Accounting for circuit breaker interrupting time (3 – 8 cycles) and relay sensing time (e.g., 0.5 cycles) for HEAF events is not necessary since it is very small (Ref: IEEE Std 242-2001, Section 9.4.3). For fast fault clearing times (FCT) less than a half a second, these can be factored in; however, the margin of error in calculating the ZOIs is greater and the ZOIs at these much shorter times are minimal. Text added at the end of Section 6.4 to address this (e.g., the analyst does NOT need to account for relay sensing time and circuit breaking opening time in the FCTs.
34	Page 6-21 Lines 29-30	correct grammar, or replace “with” with “where”.	Revised as follows: Figure 6-13 shows the total HRR for the vertical section where the HEAF originates and the propagation to the adjacent sections

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35	Section 6.4 Step 4	In section 6.4 step 4 where they instruct to obtain the available short circuit current (ASC), I am assuming they mean maximum 3 phase bolted fault. Note that you may have minimum/maximum fault currents calculated. Guidance should clarify which fault current needs to be used to determine FCT. Is it arcing current (see next comment) or 3 phase bolted fault current and if it needs to be done for both minimum and maximum fault conditions? It appears section 3.2.3 used arcing current to determine FCT (see next comment).	The following two notes are added to the end of Section 6.4 to clarify the use of the three-phase bolted fault. 1. In the early stages of the project, proof of concept used three phase bolted (zero impedance) faults for medium voltage. IEEE 1584 shows that medium voltage arc faults are consistently around 85% of the three phase bolted (zero impedance) fault (this is also supported by HEAF OE). Since the objective is to ensure all the energy is accounted for ZOI determination, use of three-phase bolted fault at the available short-circuit current (ASC) is considered acceptable. Due to the design of inverse time overcurrent relays (51), the total integrated energy is slightly less (or the same) given a 15% reduction in fault current, even though the fault clearing time (FCT) is slightly increased for an arc fault by approximately 0.1 to 0.2 seconds. This was verified against four NPP medium voltage protection and coordination calculations. The only exception would be for existing station design vulnerabilities where the time overcurrent (51) relays are not optimally set (that is, FCTs are in excess of 5 seconds at the ASC). In these cases, the arc fault current using IEEE 1584 may need to be used for FCT determination. 2. With respect to the question regarding minimum or maximum currents, since the fire PRA focuses on "operating" plants (e.g., Mode 1), Per Section 6.4.1, step 4.b, the maximum ASC associated with "Mode 1" operation should be used.
36	Section 6.4.2	I noted that section 6.4.2 for determining supply breaker limited FCT refers to section 3.2.3. However in 3.2.3 it seems to have additional step in that the 3 phase bolted fault current was used to determine arcing current before determining FCT. This would be another step then just obtain available short circuit current (ASC). Section 3.2.3 step 3 has you use IEEE 1584-2018 [24] to estimate the corresponding arcing fault current from the ASC current in step 2. Then the arcing current was used to determine FCT. Is there a disparity between 6.4.1 and 6.4.2? For 6.4.2 are we supposed to use the arcing current determined per IEEE 1584-2018 [24] to determine FCT? This is different from 3 phase bolted fault.	Step 3 converting ASC to arcing current) is in error and has been removed in the report. Table 3-2 was updated to reflect the 3-phase bolted fault clearing times.

