REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

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Question No. 19-43

10 CFR 52.47(a)(27) requires that a standard design certification applicant provide a description of the design specific PRA.

SRP Chapter 19.0, Revision 3 (Draft), Section "II. Acceptance Criteria," states that the staff determines whether, "…the technical adequacy of the PRA is sufficient to justify the specific results and risk insights that are used to support the DC or COL application. Toward this end, the applicant's PRA submittal should be consistent with prevailing PRA standards, guidance, and good practices as needed to support its uses and applications and as endorsed by the NRC (e.g., RG 1.200)."

To allow the staff to reach a reasonable assurance finding on APR1400 PRA technical adequacy of the PRA, please provide the following information related to cutsets, accident sequences, and truncation by updating the DCD and supporting documents, as necessary, for the items below.

a) Additional cutset and accident sequence information

1) For each combination of hazard group (e.g., internal, fire, flooding), operational mode (e.g., at-power, low power and shutdown), and PRA Level (e.g., Level 1, Level 2) analyzed in the APR1400 design certification PRA, please update the DCD cutsets tables to include the basic event probabilities.

2) In addition, please include in the DCD, tables of accident sequence information, similar to Table 19.1-18 "Level 1 Internal Events Top Accident Sequences," (e.g., sequence ID, frequency, cumulative contribution, sequence cutsets, sequence summary description), for the other PRA models.

3) For each combination of hazard group (e.g., internal, fire, flooding), operational mode (e.g., at-power, low power and shutdown), and PRA Level (e.g., Level 1, Level 2) analyzed in the APR1400 design certification PRA, please update the

cutsets tables to cover a sufficiently comprehensive portion (e.g., 95 percent) of the corresponding cumulative core damage frequency and large release frequency. Also, please include the basic event probabilities in these tables.

b) Truncation limit justification

For each combination of hazard group (e.g., internal, fire, flooding), operational mode (e.g., at-power, low power and shutdown), and PRA Level (e.g., Level 1, Level 2) analyzed in the APR1400 design certification PRA, please specify and justify the chosen truncation limit, with the exception of LPSD Level 1 analyses (internal events, fire, and flooding).

Response – (Rev.1)

a) The DCD will be revised as stated below:

1) The cutsets in the revised DCD Section 19.1 include basic event probabilities and descriptions, see the DCD markups associated with RAI 19-92 response.

2) Note that the various PRA models are quantified in different manners based on the model type. The “sequences” quantified in the at-power internal events model is based on individual core damage sequences; the “sequences” quantified in the LPSD internal events model are initiating event based sequences for each POS (e.g., unrecoverable loss of shutdown cooling during POS 5, etc.), and the “sequences” modeled in the fire and flood models (both at-power and LPSD) are quantified based on fire or flood scenarios. Breaking down the models into individual accident sequences would be an onerous task resulting in the necessity to create and quantify thousands of individual scenarios, for no appreciable gain in knowledge of how the plant responds to the event. For example, there are already over 7000 LPSD fire L1 scenarios developed and quantified; breaking down each of these 7000+ scenarios into individual accident sequences would result in the need to set up and quantify likely close to 20,000 – 30,000 sequences (about 3 to 4 sequences on average for each LPSD event tree). Furthermore, in doing so, we would not gain any more knowledge about which fire scenarios are most important, which POSs are more susceptible to core damage from fire, which equipment and operator actions are most important, which fire barriers are most important to shutdown fire risk, etc. Quantification in its current form provides output in the form necessary to gather important risk information for the model type in question. Therefore, the information presented in the DCD will be based on the current quantification output.

3) The cutset information required to include “a sufficiently comprehensive portion (e.g., 90 or 95 percent) of the cumulative core damage frequency and large release frequency” is too large to be included in the DCD. For example, to include the top 95% of the at-power CDF would require about 220,000 internal events cutsets, 143,000 fire cutsets, and 65,000 internal flooding cutsets. Hence, the information will be made available in the Electronic Reading Room for NRC inspection, and the cutsets in the DCD will contain the top 100 cutsets for each model, see the DCD markups associated with RAI 19-92 response.

b) The truncation limits set for all models were based on several factors. Note that the ASME Standard (ASME/ANS RA-Sb-2013) supporting requirements concerning truncation states:

> QU-B2: TRUNCATE accident sequences and associated system models at a sufficiently low cutoff value that dependencies associated with significant cutsets or accident sequences are not eliminated. NOTE: Truncation should be carefully assessed in cases where cutsets are merged to create a solution (e.g., where system level cutsets are merged to create sequence level cutsets).
>
> QU-B3: ESTABLISH truncation limits by an iterative process of demonstrating that the overall model results converge and that no significant accident sequences are inadvertently eliminated. For example, convergence can be considered sufficient when successive reductions in truncation value of one decade result in decreasing changes in CDF, and the final change is less than 5%.

