Characterizing Fire PRA Quantitative Models: An Evaluation of the Implications of Fire PRA Conservatisms

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Abstract: Conservative bias may be present in fire PRAs due to limitations in data or methodologies. An evaluation was performed to characterize the current situation with fire PRA models and the implications regarding perceived risk associated with the degree of conservative bias. The principal areas of the fire PRA data and modeling that may be subject to such biases were identified and the impacts these biases have on the reported point estimate CDF and the contributors were quantified. These biases were assessed using a number of sensitivity studies where in a set of modeling approaches or assumptions were varied from the NUREG/CR-6850 guidance that are considered to be conservatively biased. Three point estimates were developed using NUREG/CR-6850 guidance and by incrementally removing biases by crediting more realistic approaches supported in part by revised guidance or in-progress industry and NRC efforts. The conclusion from the evaluation is that reasonable (realistic) approaches to the assessment of the fire hazard will result in a reduced estimate of the fire risk, will likely change the primary risk insights, and could greatly influence the priority that is assigned to possible plant changes resulting from a re-characterization of the causes of risk significant fires and fire zones.

Keywords: Probabilistic Risk Assessment, PRA, Fire PRA.

1. INTRODUCTION

The development of external hazard Probabilistic Risk Assessment (PRA) models has generally lagged behind the development of internal events PRAs. This situation has been exacerbated because of a lack of adequate data and methods to allow a reasonably accurate quantification, i.e., to provide a quantification that is not subject to very large uncertainty bounds. The Nuclear Regulatory Commission (NRC) PRA Policy Statement states that “PRA evaluations in support of regulatory decisions should be as realistic as practicable…” [1]. During the maturation of fire PRAs, the NRC and the Electric Power Research Institute (EPRI) have established a set of data, rules, and methods that are agreed to be bounding for use in PRA applications. This set of data, rules, and methods have been codified in NUREG/CR-6850/EPRI 1011989 [2] (heretofore referred to as NUREG/CR-6850). Although the original intent was for the NUREG/CR-6850 methods to be piloted and revised prior to implementation in the industry as a whole, this was not fully achieved [3]. The resulting premature adoption of NUREG/CR-6850 has introduced a significant number of potentially conservative or bounding biases being incorporated in the data, rules, and methods. These biases generally result from a lack of knowledge. It is noted that the industry and NRC continue to make progress in developing the fire PRA methods; however, this work is not reflected in most current fire PRAs that are being used for risk informed decision-making. Given that the primary inputs to a risk-informed decision are the insights gleaned from the PRA, not a bottom line number, an undue conservative bias could confound good decision-making.

An evaluation was performed to characterize the current situation with fire PRA models and the implications regarding the degree conservative bias that may be present because of limitations in data or methodologies. For the purposes of this evaluation, the approach was to identify the principal areas of the fire PRA data and modeling that may be subject to such biases and to attempt to quantify the impact these biases have on the reported point estimate Core Damage Frequency (CDF) and the dominant contributors.

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Example areas of potential bias include the treatment of fire initiating event frequencies, transient combustible fires, electrical cabinet fires, spurious operations, and fire effects on operator actions. Potential areas for investigation were identified and assessed using a number of sensitivity studies where a set of modeling approaches or assumptions were varied from the NUREG/CR-6850 guidance that are considered to be conservatively biased.

2. METHODOLOGY

In the effort to quantify the impact that key assumptions may have on the reported point estimate CDF and the dominant risk contributors, those areas in fire PRAs that generally contribute the most to the fire risk and have potential conservative biases were identified. These areas are categorized into types.

The first type (Type 1) includes areas of the fire PRA that have matured since the guidance in NUREG/CR-6850 was adopted into fire PRAs that are currently being used for decision making. There are three processes for which new or revised guidance has been provided. The first process is the National Fire Protection Association (NFPA) Standard 805 Frequently Asked Questions (FAQ) Program which is a mechanism to provide clarifications or enhancements related to fire PRA methods and applications [4]. The second process is an EPRI led Fire PRA Methods Review Panel. Lastly, additional testing performed by the NRC and industry has been documented in a series of subsequent NUREGs. Through these three processes several clarifications and enhancements have provided additional guidance for use in fire PRAs. Four areas of the fire PRA that may have applied NUREG/CR-6850 guidance were identified where potential conservative bias may be removed by applying additional guidance provided through one of the three processes identified above. These include fire ignition frequencies, transient administrative controls, circuit failure likelihood probability and spurious operation duration probability, and treatment of electrical cabinet fires.