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37	Section 6.4.2	Potentially a rephrase of above question: Section 3.2.3 summarizes a review performed for a sample of United States NPPs and an upper bound of 4 seconds was determined for the time it takes for the Zone 1 MV switchgear bus supply circuit breaker to operate. Section 3.2.3 has an apparent additional step, in that the 3 phase bolted fault current was used to determine arcing current before determining FCT. Section 3.2.3 step 3 references use of IEEE 1584-2018 to estimate the corresponding arcing fault current from the ASC current in step 2. Then the arcing current was used to determine FCT. This is different from 3 phase bolted fault. Please resolve the disparity between 6.4.1 and 6.4.2.	See response to comment #36, copied below: Step 3 converting ASC to arcing current) is in error and has been removed in the report. Table 3-2 was updated to reflect the 3-phase bolted fault clearing times.
38	Section 6.5 Page 6-19	The fire elevation to be used in the ensuing fire should be addressed. It is not clear where the ensuing fire should start for a cabinet in a lower section, or if the cubicle height be utilized in some way.	Added the following text in Section 6.5 The elevation (location) of the ensuing fire should be modeled following existing practices as described in Supplement 1 to NUREG/CR-6850 [2] considering the expected condition of the load center or switchgear post-HEAF.
39	Section 6.5 Page 6-19	The application of this guidance calls for the ensuing fire having a maximum HRR at time 0 for switchgear and load-centers creates a zone of influence that exceeds the majority of the energetic ZOIs (Sections 7 & 8) immediately. Much of this guidance identifies HEAF events that will be significantly smaller than previously expected. Assuming, for all cases, that the ensuing fire will immediately reach the 98th% HRR significantly limits the use case for this new guidance. Less conservative guidance around the application of the ensuing fires should be pursued.	Given the limited data available for characterizing the ensuing fire, the original guidance provided in NUREG/CR-6850 was retained, which assumes the fire has a heat release rate corresponding to the 98th percentile and the fire has no growth stage. Note that although the ZOI for the ensuing fire could be larger than the energetic phase, target damage is not immediate. Heat soak methods, THIEF, and other tools may be applied to develop a damage progression timeline and credit for suppression may be integrated. Targets within the energetic phase ZOI are damaged at time zero and there is no potential for suppression credit. More realistic cabinet to cabinet propagation addressed in comment 42.

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Comment No.	Document Number Section / Paragraph	Review Comments (Print)/Basis for Comment	Disposition
40	Section 6.5.1 Page 6-21	This is because the HEAF is considered a more severe ignition factor and the side breach pattern for medium voltage switchgear is generally symmetric [46]. Reference 46 (NUREG-2178, Volume 2) doesn't appear to be the correct reference for this statement. NUREG-2178, Volume 2 doesn't discuss HEAF breaching patterns.	Agree that NUREG-2178 Volume 2 is not the correct reference for the MV symmetric breaching patterns. The correct reference is the HEAF FDS report. This reference has been updated.
41	Section 6.5.1 Page 6-21	The referenced HEAF events in Appendix A of this draft report mention damage to adjacent sections, however, they do not make any inference of sustained ignition to the adjacent cabinet sections. These events are Incident Numbers 434 (Page A-2), 106, and 112 (Page A-7). These incident reports do not support considering propagation to adjacent cabinet sections for the ensuing fire.	Reviewed the operating experience as part of this comment and the totality of the cabinet to cabinet propagation comments. For event 434; this event is in a load center (and the methodology does not recommend propagation for load centers). Events 106 and 112 were reviewed. Both events describe challenging firefighting – centered around the initiating vertical section. The working group debated the level of fire / soot spread in these events, but agreed that from a hot gas layer contribution, the effect was negligible for these two events. As discussed in comment 42, Section 6.5.1 was re-written to credit double wall construction (no spread through 200 MJ) and a probabilistic approach for cases were spread is not ruled out.
42	Section 6.5.1 Page 6-21	The assumption that a HEAF above 101 MJ allows for sustained ignition, and requires ignition of both adjacent vertical sections that must be modeled as a 98th% HRR is overly conservative based on the guidance and provided testing data.	At 101 MJ, the sides of the enclosure breach/open and expose adjacent section internals to the arc energy. Previous experience at Onagawa suggest it is possible to involve adjacent vertical sections. However, the working group acknowledged that guaranteed (1.0) spread and two additional 98th percentile fires was too conservative. Section 6.5.1 was re-written to credit double wall construction (no spread through 200 MJ) and a probabilistic approach for cases were spread is not ruled out.