The truncation analyses for the APR1400 DC PRA models were performed by quantifying each model several times starting at a truncation level a few orders of magnitude below the anticipated CDF/LRF, and performing successive quantifications each at a decade lower truncation level down to 1E-15, if possible. The results were reviewed, and truncation limits were chosen, taking into consideration several factors including: numerical convergence, the total number of cutsets, the inclusion of the risk significant accident sequences in the final results, and the inclusion of risk significant dependencies. In addition, in order to ensure that the individual models can be compared on a like-to-like basis, it is desired to have all models quantified at the same truncation level.

It must also be understood that there are limitations in PRA Codes and in the memory available in "standard PCs" to handle extremely large numbers of cutsets. The CAFTA PRA Code System currently allows several million cutsets to be generated, but appears to reach a limit around 10 million merged cutsets. This can result in the ability to quantify individual sequences at a very low truncation level, however, the results may not be able to be merged into a common set of cutsets. If the cutsets are not merged, they cannot be minimized, nor can overall importances be calculated. Therefore, in addition to the factors listed in the previous paragraph, it must be understood that at times it may be difficult, or impossible to achieve numerical convergence. However, in these cases, as long as there are a sufficient number of cutsets which include the risk significant sequences, and a review of the cutsets demonstrates that risk significant dependencies are included, then the truncation level can be stated as being sufficient to allow use of the cutsets for additional studies (e.g., risk ranking).

Likewise, simple numerical convergence may not be sufficient to determine a truncation level. Some models may numerically converge at a relatively high truncation level, but there may be an insufficient number of cutsets to ensure that risk significant accident sequences and dependencies are included. Hence, additional analysis should be performed prior to establishing the truncation level.

Based on the above discussion, the truncation values for each of the PRA models was set to 1E-13 for all CDF, and either 1E-13 or 1E-14 for LRF. A discussion of the applicability of the truncation level to each model is provided below:

1) At-Power Internal Events Level 1 PRA

The at-power internal events (AP-IE) Level 1 (L1) model was quantified using successively lower order of magnitude truncation values from 1E-07 through 1E-15. The final truncation chosen was 1E-13 based on the following:

- The % increase in CDF from 1E-12 to 1E-13 is about 17%, and the increase from 1E-13 to 1E-14 is about 9%. (Truncation could not be successfully performed at 1E-15/yr due to memory overload issues.) However, due to the complexity of the model, the AP-IE Level 2 (L2) analysis cannot be quantified at 1E-14. Therefore, to maintain quantification consistency between the AP-IE L1 and L2 results, the AP-IE L1 will be quantified at 1E-13. The remaining bullets below provide additional justification for AP-IE L1 quantification at 1E-13.

- The number of minimal cutsets generated at 1E-13 and 1E-14 is over 650,000 and 4.1 million respectively. Both truncation levels provide an adequate number of cutsets; however, the file size of the 1E-14 truncation is too large (about 495 MB) to allow manipulation of the cutsets without occasionally crashing.

- The truncation at 1E-13 results in 11 of 135 accident sequences with no cutsets. Truncation at 1E-14 results in 0 of 135 accident sequences with a no cutsets, so there are 11 additional accident sequences represented in the 1E-14 cutsets which are not in the 1E-13 cutsets. However, the cumulative CDF of these 11 additional accident sequences is 9.5E-12 which represents about 0.0009% of the total 1E-13 CDF of 1.10E-06. Therefore, the non-inclusion of these 11 accident sequences in the 1E-13 CDF results will not likely change the results of any studies performed on the cutsets.

- Review of the cutsets at 1E-13 demonstrates all postulated accidents, and credited systems are represented in the 1E-13 cutsets.

In conclusion, quantification of the AP-IE L1 model at a truncation level of 1E-13 is deemed to provide an acceptable set of minimal accident sequence cutsets. It provides a usable set of more than 650,000 cutsets which incorporates all risk significant accident sequences and dependencies of the PRA model. In addition, quantification at 1E-13 makes the AP-IE CDF consistent and comparable to the CDF results of all other models.

Note that the intent of SR's QU-B2 and QU-B3 are to ensure that "dependencies associated with significant cutsets or accident sequences are not eliminated," and to demonstrate "that the overall model results converge and that no significant accident sequences are inadvertently eliminated," respectively. Although the model does not converge well, all other requirements can be shown to be met. Note that the 5% increase stated in QU-B3 is only an example, and is not a requirement. The %

increase should be used in combination with the other requirements to ensure risk significant information is included in the final cutsets.