The second type (Type 2) includes areas of the fire PRA where application of NUREG/CR-6850 guidance is believed to result in conservative biases; however, to date there is no supplemental guidance. Testing may be in progress to support revised guidance for these areas; however, the testing is in the early stages and conclusions cannot be made to date. Two areas of the fire PRA that may have applied NUREG/CR-6850 guidance were identified where potential conservative biases are believed to exist. These include fire ignition source heat release rates and fire growth and suppression modeling.

The third type (Type 3) includes areas of the fire PRA where assumptions are made that may introduce potential conservative biases into the fire PRA because of resource constraints, lack of knowledge, or a particular area has yet to be explored in detail. Four areas of the fire PRA where assumptions may introduce conservative biases were identified. These include fire induced initiating events, fire human reliability analysis (HRA), recovery of fire induced loss of offsite power, and mitigation of adverse environmental conditions in the Main Control Room (MCR).

To explore the individual and overall extent of conservative bias that may exist in these areas of the fire PRA, a sensitivity study is performed for each identified area. Three point estimate CDFs were developed to quantify the impact that conservative biases may have on the reported point estimate CDF and the corresponding dominant contributors used in decision making. An “upper bound” point estimate was developed using the guidance in NUREG/CR-6850. A “nominal” point estimate was developed using the guidance in NUREG/CR-6850 supplemented by clarifications and enhancements from FAQs, the industry review panel, and subsequent NUREGs. The “nominal” point estimate includes modifications to the four areas identified above categorized as Type 1. A “lower bound” point estimate was developed that includes modifications to each of the areas discussed above. Comparison of the three point estimates were made to identify the extent conservative biases may influence decision making.

Fire PRAs were selected for use from three operating U.S. nuclear power plants. These plants were selected because the plants are of differing designs such that certain areas of the fire PRA may influence the plant risk in substantially different ways. Therefore, each area explored can be quantified and the extent to which a conservative bias may influence fire PRAs can be more broadly investigated.

It should be noted that the introduction of multiple, significant conservative biases may not only obscure the important insights from the study, but the cumulative impact of these biases can lead to computed core damage frequencies that are overstated, in some cases even approaching or exceeding the subsidiary safety goals for total CDF. Such a result may mask areas where more realistically determined risk contributors could benefit from increased scrutiny.

3. SENSITVITY STUDIES

3.1. Fire Ignition Frequency

Fire ignition frequency (FIF) is an area of the fire PRA categorized as Type 1 where industry efforts have resulted in updated FIFs which are documented in EPRI 1016735 [5]. The NUREG/CR-6850 FIFs are based on a review of all of the industry fire events from 1968 through 2000. In EPRI 1016735 the FIFs were revised based on the trend of fire events in the industry and include industry fire events from 1991 through 2000. The NRC position on the use of the updated FIFs is documented in FAQ 08-0048 which is included in Supplement 1 of NUREG/CR-6850 [4]. The interim NRC position is that the NRC accepts the use of the revised FIFs with the provision that the sensitivity of the risk must also be evaluated using the NUREG/CR-6850 FIFs. Any situations in which the sensitivity of the FIFs changes the risk significance of elements of the fire PRA must be addressed.

An industry and NRC effort has been in progress to update fire FIFs based on a more complete data set and a re-classification of fire events for the years 1990 through 2009. Nevertheless, current fire PRA results used in decision-making are based on generic FIFs from NUREG/CR-6850 and EPRI 1016735. Table 1 presents the sensitivity of fire risk to FIFs used in decision-making when EPRI 1016735 FIFs were used instead of NUREG/CR-6850 FIFs. Approximately a 20-25% decrease in fire induced CDF is calculated when the revised EPRI 1016735 FIFs are applied.

Table 1: Fire PRA Sensitivity to Fire Ignition Frequency

Fire PRA	Change in CDF
Plant 1	-21%
Plant 2	-25%
Plant 3	-21%

3.2. Transient Combustible and Ignition Source Administrative Controls

The apportioning of transient FIF is an area of the fire PRA categorized as Type 1 where industry efforts have resulted in updated guidance. NUREG/CR-6850 guidance includes the use of weighting factors to apportion the FIFs to plant areas. Fire PRAs developed for the NFPA 805 application identified the need for a process that gives more credit to plant areas that have stricter transient controls in place. Through NFPA 805 RAIs, the NRC found the deviations from NUREG/CR-6850 unacceptable. However, with the understanding that the guidance in NUREG/CR-6850 had been interpreted differently and had limitations, the NRC proposed additional guidance and refinements to the NUREG/CR-6850 guidance to address the application of transient weighting factors in FAQ 12-0064 [6]. The guidance in FAQ 12-0064 did address some of the deviations; however, others were still ultimately found unacceptable. For example, the guidance in NUREG/CR-6850 and FAQ 12-0064 only address transient weighting factors on an area basis. Specifically, when additional credit was provided for individual postulated transients where transient controls would be stricter but do not apply to the area as a whole, the NRC found the deviation unacceptable.

