LESSONS LEARNED IN THE DEVELOPMENT OF AN AT-POWER RISK MONITOR FOR THE **AP1000®[1]** PLANT

Nathan Larson – Principal Engineer

Glen Rose, TX

Rachel Christian – Senior Engineer

Cranberry Twp., PA

Purpose

- The purpose of this paper was to present lessons learned and challenges that were encountered during the development of the initial at-power **AP1000** plant risk monitor model.

Use of Risk Monitor Models for the Existing Fleet

- Provides an additional layer of support for maintaining defense in depth beyond common technical specification requirements.
- Insights gained from accident scenarios/sequences where the plant configuration would be challenged can be used to
  - Defer the combining of multiple activities (re-schedule some or all activities)
  - Institute risk mitigation measures (temporary equipment, stationing personnel, etc.)
  - Accelerate the return of equipment to service (back out of testing/maintenance if an emergent situation occurs)

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Use of Risk Monitor Models for the Existing Fleet

- While there is variability in the application of risk monitoring from plant to plant across the industry, risk thresholds are well understood

GREEN	Minimal Risk Increase	Nominal operating conditions; no or limited risk important equipment out of service.
YELLOW	Moderate Risk Increase	Some risk importance equipment is out of service. May be entered for routine testing and maintenance if deemed necessary to support plant operations.
ORANGE	Potentially Risk Significant Increase	Risk management action should be taken immediately, including restoration of equipment to reduce plant risk. This condition should not be entered for routine test and maintenance activities it should only be entered on an emergent basis.
RED	Unacceptable Risk Increase	This condition should only be entered on an emergent basis and actions should be taken immediately to restore equipment and provide additional mitigating actions for the dominant risk contributors.

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Use of Risk Monitor Models for the Existing Fleet

- Typical methods to implement the color scheme include
  - Increases to CDF/LERF by risk thresholds (increases in instantaneous risk greater than a certain values)
  - Cumulative risk (accumulation of risk until certain values are reached)
  - Multiplier methods (increases in risk by certain multiplicative factors)
- Existing industry accepted risk metrics for a risk significant increase above the baseline risk values

CDF	1E-06
LERF	1E-07

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Unique Considerations for **AP1000** Plant

- No operating experience or industry experience with passive plants in risk monitor models was available.
- Passive features introduce unique considerations:
  - Significantly lower level of risk (greater than 1-2 orders of magnitude reduction for CDF and LERF).
  - Testing and/or maintenance activities during at-power operation is unlikely due to nature of passive systems
  - Passive components typically ‘fail-safe’ or only require DC power to perform their intended functions.
  - Minimal impact of defense-in-depth (DID) components to overall risk compared to baseline CDF/LERF values of existing fleet
  - Activation of some passive features would require significant effort to restore the plant to operational readiness.

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Risk Metric Challenges for **AP1000** Plant

- Considerations for defining appropriate CDF/ LERF threshold values:
  - Application of the current industry values → Demonstrates sufficient means to protect the overall safety of the plant to ensure the health and safety of the public, but does not address the economic and operational risks associated with operating an advanced plant
  - Lower CDF/LERF threshold values to be in-line with the **AP1000** plant design → Creates a handicap for a plant that was designed to have lower risk and increased operating flexibility and could have unintended consequences to existing fleet

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Risk Metric Challenges for **AP1000** Plant

- Potential solution is to investigate the use of alternative risk metrics for the **AP1000** plant to be used in parallel with the existing CDF/ LERF metrics.
  - Risk metric(s) to quantify likelihood of passive safety-system actuations which produce an undesired result (e.g., steam environment in containment, breaching the RCS boundary, etc.).
  - Focus on accident scenarios that can be fully mitigated using only DID systems and do not result in breaching the reactor coolant system boundary (i.e. non-LOCA initiators)

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Lack of Operational History

- Availability of Test and Maintenance procedures directly impacted the risk monitor model development and resulted in challenges with respect to vetting and testing the **AP1000** plant risk monitor model.
- Insights from operating reactors with regard to potential testing and maintenance schedules were used to define an initial set of tests.
- Future testing will need to consider complex combinations of SSCs out of service which could occur on a scheduled or emergent basis due to removal of DID SSCs from service which are not included in the Technical Specifications (and could therefore be removed for extended durations).

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Lack of Operational History

- Development will be a continuous and iterative process:
  - Work schedules will need to be reviewed proactively → identify errors/conservatism prior to the performance of the activity.
  - In-depth testing and early identification of issues will be key → do not want to prevent work from being performed due to potential items in the PRA model that were either not considered or do not accurately reflect the plant configuration.
  - Need to ensure alignment when using an alternative risk metric to make a plant risk declaration → decisions could be made on the interpretation of the results to override the risk monitor model (higher or lower)
    - Will need to ensure procedural flexibility to allow this practice

Impacts of Modeling Methods

- Risk Monitor Model Mapping Lessons Learned
  - Mapping of impacted equipment to the applicable component basic events requires review for consistency with maintenance practices → when the plant is performing maintenance on a component it is likely 'tagged' out in a manner that may not be reflected in the PRA model.
  - To deal with these maintenance configurations which differ from the PRA model configuration an equivalent or surrogate basic event can be used.

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Impacts of Modeling Methods

- Managing Increased Model Complexity/Size
  - **AP1000** plant PRA is a detailed and highly complex model.
    - Digital I&C model with 100s of tops
    - Modeling of passive failures that are screened in the existing fleet models (non-flooding pipe breaks)
    - Conservatisms in the treatment of DID systems
  - Results in longer quantification times that may not support prompt determination of plant risk day to day.
  - Goal is to reduce the complexity of the model while maintaining the fidelity and quality of the results.
  - This area is still being investigated for ultimate usability of the risk monitor model. Options may include restructuring of various portions of the model, enhanced screening, etc.

Impacts of Modeling Methods

- Building in Model Flexibility
  - Although the operating practice/alignments for systems are not yet defined, the **AP1000** plant model has implemented various alignment flags to account for many possible system configurations using cross connection alignments.
  - However, in some cases alternate alignments that weren't modeled in Internal Events PRA model due to limited benefit will need to be addressed in the risk monitor model (e.g., Component Cooling Water System heat exchanger swap over is a manual action that isn't credited).

Conclusion

- Complexity in the PRA models of advanced passive plants should be thoroughly reviewed to determine if alternative methods are available to streamline the model while maintaining its quality and fidelity.
- Alternative risk metrics will likely be necessary to accurately depict the risks associated with the operations of an advanced passive plant.
- Flexibility in the risk assessment process will be key to dealing with the lack of operational history and ensuring operational flexibility while not arbitrarily impacting plant operations.
- Individual plant site processes will likely require significant effort knowledgeable PRA personnel during the early implementation phases of the risk monitor model.

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Questions?