The likely cause of the "non-convergence" is the high level of redundancy of the systems credited in the APR1400 DC PRA. In addition, incorporation of the components of the digital control systems increases the complexity of the models. Most existing plants have 2 or at most 3 trains, and numerical convergence is easily achieved with the processing power and memory of current PCs. However, having a 4 train plant pushes the limits of today's computing technology, and therefore, convergence may not be possible. Hence, when numerical convergence cannot be met, one must ensure that risk significant sequences, equipment and dependencies are contained in the final cutsets.

2) At-Power Fire Level 1 PRA

The at-power fire (AP-Fire) L1 model was quantified using successively lower order of magnitude truncation values from 1E-07 through 1E-14. The final truncation chosen was 1E-13 based on the following:

- The % increase in CDF from 1E-12 to 1E-13 is about 7.2%. The increase from 1E-13 to 1E-14 drops to about 3.6%, but the resultant cutset file (almost 3.3 million cutsets) is too large to manipulate without occasionally crashing. Additionally, due to the complexity of the model, the AP-Fire L2 analysis cannot be quantified at 1E-14. Therefore, to maintain quantification consistency between the AP-Fire L1 and L2 results, the AP-Fire L1 will be quantified at 1E-13. The remaining bullets below provide additional justification for AP-Fire L1 quantification at 1E-13.

- The number of minimal cutsets generated at 1E-13 is over 620,000 providing an adequate number of cutsets.

- Review of the cutsets at 1E-13 demonstrates all 480 postulated fire initiators, and all credited systems are represented in the 1E-13 cutsets.

In conclusion, quantification of the AP-Fire L1 model at a truncation level of 1E-13 is deemed to provide an acceptable set of minimal accident sequence cutsets. It provides a usable set of over 620,000 cutsets which incorporates all risk significant accident sequences and dependencies of the PRA model. In addition, quantification at 1E-13 makes the AP-Fire CDF consistent and comparable to the CDF results of all other models.

Note that the intent of SR's QU-B2 and QU-B3 are to ensure that "dependencies associated with significant cutsets or accident sequences are not eliminated," and to demonstrate "that the overall model results converge and that no significant accident sequences are inadvertently eliminated," respectively. Although the model does not converge well, all other requirements can be shown to be met. Note that the 5% increase stated in QU-B3 is only an example, and is not a requirement. The % increase should be used in combination with the other requirements to ensure risk significant information is included in the final cutsets.

Like the AP-IE L1 model, the likely cause of the non-convergence is the high level of redundancy of the systems credited in the APR1400 DC PRA. In addition, incorporation of the components of the digital control systems increases the complexity of the models. Most existing plants have 2 or at most 3 trains, and numerical convergence is easily achieved with the processing power and memory of current PCs. However, having a 4 train plant pushes the limits of today's computing technology, and therefore, convergence may not be possible. Hence, when numerical convergence cannot be met, one must ensure that risk significant sequences, equipment and dependencies are contained in the final cutsets.

3) At-Power Flood Level 1 PRA

The at-power flood (AP-Flood) L1 model was quantified using successively lower order of magnitude truncation values from 1E-08 through 1E-15. The final truncation chosen was 1E-13 based on the following:

- The % increase in CDF from 1E-12 to 1E-13 is about 13.0%, from 1E-13 to 1E-14 is about 5.3%, and from 1E-14 to 1E-15 is about 1.9%. The model will quantify at 1E-15, and the individual accident sequence files will merge, but the resultant file is too large (about 409 MB) to allow easy manipulation of the cutsets without occasionally crashing.

- The number of minimal cutsets generated at 1E-13 and 1E-14 is over 190,000 and 880,000, respectively; hence, both truncation levels provide an adequate number of cutsets for review and analysis.

- Truncation at 1E-13 results in 42 of 155 flood scenarios with no cutsets; however, truncation at 1E-14 still results in 27 of 155 flood scenarios with no cutsets; hence, there are 15 additional flood scenarios represented in the 1E-14 cutset when compared to the 1E-13 results. However, the cumulative CDF of these 15 flood events is about 7.3E-13 which is less than 0.0002%. Therefore, the non-inclusion of these 15 flood scenarios in the 1E-13 CDF results will not likely change the results of any flood event importance studies.