The fire PRA results being used for decision-making generally do not include or fully incorporate the guidance included in FAQ 12-0064. Additionally, processes that refine the apportioning of transient FIFs continue to be explored and presented at industry conferences. Table 2 presents the results of a sensitivity study exploring the potential benefit of additional credit for administrative controls using the guidance in FAQ 12-0064 and considering additional potential refinements to the treatment of administrative controls. Additional transient administrative control credit may reduce the fire induced CDF between 3% and 11% based on the sample plants examined.

Table 2: Fire PRA Sensitivity to Transient Administrative Control Credit

Fire PRA	Change in CDF
Plant 1	-3%
Plant 2	-11%
Plant 3	-7%

3.3. Circuit Failure Likelihood and Duration Probability

Circuit failure likelihood and duration probabilities are areas of the fire PRA categorized as Type 1 where industry efforts have resulted in updated guidance even though some of the guidance may be in draft form. NUREG/CR-6850 provides guidance for applying circuit failure likelihood probabilities. NUREG/CR-6850 guidance includes probabilities for circuits with and without a control power transformer (CPT). The guidance includes a reduction of a factor of two for circuits with a CPT. This guidance was generally applied in fire PRAs. Subsequent testing in a joint effort by the NRC and EPRI resulted in the conclusion that the reduction of a factor of two does not accurately reflect the test data. The conclusion is based on a Phenomena Identification and Ranking Table (PIRT) panel and is documented in NUREG/CR-7150 [7]. In addition, the PIRT panel is in process of developing new circuit failure likelihood probabilities and spurious operation durations based on the test data. The preliminary results were presented at the 2013 NEI Fire Protection Forum and the PSA conference.

In decision-making, the NRC issued interim guidance in June 2013 that did not allow the use of the NUREG/CR-6850 circuit failure likelihood failure probabilities for circuits with CPT [8]. However, the interim guidance did not include spurious operation probabilities for motor operated valves (MOVs) or spurious operation duration probabilities. Therefore, fire PRA results being used in decision-making do not include circuit failure likelihood probabilities for MOVs and spurious operation duration probabilities have not been included. Table 3 presents the results of a sensitivity study that explores the potential reduction when spurious operation and duration probabilities are applied. These results indicate at least a 22% reduction in fire induced CDF was identified.

Table 3: Fire PRA Sensitivity to Spurious Operation Probability and Duration

Fire PRA	Change in CDF
Plant 1	-41%
Plant 2	-22%
Plant 3	-30%

3.4. Alignment Factor for Electrical Cabinet Fires

ERIN Engineering Research, Inc. developed a method that treated electrical cabinets based on a detailed review of the industry fire events which included distinguishing electrical cabinets by type (i.e., switchgears, motor control centers (MCCs), and low voltage cabinets). The application of alignment factors for electrical cabinet fires is an area of the fire PRA categorized as Type 1 because industry efforts have resulted in acceptance of the method [9]. On the other hand, the NUREG/CR-6850 guidance groups electrical cabinets together with a single fire ignition frequency and recommends heat release rates (HRRs) for the different types based on typical configurations. The revised method derived alignment factors for electrical cabinets based on the fire events for each type of electrical cabinet.

The method was reviewed by an industry panel which accepted the use of the method in certain circumstances with a dissenting opinion. Subsequently, the NRC sent a letter to the Nuclear Energy Institute (NEI) that did not endorse the method for use in risk informed regulatory applications [10]. Part of the basis for the dissent was that applying NUREG/CR-6850 guidance and detailed fire modeling would provide comparable results. Based on this dissent, NRC RAIs have requested risk results without the alignment factor for use in decision-making. In response to RAIs, significant resources have been expended to replace the alignment factors in an effort to achieve comparable results. A sensitivity study was performed to compare the fire risk with and without the alignment factors. In one case a significant reduction in plant fire induced CDF (65% reduction) was calculated when the electrical cabinet alignment factors were applied. Additionally, in each case plant configurations exist where fire modeling does not provide comparable results as suggested by the dissent.