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43	Section 6.5.1 Page 6-21	Regarding: Testing by Sandia [53] indicate that sustained ignition after a HEAF requires energy fluxes greater than 30 MJ/m². The basis for the methodology to ignite the adjacent vertical section does not seem to be in alignment with the referenced documents. The referenced Sandia testing was performed on open box enclosures, and with no secondary combustibles adjacent to them. The conclusions of this draft report are focused on the characteristics of a HEAF (i.e., thermal energy, mass loss, air conductivity, surface conductivity, and electromagnetic interference), not on propagation. While there is some severe damage to the enclosures for HEAFs over ~22MJ (e.g., Test OBMV06, Section 4.2.4), it doesn't consider that the vertical sections could have more than one layer of steel between them, and none of the tests looked at secondary combustibles or the possibility of ignition in adjacent cabinet vertical sections. Therefore, how this testing was used to develop the basis for requiring 30 MJ/m² is unclear. Recommend revising the guidance to allow screening the possibility of adjacent cabinet spread.	Given the limited state of knowledge, an assessment of available information and insights from the calculated ZOIs, enclosure breach areas, and the target fragilities was used to define a minimum arcing energy for propagation. Updated to include the correct references to the Sandia fragility testing and the subsequent working group analysis. Sentence revised as: • Testing by Sandia [14], subsequently analyzed by the working group [15] indicates that sustained ignition after a HEAF requires energy fluxes greater than 30 MJ/m². The 30 MJ/m² fragility ZOI for HEAFs with an arc energy of 101 MJ or less is 0.5 ft (15 cm) (see Table 8-4 and Table 8-6), which indicates that the exposure is marginally greater than the sustained ignition threshold at the boundary of the adjacent vertical section. Given this, sustained ignition in this section is not expected. See response to comment 42 for improvements in HEAF cabinet to cabinet propagation.

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Comment No.	Document Number Section / Paragraph	Review Comments (Print)/Basis for Comment	Disposition
44	Section 6.5.1 Page 6-21	Regarding: Fire propagation is likely in the adjacent vertical sections. None of the testing performed for this issue supports the conclusion that adjacent cabinet propagation is realistic, and this statement should be removed. Per NUREG-2178, Volume 2, Section 4.2.2.7, switchgears and load centers have limited fuel loads (low/very low) and are normally ventilated. Propagation to adjacent cabinet sections is not considered for HEAF scenarios since the mechanical force associated with the HEAF event will cause the cabinet doors to blow open. This will result in venting in the cabinet preventing an internal hot gas layer from forming which is what NUREG/CR-6850 states is the basis for adjacent cabinet spread. Section 4.2.2.2 of NUREG-2178, Volume 2 states that cabinets with open top configurations allow the heat generated by the fire to be transferred outside of the enclosure reducing the likelihood of propagation. This would also be true for a cabinet whose doors have been blown open by the HEAF. Also, many Switchgear cabinets have open vents at the top, by design, which would also support venting and meet RF2 criteria for screening adjacent cabinet propagation. The cables within switchgear cubicles are typically a larger diameter which would be difficult to ignite from radiant energy. There is usually a double wall with an air gap between the switchgear sections as well. Even if the HEAF provided a greater than 5% opening between adjacent vertical sections, there is no combustible continuity between the vertical sections for the ensuing fire to spread. All of these factors would exclude propagation to adjacent vertical sections under normal circumstances.	Revised statement to: Fire propagation is possible in the adjacent vertical section. The full-scale testing was primarily performed on single cabinet vertical sections and only of energies up to ~148 MJ so the state of knowledge is low originally, and there is a lack of both operational experience and testing at the higher energies (e.g., 233 MJ & 300 MJ). The propagation of concern is to the relay/metering cabinet where the bulk of the combustibles are located. The working group agrees that breach can occur into adjacent cubicles, but those cubicles may be sparsely loaded (e.g., the primary cable compartment bus bar propagating into the adjacent primary cable compartment bus bar does not pose a secondary combustible/hot gas layer concern). In the new Section 6.5.1 the operating experience and potential locations of spread are considered in the probabilistic model. Section 6.5.1 was re-written to credit double wall construction (no spread through 200 MJ) and a probabilistic approach for cases were spread is not ruled out. The double wall with air gap is now explicitly part of the factors to consider if propagation is necessary. The 101 MJ is derived from FDS simulations which use a single wall construction. With the second layer, the amount of energy required to melt/breach two panels is expected to be linear (2x as much energy). For double wall construction, propagation only remains for 233 and 300 MJ cases.