- Review of the systems and operator actions of AP-Flood L1 quantification at 1E-13 and 1E-14 demonstrates that there would be no risk operator actions, or systems excluded due to AP-Flood quantification at 1E-13 vs. quantification at 1E-14.

In conclusion, quantification of the AP-Flood L1 model at a truncation level of 1E-13 is deemed to provide an acceptable set of minimal accident sequence cutsets. It provides a usable set of over 190,000 cutsets which incorporates all risk significant accident sequences and dependencies of the PRA model. In addition, quantification at 1E-13 makes the AP-Flood CDF consistent and comparable to the CDF results of all other models.

Note that the intent of SR's QU-B2 and QU-B3 are to ensure that "dependencies associated with significant cutsets or accident sequences are not eliminated," and to demonstrate "that the overall model results converge and that no significant accident sequences are inadvertently eliminated," respectively. Although the model does not converge well, all other requirements can be shown to be met. Note that the 5% increase stated in QU-B3 is only an example, and is not a requirement. The % increase should be used in combination with the other requirements to ensure risk significant information is included in the final cutsets.

Like the AP-IE L1 model and the AP-Fire L1 model, the likely cause of the non-convergence is the high level of redundancy of the systems credited in the APR1400 DC PRA. In addition, incorporation of the components of the digital control systems increases the complexity of the models. Most existing plants have 2 or at most 3 trains, and numerical convergence is easily achieved with the processing power and memory of current PCs. However, having a 4 train plant pushes the limits of today's computing technology, and therefore, convergence may not be possible. Hence, when numerical convergence cannot be met, one must ensure that risk significant sequences, equipment and dependencies are contained in the final cutsets.

4) At-Power Internal Events Level 2 PRA

The Level 2 model begins with Level 1 sequences, and proceeds to separate the sequences through a series of split fractions and fault tree logic gates (success and failures). Therefore, in the Level 2 analysis, some of the Level 1 cutsets will drop below the Level 1 truncation. For example, if the Level 1 truncation is set at 1E-13/yr, a 1E-13 cutset that is split into two equal parts would yield two 5E-14/yr cutsets in the Level 2. If the same 1E-13/yr truncation is utilized in the Level 2, then some of the Level 1 frequency will not be counted in the Level 2. Conversely, if the Level 2 truncation is set at 1E-14/yr, then many cutsets that were truncated in the Level 1 would then appear in the Level 2, and the total Level 2 frequency could increase above the Level 1 total. Ideally, the total Level 2 frequency would equal the total Level 1 frequency, but an exact match cannot be achieved using the CAFTA software. Therefore, setting an appropriate Level 2 truncation is not as straightforward as setting the Level 1 truncation.

Additionally, it is important to note that the Level 2 model necessarily adds complexity to the evaluation of each sequence. The Level 1 truncation discussions above identify that a significant consideration in setting the truncation is the ability for the software to solve the models. Since the Level 1 models are solved with a truncation near the practical limit of the code to solve, it is difficult for the Level 2 models to be solved with a significantly lower truncation than what was used in the Level 1 models.

Since the focus of the Level 2 portion of the Design Certification process is Large Release Frequency (LRF), this is the focus of the Level 2 truncation evaluation. The AP-IE LRF model was quantified using successively lower order of magnitude truncation values from 1E-08/yr through 1E-13/yr. Truncation could not be successfully performed at 1E-14/yr due to memory overload issues.

The % increases in LRF are as follows: 1E-10 to 1E-11: 35.8%. 1E-11 to 1E-12: 19.2%. 1E-12 to 1E-13: 13.4%. As stated, the model did not solve at 1E-14/yr. The baseline LRF truncation is set at 1E-13/yr for the following reasons:

- The increase in LRF when decreasing from 1E-12 to 1E-13 is about 13%, which is comparable to the AP-IE Level 1 increase from 1E-12 to 1E-13.

- The highest LRF Source Term Category (STC) is STC 1, comprised of SGTR LRF sequences and induced SGTR events. The dominant cutsets in this category have a conditional probability of large release of 1.0 (given core damage). Since their applicable core damage sequences were truncated at 1E-13/yr, lowering the truncation for LRF calculation would yield a higher LRF than the sequences' CDF.

- A 1E-13/yr truncation is one in 10 trillion years, and is more than 6 orders of magnitude lower than the total APR1400 LRF. This provides a high confidence that nothing significant is missing from these results.

- Results reviews focus on dominant cutset contributors to the LRF. Cutsets in the 1E-13/yr and below range have not been reviewed in detail, and conservatism in these results exists. Additional recovery actions on these low level cutsets would be expected to reduce their contribution to the total LRF.