Table 4: Fire PRA Sensitivity to Use of Panel Factors

Fire PRA	Change in CDF
Plant 1	-65%
Plant 2	-8%
Plant 3	-12%

3.5. Fire Growth and Suppression

The modeling of fire growth and suppression is an area of the fire PRA categorized as Type 2 because the available guidance is believed to be conservative; however, no updated guidance has been provided for use in risk informed applications. The part of fire growth in fire PRA that is believed to include the most significant bias is the evaluation of fire duration. NUREG/CR-6850 Appendix P provides guidance on fire non-suppression probabilities. NUREG/CR-6850 Table P-3 recommends a floor non-suppression probability of 1E-3 be applied. In NFPA 805 RAIs, this guidance has been interpreted by the NRC that a fire may continue to grow indefinitely and ultimately may result in full room damage and multi-compartment interactions. In contrast, NUREG/CR-6850 Section 12.5.3.6 suggests that the analysis of operator actions required after the first hour can assume the fire to be extinguished and therefore would not cause late scenario complications.

The recommended floor non-suppression probability is not realistic. For example, using this guidance the Main Control Room (MCR) fire non-suppression probability would be 1E-3 from 20 minutes until the end of the postulated fire scenario. Additionally, NUREG/CR-6850 Appendix P provides no guidance with respect to fire response practical application. Specifically, while a fire may not be declared suppressed, the plant operators and fire brigade may have engaged in sufficient activity to control the fire. A classic example would be the prescribed action to de-energize an electrical cabinet fire and let the fire self-extinguish.

The guidance in NUREG/CR-6850 Section 12.5.3.6 indicates that a sense of realism should be considered. However, in application RAIs, the NRC has interpreted the guidance that fires will continue to burn with a non-suppression probability of 1E-3. Table 5 presents the results of a sensitivity study which explored the fire risk assuming that fire growth is limited and fires do not continue to grow and result in full room damage if the fire brigade and operator response prevents fire growth. The results vary significantly among the sample plants based on plant configuration. A large reduction is calculated for certain plant configurations.

Table 5: Fire PRA Sensitivity to Fire Growth

Fire PRA	Change in CDF
Plant 1	-64%
Plant 2	-1%
Plant 3	-4%

3.6. Heat Release Rate

The NUREG/CR-6850 recommended HRRs is an area of the fire PRA categorized as Type 2 because the available guidance is believed to be conservative; however, no updated guidance has been provided for use in risk informed applications. NUREG/CR-6850 Appendix E and G provide guidance for ignition source HRRs. The HRRs are based on a set of generic tests that are largely considered to not reflect equipment or practices in a nuclear power plant. The recommended HRRs have been considered conservative by the industry for application in nuclear plant applications.

Industry efforts to revise the NUREG/CR-6850 HRRs include the work published in EPRI 1022993 [11] regarding electrical cabinet HRRs and clarifications regarding transient HRRs resulting from the industry review panel [12]. Subsequently, the NRC endorsed the transient HRR review panel decision, but did not endorse the EPRI 1022993 electrical cabinet HRRs for risk informed regulatory applications [10]. The NRC did not endorse the EPRI 1022993 HRRs because of planned additional fire testing of electrical cabinets by the NRC to develop improved guidance. The electrical cabinet fire tests are in progress. Nevertheless, the fire PRA results used in decision-making are based on the recommended NUREG/CR-6850 HRRs. A sensitivity study explored the potential reduction in risk given a smaller electrical cabinet HRR that did not result in damage to target cables. A fire induced CDF decrease of up to nearly a factor of 4 (up to a 72% reduction) was calculated for the sample fire PRAs examined.

Table 6: Fire PRA Sensitivity to Heat Release Rate

Fire PRA	Change in CDF
Plant 1	-69%
Plant 2	-72%
Plant 3	-34%

3.7. Fire PRA Human Reliability Analysis

Fire PRA human reliability analysis (HRA) is an area of the fire PRA categorized as Type 3 because the available guidance is believed adequate; however, the guidance has been difficult to implement in full. NUREG/CR-6850 Section 12 provides guidance on fire PRA HRA and the determination of human error probabilities (HEPs). Subsequently, NUREG-1921 [13] was published and provides additional guidance on fire PRA HRA. One of the greatest obstacles in fire PRA HRA is not necessarily related to the available guidance but the required resources to adequately apply the guidance. Two areas of significant resources that have generally been treated conservatively are the treatment of available cues and scenario specific influences on operator actions.