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Comment No.	Document Number Section / Paragraph	Review Comments (Print)/Basis for Comment	Disposition
45	Section 6 General	The guidance provided earlier in Section 5 of the NUREG modifies the counting for switchgears such that each switchgear is counted as a unit. The guidance provided in Section 6 seems to suggest that the HEAF must be assumed to originate anywhere along the 'footprint' of the entire switchgear. While the guidance in Section 5 provides some guidance in varying the treatment of incoming versus outgoing breakers, it is unclear how the assigned frequency is to be partitioned for each of the HEAF scenarios for the switchgear. It is also unclear if the EDG supply breaker is considered a 'load' or 'supply' breaker in the context of this NUREG.	The counting guidance was changed for MV switchgear as the operating experience determined that there was not equal likelihood of a HEAF in each vertical section. The supply sections are much more likely to experience a HEAF – as noted in the operating experience, potential single circuit breaker points of failure, and in the event trees in Section 8. Nevertheless, a HEAF can still occur in the main bus bar portion of the switchgear or the load circuit breakers (15% in Zone 1, 14% in Zone 2) that consider the remaining portion of the MV switchgear. Section 5 provides the Task 6 counting guidance/scenario frequency for the MV switchgear (by vertical section). (note: this section does not provide guidance for the EDG supply breakers since ignition source counting is at the bank level). In Section 8 the scenario frequency can be used with the screening values in Table 8-2. When more detail is necessary the analyst can enter the corresponding event tree (Zone 1, Zone 2: refinement 1, Zone 2: refinement 2) with the scenario frequency. The partitioning of frequency is on a vertical section level for the supply section (s). When analyzing the load portion the analyst can take the remainder of the load bank cabinets and partition the frequency into one or more sub-scenarios as determined by the analyst. Added this to Section 8.2.2, page 8-11 (Zone 1 conf specific), and 8.6.2 (Zone 2 refinement level 2) In regards to EDG supply breaker treatment; the document in Section 8.2.2 states: *Some switchgear may contain a vertical section associated with the EDG, as shown in Figure 3-1. The energy associated with the EDG is not sufficient to produce damage on a similar scale as a generator- or switchyard-supply-fed fault. Therefore, EDG supply vertical sections are analyzed with the load vertical sections.*

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46	Page 7-1 Section 7.1	Provide definitions the types of circuit breakers that are discussed in Section 7 if they impact the application of the analysis. For instance, "load center supply circuit breakers" and "load breakers" are not defined in Section 2, but could change the location where a HEAF is postulated. These terms should be explicitly defined to ensure the user understands the terminology adequately.	Defined the following terms in Section 2 and Section 7. Load Center Supply Circuit Breakers: These are the low voltage circuit breakers that supply power from the load center transformer to the low voltage switchgear (i.e., 480Vac or 600Vac). Load Circuit Breakers: These are any medium or low voltage circuit breakers that serve a load, such as: • Motor load • Motor control center (MCC) • Step down transformer • Another switchgear • Bus Tie Reviewed and edited Section 7 to use terms consistently.

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Comment No.	Document Number Section / Paragraph	Review Comments (Print)/Basis for Comment	Disposition
47	Page 7-3 Section 7.2 & Figure 7-1	Include guidance about how to apportion the frequency of a fire occurring at the different circuit breaker locations. There is no specific instruction about how to apportion the frequency of the fire if incorporating the Table 7-1 guidance. For example, if a vertical section has 3 cubicles, two would be "lower elevation" and one "upper elevation." It is not clear if the ZOI from Table 7-1 would apply to 2/3 of the vertical section's frequency and 1/3 to the upper elevation's frequency.	Revised the introduction for Section 7.3 to clarify that the fire ignition frequency is assigned per load center supply circuit breaker. Load center HEAFs are no longer counted by vertical section. The location-specific ZOIs are provided for the most realism, however, an analyst could select the most conservative ZOI (location A) if analyzing the entire load center as one scenario. Revised text as follows: Load center HEAFs are modeled with the fault initiated at load center supply circuit breakers. Scenario frequency for load centers is apportioned to each load center supply circuit breaker as described in Section 5.2.1.2 and Section 5.2.5.1. For example, in Figure 7-2, consider the red colored boxes (B and D) both contain supply breakers. The assigned frequency for the load center is two over the total number of load center supply circuit breakers at the plant. The supply circuit breaker at location B has a scenario frequency of one out of the total number of load center supply circuit breakers at the plant with a ZOI corresponding to location B in Table 7-1. Similarly, the supply circuit breaker at location D also has a scenario frequency of one out of the total number of load center supply circuit breakers at the plant with a ZOI corresponding to location D in Table 7-1.
48	Page 7-3 Section 7.3	It would be helpful to state in this section that spread between adjacent vertical sections should not be applied to load centers. While this is stated in Section 6.5.1, consider also including it in Section 7 for clarity.	Agree – added this to the section on the post-HEAF ensuing fire. New text added: Consistent with the conclusions in Section 6.5.1, the low-voltage HEAF energy of 90 MJ is below the threshold to require fire propagation to adjacent cabinets. Fire propagation to adjacent load center cubicles should not be postulated.