- Not all AP-IE STCs necessary to calculate LRF can quantify at 1E-14.

5) At-Power Fire Level 2 PRA

The Level 2 model begins with Level 1 sequences, and proceeds to separate the sequences through a series of split fractions and fault tree logic gates (success and failures). Therefore, in the Level 2 analysis, some of the Level 1 cutsets will drop below the Level 1 truncation. For example, if the Level 1 truncation is set at 1E-13/yr, a 1E-13 cutset that is split into two equal parts would yield two 5E-14/yr cutsets in the Level 2. If the same 1E-13/yr truncation is utilized in the Level 2, then some of the Level 1 frequency will not be counted in the Level 2. Conversely, if the Level 2 truncation is set at 1E-14/yr, then many cutsets that were truncated in the Level 1 would then appear in the Level 2, and the total Level 2 frequency could increase above the Level 1 total. Ideally, the total Level 2 frequency would equal the total Level 1 frequency, but an exact match cannot be achieved using the CAFTA software. Therefore, setting an appropriate Level 2 truncation is not as straightforward as setting the Level 1 truncation.

Additionally, it is important to note that the Level 2 model necessarily adds complexity to the evaluation of each sequence. The Level 1 truncation discussions above identify that a significant consideration in setting the truncation is the ability for the software to solve the models. Since the Level 1 models are solved with a truncation near the practical limit of the code to solve, it is difficult for the Level 2 models to be solved with a significantly lower truncation than what was used in the Level 1 models.

Since the focus of the Level 2 portion of the Design Certification process is Large Release Frequency (LRF), this is the focus of the Level 2 truncation evaluation. The AP-Fire LRF was quantified with truncations of 1E-08/yr through 1E-13/yr. The model did not solve at 1E-14/yr.

The % increases in LRF are as follows: 1E-11 to 1E-12: 19.0%. 1E-12 to 1E-13: 13.5%. The baseline LRF truncation is set at 1E-13/yr for the following reasons:

- By far, the most dominant LRF cutsets involve either control room evacuation (alternate shutdown failure) or failure of containment isolation. The control room evacuation cutsets are of relatively high frequency, and the LRF from these cutsets is insensitive to low level truncation changes. The cutsets involving containment isolation failure (those in STC 6) are dominated by fire scenarios that directly disable the containment isolation function. Therefore, these cutsets have a conditional probability of large release of 1.0 (given core damage). Since their applicable core damage sequences were truncated at 1E-13/yr, lowering the truncation for LRF calculation would yield a higher LRF than the sequences' CDF.

- A 1E-13/yr truncation is one in 10 trillion years, and is nearly 6 orders of magnitude lower than the total APR1400 LRF. This provides a high confidence that nothing significant is missing from these results.

- Results reviews focus on dominant cutset contributors to the LRF. Cutsets in the 1E-13/yr and below range have not been reviewed in detail, and conservatism in these results exists. Additional recovery actions on these low level cutsets would be expected to reduce their contribution to the total LRF.

- Not all AP-Fire STCs necessary to calculate LRF can quantify at 1E-14.

6) At-Power Flood Level 2 PRA

The Level 2 model begins with Level 1 sequences, and proceeds to separate the sequences through a series of split fractions and fault tree logic gates (success and failures). Therefore, in the Level 2 analysis, some of the Level 1 cutsets will drop below the Level 1 truncation. For example, if the Level 1 truncation is set at 1E-13/yr, a 1E-13 cutset that is split into two equal parts would yield two 5E-14/yr cutsets in the Level 2. If the same 1E-13/yr truncation is utilized in the Level 2, then some of the Level 1 frequency will not be counted in the Level 2. Conversely, if the Level 2 truncation is set at 1E-14/yr, then many cutsets that were truncated in the Level 1 would then appear in the Level 2, and the total Level 2 frequency could increase above the Level 1 total. Ideally, the total Level 2 frequency would equal the total Level 1 frequency, but an exact match cannot be achieved using the CAFTA software. Therefore, setting an appropriate Level 2 truncation is not as straightforward as setting the Level 1 truncation.

Additionally, it is important to note that the Level 2 model necessarily adds complexity to the evaluation of each sequence. The Level 1 truncation discussions above identify that a significant consideration in setting the truncation is the ability for the software to solve the models. Since the Level 1 models are solved with a truncation near the practical limit of the code to solve, it is difficult for the Level 2 models to be solved with a significantly lower truncation than what was used in the Level 1 models.

Since the focus of the Level 2 portion of the Design Certification process is Large Release Frequency (LRF), this is the focus of the Level 2 truncation evaluation. The AP-Flood LRF was quantified with truncations of 1E-09/yr through 1E-15/yr.