Fire PRA HRA introduces the need to explicitly identify primary and secondary cues and address the potential for degraded cues because of fire damage. A large set of primary and secondary instruments may be available to include in the full set of cues available to operators. In general, primary cues include instrumentation on the plant's safe shutdown equipment list. However, secondary cues are generally not included and require circuit analysis and cable location identification to explicitly credit in fire PRA. Therefore, generally the fire PRA HRA incorporates a conservative bias that assesses the secondary cues as degraded or provides no credit for secondary cues because the lack of data.

Fire HRA generally builds on the internal events HRA which includes sequence timing and available personnel. The timing involved in fire scenarios may be significantly different because of fire growth, time to target cable damage, and suppression activities. Additionally, there is the potential that some operators may participate in fire brigade activities reducing the number of available operators. Each of these items is specific to the postulated fire scenario. However, the fire PRA typically includes hundreds to thousands of fire scenarios. Therefore, scenario specific HRA may be deferred to the most risk significant scenarios if performed at all.

A sensitivity study explored the potential fire risk reduction if the fire HEPs were no worse than the internal events HEPs. A fire induced CDF reduction of up to 46% was calculated for the sample fire PRAs examined.

Table 7: Fire PRA Sensitivity to Human Error Probability

Fire PRA	Change in CDF
Plant 1	-46%
Plant 2	-13%
Plant 3	-13%

3.8. Assumed Plant Trip

Fire PRA plant response is an area of the fire PRA categorized as Type 3 because the available guidance is believed adequate; however, the guidance has been difficult to implement in full. One of the more difficult elements of a fire PRA is determining how an ignition source and subsequent damage to cables will affect plant operation. NUREG/CR-6850 equipment selection task provides guidance for identifying equipment which if lost may result in a fire induced initiating event. Fire damage to equipment and cables that may result in a more challenging initiating event typically has the necessary cable and routing data available. For example, damage to cables that may cause spurious opening of valves that could result in an inventory loss would be identified and the cables location in the plant would typically be known. Therefore, it is easy to identify if a postulated fire scenario will result in the fire induced initiating event. However, cable data for all equipment in the plant is not typically identified. Therefore, for many scenarios it is uncertain what may be the effect of the fire if any at all. NUREG/CR-6850 guidance acknowledges that for these cases a fire induced initiating event may have to be assumed. Typically, at a minimum a plant trip will be assumed.

A sensitivity study was performed in which a plant trip was not assumed. In the sensitivity study, a fire induced initiator was considered only if the consequence of the fire damage was known. A reduction of up to 21% in fire induced CDF was calculated for the sample fire PRAs examined.

Table 8: Fire PRA Sensitivity to Assumed Plant Trip

Fire PRA	Change in CDF
Plant 1	-21%
Plant 2	-4%
Plant 3	-13%

3.9. Main Control Room Abandonment Modeling

Modeling MCR abandonment because of environmental conditions is an area of the fire PRA categorized as Type 3 because there is available guidance; however, the guidance may not fully assess the potential operator or fire brigade response actions. The MCR abandonment criteria guidance is included in NUREG/CR-6850 Section 11.5.2. The guidance recommends the use of zone and field fire modeling tools to determine the time the habitability criteria are exceeded. When the models predict these conditions, then MCR abandonment is assumed. A factor that has not been explored is operator actions and fire brigade response activity in preventing abandonment conditions. For example, operators may open MCR doors or use portable fans. There are complications in crediting such actions because these types of actions may interfere with plant response actions and may not be proceduralized or trained. However, when MCR abandonment is identified as a risk significant fire scenario, then conservative biases should be explored.

A sensitivity study resulted in a reduction of up to 10% in the fire induced CDF when the MCR abandonment scenarios were removed from the sample fire PRAs examined.

Table 9: Fire PRA Sensitivity to MCR Abandonment

Fire PRA	Change in CDF
Plant 1	-10%
Plant 2	0%
Plant 3	-2%

3.10. Fire Induced Offsite Power Recovery

Modeling fire induced offsite power recovery is an area of the fire PRA categorized as Type 3 because the available guidance addresses equipment recovery; however, the lack of knowledge may prevent explicit credit. Fire scenarios that result in a fire induced loss of offsite power typically do not credit the recovery of offsite power in the fire PRA. It is often considered that the cause of the loss of offsite power may not be easily diagnosed. Also, the timing associated with identifying the cause for the loss of offsite power and taking actions to restore it may be difficult to assess. Another factor is that the necessary actions may not be proceduralized or may require special skill of craft knowledge.

A sensitivity study was performed in which offsite power recovery was credited. Table 10 presents the results which indicate up to an 18% reduction in fire induced CDF for the sample fire PRAs examined.