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Comment No.	Document Number Section / Paragraph	Review Comments (Print)/Basis for Comment	Disposition
49	Page 7-3 Section 7.3	Regarding: "A supply circuit breaker in the mid or lower elevation, location E or F in Figure 7-2, does not have a ZOI external to the switchgear. For this case, an ensuing fire should still be postulated at the supply circuit breaker. See Section 6.5 for modeling the ensuing fire." This bullet specifies that an ensuing fire should still be modeled for this situation, however the ensuing fire is not addressed for the previous three bullets. Should the ensuing fire therefore not be modeled for the situations in the previous three bullets?	Agree that calling out the ensuing fire in only the last bullet could call into question the ensuing fire for the first three bullets. Since the objective of the bulleted list was to provide insights on the ZOI, the mentioning of the post-HEAF ensuing fire (for all supply circuit breaker locations) should be moved (and clarified that it is intended to capture all low-voltage HEAFs). Revised text as follows: In addition to the energetic ZOIs an ensuing fire is postulated at the supply circuit breaker. See Section 6.5 for modeling the ensuing fire. Consistent with the conclusions in Section 6.5.1, the low-voltage HEAF energy of 90 MJ is below the threshold required to model fire propagation to adjacent vertical sections. Fire propagation to adjacent load center cubicles should not be postulated.
50	Table 8-3 Table 8-4 Table 8-5 Table 8-6	Acronym GF is used in Tables 8-3, 8-4, 8-5, and 8-6, but is not defined until a footnote in Table 9-2.	Added GF to acronym list and also added note at the bottom of Tables 8-3 through 8-6.
51	Page 8-8 Lines 9 & 10 Section 8.4	Regarding: "… (shown in Figure 8-2 and Figure 8-3) The screening…" A period should be placed after "…Figure 8-3)." to end the sentence.	Corrected.
52	Page 9-5 Figure 9-1	Keep Figure 9-1 Title with the figure on page 9-5	Together in the public comment version and also confirmed together in the final version.
53	Page 9-4 Page 9-7 Page 9-8 Page 9-12	Remove the extra page breaks on Pages 9-4, 9-7, 9-8, and 9-12	Corrected

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54	Section 10.2.2	Change: Do not postulated fire propagation for arc energies of 101 MJ and below. To: Change to "Do not postulate fire propagation for arc…"	Corrected
55	Table A-1 Pages A-2, A-4, A-11, A-12	There are multiple instances where there is a typo for "ensuing" fires where it's spelled "ensuring".	Corrected as part of tech edit
56	Appendix E Tables	Request note to correlate to tables in body of report.	Added links in the main body of the report to the metric tables in Appendix E. This is summarized as follows: Table E-1 to Table 7-1 Table E-2 to Table 8-2 Table E-3 to Table 8-3 Table E-4 to Table 8-4 Table E-5 to Table 8-5 Table E-6 to Table 8-6 Table E-7 to Table 9-2
57	Page G-6 Section G.1.4	Row 20: "For the post-HEAF ensuing fire, the first cable tray ignites dur to the ensuing fire and eventually propagates to the third tray in the cable tray stack." Typo: "dur" should be "due"	Corrected

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58	Page G-11 Line 18	Regarding: The ignition frequency for each scenario is split between the supply sections and supply breaker limited fault in Error! Reference source not found. (shown below as Figure 11-23). Correct reference error	Corrected