The % increases in LRF are as follows: 1E-11 to 1E-12: 100.6%. 1E-12 to 1E-13: 48.1%. 1E-13 to 1E-14: 27.0%. 1E-14 to 1E-15: 13.8%. The baseline LRF truncation is set at 1E-14/yr for the following reasons:

- Unlike the AP-IE and AP-Fire LRF discussions above, the AP-Flood LRF is not dominated by cutsets with a high conditional probability of large release, and therefore it is significantly more susceptible to Level 1 frequency being truncated if the same truncation was used for both Level 1 and Level 2. Since the AP-Flood Level 1 model was truncated at 1E-13/yr, an order of magnitude lower truncation would capture the significant frequency from the Level 1 sequences.

- A 1E-14/yr truncation is one in 100 trillion years, and is more than 7 orders of magnitude lower than the total APR1400 LRF. This provides a high confidence that nothing significant is missing from these results, and that a lower truncation is not necessary.

- Results reviews focus on dominant cutset contributors to the LRF. Cutsets in the 1E-14/yr and below range have not been reviewed in detail, and conservatism in these results exists. Additional recovery actions on these low level cutsets would be expected to reduce their contribution to the total LRF.

- Even if the total APR1400 LRF were increased by 13.8% (by truncating at 1E-15), the total LRF would still be well below the safety goal of <1E-6/yr.

7) <u>Low Power and Shutdown Internal Events Level 1 PRA</u>

The low power and shutdown internal events (LPSD-IE) L1 model was quantified using successively lower order of magnitude truncation values from 1E-08 to 1E-15. The final truncation chosen was 1E-13 based on the following:

- The % increases in CDF from 1E-10 to 1E-11 and from 1E-11 to 1E-12 are about 4.2% and 2.3%, respectively which demonstrates an acceptable increase for numerical convergence; however, there are too few minimal cutsets at 1E-11 (2,698) and 1E-12 (15,765) to ensure that risk significant accident scenarios and dependencies are captured. The % increase in CDF from 1E-12 to 1E-13 is about 0.6% which further demonstrates numerical convergence; however, the 1E-13 quantification produces a significantly larger number of minimal cutsets (80,843).

- The truncation at 1E-13 results in 5 of 198 accident sequences with no cutsets. Truncation at 1E-14 results in 0 of 198 accident sequences with a no cutsets, so are 5 additional accident sequences represented in the 1E-14 cutsets which are not in the 1E-13 cutsets. However, the cumulative CDF of these 5 additional accident sequences is 7.98E-13 which represents about 0.00004% of the total 1E-13 CDF of 1.80E-06. Therefore, the non-inclusion of these 5 accident sequences in the 1E-13 CDF results will not likely change the results of any studies performed on the cutsets.

- Review of the importances of event in the 1E-13 and 1E-14 cutsets demonstrates all postulated accidents are represented in the cutsets. In addition, there were no risk significant components or operator actions which were in the 1E-14 cutsets which were not in the 1E-13 cutsets

In conclusion, quantification of the LPSD-IE L1 model at a truncation level of 1E-13 is deemed to provide an acceptable set of minimal accident sequence cutsets. It provides a usable set of over 80,000 cutsets which incorporates all risk significant accident sequences and dependencies of the PRA model. In addition, quantification at 1E-13 makes the LPSD-IE CDF consistent and comparable to the CDF results of all other models.

Note that the intent of SR's QU-B2 and QU-B3 are to ensure that "dependencies associated with significant cutsets or accident sequences are not eliminated," and to demonstrate "that the overall model results converge and that no significant accident sequences are inadvertently eliminated," respectively. Although the model numerically converges well at 1E-11 with only a 4.2% increase in CDF, all of the other requirements may not be met due to the small number of cutsets. Note that the 5% increase stated in QU-B3 is only an example, and is not a requirement. The % increase should be used in combination with the other requirements to ensure risk significant information is included in the final cutsets.

Finally, note that the ease in convergence of the LPSD-IE model is due to the fact that the main function during shutdown (continued shutdown cooling) is a made up of a two train system, and one of those trains is already failed as a result of most of the postulated initiating events. In addition, although the transition modes, Plant Operating States (POS) 1, 2, 14 and 15 credit all four trains, the duration in these POSs are so small that the CDF impact of this portion of the model (about 4.7% CDF) with respect to the shutdown POSs 3a – 13 is not risk significant.