Table 10: Fire PRA Sensitivity to Offsite Power Recovery

Fire PRA	Change in CDF
Plant 1	-10%
Plant 2	-18%
Plant 3	-1%

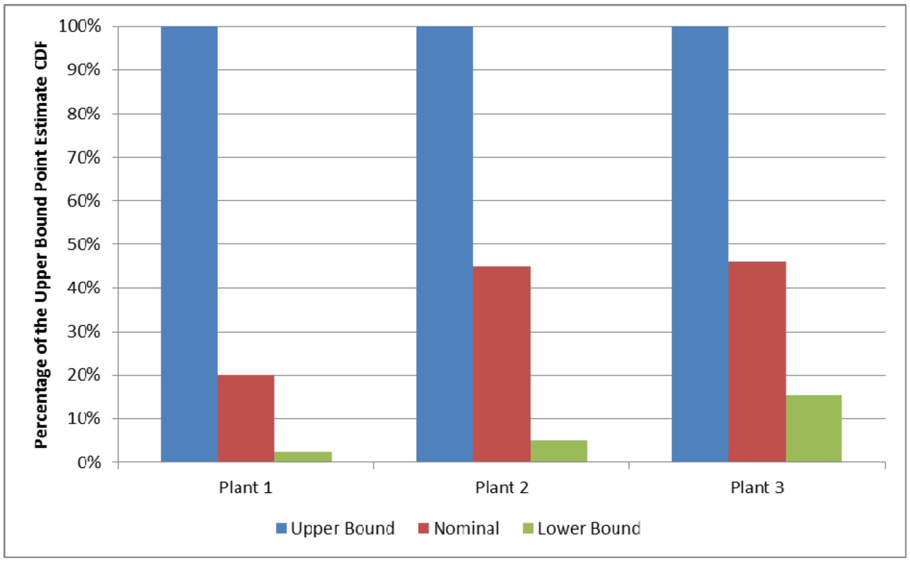
4. RESULTS

4.1. Overall Fire CDF Point Estimates

Three fire PRA point estimate CDFs were developed for each of the three plants. The “upper bound” was developed using NUREG/CR-6850 guidance. The “upper bound” point estimate CDF may be representative of fire PRA results that were developed and used for risk informed applications prior to NUREG/CR-6850 supplemental guidance. Using this guidance, a “high” fire CDF could be calculated (i.e., fire CDF > 1E-4/yr.) when the NUREG/6850 guidance is strictly applied. The “nominal” point estimate CDF may be representative of fire PRA results developed more recently and used for risk informed applications that implement NUREG/CR-6850 supplemental guidance or methods from FAQs, industry review panel, or subsequent NUREGs. It is noted that not all methods accepted by the industry review panel is endorsed by the NRC for use in risk informed applications. Using these sets of guidance, it was found that the calculated fire CDF could be at least a factor of two less than the “upper bound” fire induced CDF. Additionally, for each plant the “nominal” fire CDF was calculated to be less than 1E-4/yr. The "lower bound" point estimate CDF may represent fire PRA results that could be expected as fire PRAs mature to the level of internal event PRAs. In fact, the "lower bound" fire CDF estimates could be comparable to the internal events calculated CDFs.

Figure 1 presents the results for each plant fire PRA. Each fire CDF point estimate is presented as a percentage of the "upper bound" point estimate CDF.

Figure 1: Comparison of Fire CDF to the Upper Bound Estimate



4.2. Contributors to Fire Related CDF

The value of the fire PRA is the ability to provide the plant with insights so that risk informed decisions can be made in support of plant operations. Conservative biases can result in insights that may lead the plant to make decisions that do not provide real safety benefit, and could introduce additional risks. At the very least, biases could result in not prioritizing the most realistic sources of risk sufficiently high to be treated by decision makers. Three examples of the use of the fire PRA results insights is the understanding of the risk by plant location, the risk by ignition source type, and the risk by fire scenarios.

Fire related risk by plant location may be useful for identifying ways to reduce the plant fire risk. For example, a high risk area may not have an automatic detection or suppression system. A plant modification to install a system may be a reasonable solution to reduce plant fire risk. Figure 2 presents one of the plant's fire risks by location. For this plant, the Auxiliary Electric Equipment Room (AEER) contributes approximately 50% to the fire risk when looking at the "upper bound" CDF. However, as conservative biases are removed other plant locations become larger contributors which may not necessarily have been properly prioritized in making safety decisions regarding resource allocation.

Fire related risk by ignition source type may be useful for identifying ways to reduce the plant fire risk. For example, a high risk ignition source type may be vented panels that damage or ignite risk significant cables. A plant modification to seal the panels or install tray covers may be a reasonable solution to reduce plant fire risk. Figure 3 presents one plant's fire risk by ignition source type. For this plant, switchgear fires contribute approximately 50% to the fire risk when looking at the "upper bound" CDF. However, as conservative biases are removed high energy arching fault (HEAF) events become more significant contributors to the plant risk. Also, when looking at the "lower bound" CDF it is noticed that the importance of low voltage panels and motor control centers (MCCs) may be masked by conservative biases.

Fire related risk ranked by fire scenario contribution may be useful for identifying ways to reduce the plant fire risk. For example, plant resources could be focused on the most significant fire scenarios to reduce the risk. Changes in administrative controls, procedures, circuits, or plant operation could reduce the risk associated with a particular fire scenario. Figure 4 presents one plant's fire risk by the top 10 fire scenarios. For this plant, a transient fire scenario contributes approximately 5% to the fire risk when looking at the "upper bound" CDF. However, as conservative biases are removed the contribution of the transient fire scenario increases to approximately 40% when looking at the "lower bound" CDF.

Figure 2: Example CDF Point Estimates by Plant Location

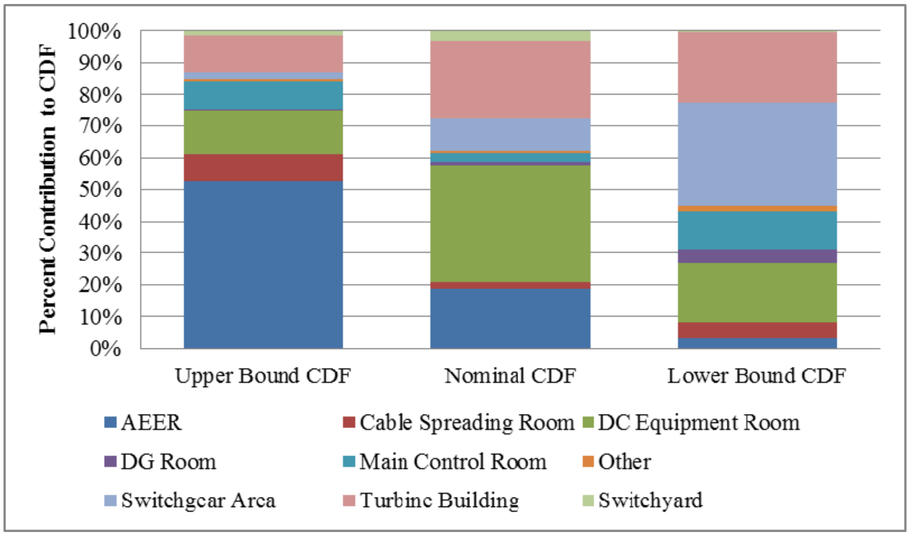


Figure 3: Example CDF Point Estimates by Ignition Source

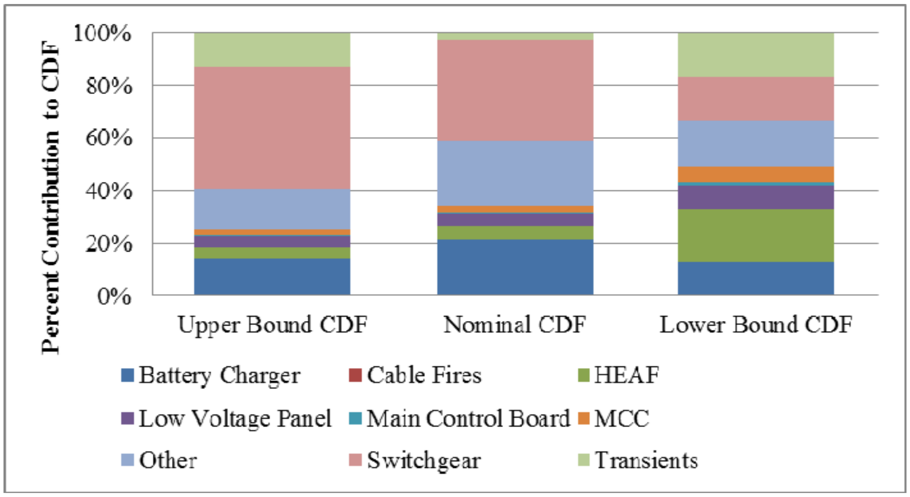
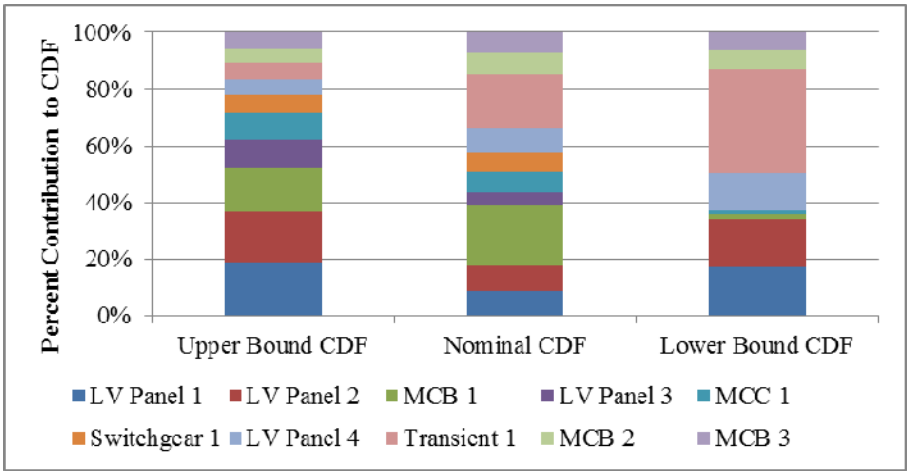