8) <u>Low Power and Shutdown Fire Level 1 PRA</u>

The LPSD Fire L1 model was quantified using successively lower order of magnitude truncation values from 1E-08 to 1E-15. The final truncation chosen was 1E-13 based on the following:

- The % increase in CDF from 1E-10 to 1E-11 is about 4.3% which demonstrates an acceptable increase for numerical convergence; however, there are too few minimal cutsets at 1E-11 (2,162) to ensure that risk significant accident scenarios and dependencies are captured. The % increase in CDF from 1E-11 to 1E-12 is about 1.7%, and from 1E-12 to 1E-13 is about 0.8% which further demonstrates numerical convergence; however, the 1E-13 quantification produces a significantly larger number of minimal cutsets (39,639).

- Truncation at 1E-13, 1E-14 and 1E-15 all result in a CDF of 1.24E-06, so it appears LPSD-Fire CDF asymptotes at 1E-13. Quantification 1E-14 and 1E-15 does produce additional cutsets, but the impact is so small as to not be noticed given the number of significant digits.

- The truncation at 1E-13 results in 235 fire initiators. Truncation at 1E-15 results in 254 fire initiators, so there are 19 additional fire initiators represented in the 1E-15 cutsets which are not in the 1E-13 cutsets. However, the cumulative FV of these 13 additional fire initiators is about less than 0.00001%. Therefore, the non-inclusion of these 19 fire initiators in the 1E-13 CDF results will not likely change the results of any studies performed on the cutsets.

- Review of the fire initiators, operator actions, basic event and common cause event importances of LPSD-Fire L1 quantification at 1E-13 and 1E-14 demonstrates that there would be no risk significant fire initiators, operator actions, or components excluded due to LPSD-Fire quantification at 1E-13.

In conclusion, quantification of the LPSD-Fire L1 model at a truncation level of 1E-13 is deemed to provide an acceptable set of minimal accident sequence cutsets. It provides a usable set of over 39,000 cutsets which incorporates all risk significant accident sequences and dependencies of the PRA model. In addition, quantification at 1E-13 makes the LPSD-Fire CDF consistent and comparable to the CDF results of all other models.

Note that the intent of SR's QU-B2 and QU-B3 are to ensure that "dependencies associated with significant cutsets or accident sequences are not eliminated," and to demonstrate "that the overall model results converge and that no significant accident sequences are inadvertently eliminated," respectively. Although the model converges well at 1E-11 with only a 3.4% increase in CDF, all of the other requirements may not be met due to the small number of cutsets. Note that the 5% increase stated in QU-B3 is only an example, and is not a requirement. The % increase should be used in combination with the other requirements to ensure risk significant information is included in the final cutsets.

Finally, note that the ease in convergence of the LPSD-Fire model is due to the fact that the main function during shutdown (continued shutdown cooling) is a made up of a two train system, and one of those trains is already failed as a result of the postulated initiating event.

9) <u>Low Power and Shutdown Flood Level 1 PRA</u>

The LPSD Flood L1 model was quantified using successively lower order of magnitude truncation values from 1E-08 to 1E-16. The final truncation chosen was 1E-13 based on the following:

- The % increase in CDF from 1E-11 to 1E-12 is about 11.3%, and from 1E-12 to 1E-13 is about 3.4% which demonstrates numerical convergence. The 1E-13 quantification produces 10,923 minimal cutsets.

- The truncation at 1E-13 results in 65 LPSD flood initiators. Truncation at 1E-16 results in 73 LPSD flood initiators, so there are 8 additional flood initiators represented in the 1E-16 cutsets which are not in the 1E-13 cutsets. However, the cumulative FV of these 8 additional flood initiators is less than 0.00001%. Therefore, the non-inclusion of these 8 flood initiators in the 1E-13 CDF results will not likely change the results of any studies performed on the cutsets.

- Review of the flood initiators, operator actions, basic event and common cause event importances of LPSD-Fire L1 quantification at 1E-13 and 1E-14 demonstrates that there would be no risk significant LPSD flood initiators, operator actions, or components excluded due to LPSD-Flood quantification at 1E-13.

In conclusion, quantification of the LPSD-Flood L1 model at a truncation level of 1E-13 is deemed to provide an acceptable set of minimal accident sequence cutsets. It provides a usable set of over 10,900 cutsets which incorporates all risk significant accident sequences and dependencies of the PRA model. In addition, quantification at 1E-13 makes the LPSD-Flood CDF consistent and comparable to the CDF results of all other models.