Figure 4: Example CDF Point Estimates Top 10 Scenarios



6. CONCLUSION

As identified in the NRC's PRA Policy Statement, PRA is most useful when it presents a realistic assessment of the conditions and then allows a realistic portrayal of the uncertainties. The evaluation reported here resulted in "upper bound" CDF point estimates greater than 1E-4/yr. and reductions in calculated CDF up to approximately one order of magnitude. The reductions were obtained by using realistic modeling approaches for only a limited number of issues. The reductions were obtained without fully addressing other potential biases not identified in this paper. The results were summarized from different perspectives to determine the impact on the dominant contributors. A comparison of the results showed that the relative plant location contribution to the risk profile could vary dramatically depending on the assumptions or biases imposed on the modeling. For example, a comparison of the results identified that the application of the same treatment regardless of the types of electrical cabinets (i.e., switchgears, MCCs, and low voltage panels) could mask the relative importance of a specific electrical cabinet. A comparison of the results also identified that the fire scenario contribution to the risk profile could vary depending on the assumptions imposed on the modeling.

There are interface and competing issues associated with identifying which of these uncertainties or conservative biases are currently being pursued as viable today and those that might be a "bridge too far". Nevertheless, the conclusion from the evaluation is that reasonable (realistic) approaches to the assessment of the fire hazard will result in a substantially reduced estimate of the fire risk and will likely change the priority that is assigned to the fire zones and the causes of risk significant fires. This change in insights could then lead to reprioritization of possible plant or procedural changes.

In addition to the methodological differences that may affect the fire risk profile, there are real plant or procedure changes that may influence the fire risk profile. The risk significance of these may dramatically change based on the degree of conservative biases that are imposed on the fire PRA. These might include protecting, replacing or rerouting cables, changes in system design or normal configuration, circuit modifications, or procedural changes to mitigate multiple spurious operations. Therefore, the risk reduction because of plant changes may be over stated due to conservative biases, and there may be risk beneficial plant changes being masked. Again, the conclusion from the evaluation is that reasonable (realistic) approaches to the assessment of the fire hazard will result in a reduced estimate of the fire risk and will likely change the priority that is assigned to plant changes.

Lastly, conservative bias fire PRAs may not adequately support risk input for other risk-informed applications. The possibility of mis-prioritizing plant modifications is a critical issue for an industry that is under severe economic pressure. The need to perform those safety enhancements that are most beneficial is critical to public safety. In addition, point estimate CDFs and computed delta CDFs input into the Significance Determination Processes (SDPs), Notice of Enforcement Discretions (NOEDs), or License Amendment Requests (LARs) may result in greater findings or administrative controls than are realistic. Alternatively, conservative bias fire PRAs may result in masking effects in computed delta CDFs in applications such as technical specification completion time evaluations. EPRI 1026511 Section 5.3.3.2 addresses potential issues related to conservative biases because of large uncertainty [14]. While this evaluation did not explore the potential issues related to conservative bias effects on computed delta CDF input into applications, an insight from this evaluation is that the comparison between the point estimate CDFs shows that the models could lead to different conclusions when used in applications and compared to specific acceptance guidelines or risk metric thresholds.

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