Note that the intent of SR's QU-B2 and QU-B3 are to ensure that "dependencies associated with significant cutsets or accident sequences are not eliminated," and to demonstrate "that the overall model results converge and that no significant accident sequences are inadvertently eliminated," respectively. The model converges well at 1E-13 with only a 3.4% increase in CDF, all of the other requirements are met even though there are only 10,588 cutsets. Note that the 5% increase stated in QU-B3 is only an example, and is not a requirement. The % increase should be used in combination with the other requirements to ensure risk significant information is included in the final cutsets.

Finally, note that the ease in convergence of the LPSD-Flood model is due to the fact that the main function during shutdown (continued shutdown cooling) is a made up of a two train system, and one of those trains is already failed as a result of the postulated initiating event.

10) Low Power and Shutdown Internal Events Level 2 PRA

The LPSD-IE L2 model was quantified using successively lower order of magnitude truncation values from 1E-08 to 1E-16. The final truncation chosen was 1E-14 based on the following:

- The % increases in CDF from 1E-12 to 1E-13 and from 1E-13 to 1E-14 are about 8.1% and 5.3%, respectively, which demonstrates an acceptable increase for numerical convergence. The 1E-14 quantification produces over 129,000 minimal cutsets.

- Quantification at 1E-15, while adding almost 600,000 cutsets only produces a 2.7% increase in CDF. Quantification at 1E-16 adds an additional 1% over the 1E-15 quantification, but results in adding almost 2.5 million cutsets which is too large to be able to manipulate the files during review.

In conclusion, quantification of the LPSD-IE L2 model at a truncation level of 1E-14 is deemed to provide an acceptable set of minimal accident sequence cutsets. It provides a usable set of over 129,000 cutsets which incorporates all risk significant accident sequences and dependencies of the PRA model.

Note that the intent of SR's QU-B2 and QU-B3 are to ensure that "dependencies associated with significant cutsets or accident sequences are not eliminated," and to demonstrate "that the overall model results converge and that no significant accident sequences are inadvertently eliminated," respectively. Although the model numerically converges well at 1E-13 with only a 8.1% increase in CDF, all of the other requirements may not be met due to the small number of cutsets. Note that the 5% increase stated in QU-B3 is only an example, and is not a requirement. The % increase should be used in combination with the other requirements to ensure risk significant information is included in the final cutsets.

Finally, note that the ease in convergence of the LPSD-IE model is due to the fact that the main function during shutdown (continued shutdown cooling) is a made up of a two train system, and one of those trains is already failed as a result of most of the postulated initiating events. In addition, although the transition modes, Plant Operating States (POS) 1, 2, 14 and 15 credit all four trains, the duration in these POSs are so small that the CDF impact of this portion of the model (about 4.7% CDF) with respect to the shutdown POSs 3a – 13 is not risk significant.

11) <u>LPSD Fire Level 2 PRA</u>

The LPSD-Fire L2 model was quantified using successively lower order of magnitude truncation values from 1E-09 to 1E-16. The final truncation chosen was 1E-14 based on the following:

- The % increases in CDF from 1E-12 to 1E-13 and from 1E-13 to 1E-14 are about 5.1% and 2.0%, respectively, which demonstrates an acceptable increase for numerical convergence. The 1E-14 quantification produces over 56,000 minimal cutsets.

- Quantification at 1E-15, while adding almost 170,000 cutsets only produces a 0.7% increase in LRF. Further quantification at 1E-16 result in the addition of more than 635,000 cutsets, but only produces a 0.3% increase in LRF.

In conclusion, quantification of the LPSD-Fire L2 model at a truncation level of 1E-14 is deemed to provide an acceptable set of minimal accident sequence cutsets. It provides a usable set of over 56,000 cutsets which incorporates all risk significant accident sequences and dependencies of the PRA model.

Note that the intent of SR's QU-B2 and QU-B3 are to ensure that "dependencies associated with significant cutsets or accident sequences are not eliminated," and to demonstrate "that the overall model results converge and that no significant accident sequences are inadvertently eliminated," respectively. Although the model numerically converges well at 1E-13 with only a 5.1% increase in CDF, all of the other requirements may not be met due to the small number of cutsets. Note that the 5% increase stated in QU-B3 is only an example, and is not a requirement. The % increase should be used in combination with the other requirements to ensure risk significant information is included in the final cutsets.

Conclusion

In conclusion, all models were demonstrated to converge sufficiently at a truncation of 1E-13 or 1E-14. Although some models numerically converged earlier, and some later, all models were evaluated, and it was determined that no risk significant sequences or scenarios would not be captured using these truncation levels. In addition, the comparison of the model results in relation to each other is more meaningful when truncated at or near the same value.

Impact on DCD

There is no impact on the DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.