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US NRC Probabilistic Risk Assessment Confirmatory Success Criteria Analysis Using Grand Gulf Nuclear Station

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Acronyms

- ADS – automatic depressurization system
- BWR – boiling water reactor
- CRDHS – control rod drive hydraulic system
- ESF – engineered safeguard features
- FSG – FLEX Support Guideline
- GGNS – Grand Gulf Nuclear Station
- HPCI – high-pressure coolant injection
- LPCI – low-pressure coolant injection
- MELCOR – not an acronym
- MSIV – main steam isolation valves
- NRC – Nuclear Regulatory Commission
- NSSS – nuclear steam supply system
- PRA – probabilistic risk assessment
- RCIC – reactor core isolation cooling
- RHR – residual heat removal system
- RPS – reactor protection system
- RPV – reactor pressure vessel
- SPAR – Standardized Plant Analysis Risk models
- SRV – Safety Relief Valve

Purpose and Desired Outcome

- Purpose:
  - To discuss confirmatory success criteria analysis activities to refine and improve independent Standardized Plant Analysis Risk (SPAR) models using Grand Gulf Nuclear Station (GGNS) as the reference plant;
  - To provide an opportunity for the NRC to describe the plans for this project, and for GGNS and other interested parties to provide feedback;
  - To communicate that this activity is not directly associated with an existing regulatory issue or decision for GGNS.
- Desired outcome:
  - Public awareness of the project;
  - Input on how the work should be framed and executed;
  - Identification of any related activities or interactions that might not be on the team's radar.

Meeting outline

- Introductions
- Background on this project
- More details about what we're doing and where we're heading
- Discuss topics to be investigated
- Wrap-up

Background on this project

- Objectives:
  - To support confirmation/changes to the independent SPAR models
  - To provide off-the-shelf analyses for NRC risk analysts to consult
  - To foster in-house expertise and knowledge transfer
- Led by the Office of Nuclear Regulatory Research at the request of the Office of Nuclear Reactor Regulation
  - Contractor involvement in the SPAR model implementation
- To support NRC risk analysts, but not part of a specific regulatory action
- PRA scope:
  - Level 1 – i.e., beyond-design-basis scenarios up to the time of core damage
  - Equipment/system performance requirements to support system analysis (i.e., fault tree modeling) and sequence timing to support human reliability analysis
    - Does not deal directly with issues related to reliability modeling (e.g., common cause failure, human performance) – these are covered under other NRC projects

Background on this project (2)

- Past work:
  - NUREG-1953 – Selected issues for 3-loop Westinghouse and General Electric BWR Mark I plants
  - NUREG/CR-7177 – Selected success criteria modeling issues (e.g., core damage surrogate selection, effect of specific modeling assumptions)
  - NUREG-2187 – Selected issues for 4-loop Westinghouse plants with large, dry containments
  - Draft NUREG Confirmatory Thermal- Hydraulic Analysis to Support Specific Success Criteria in the Standardized Plant Analysis Risk Models- Duane Arnold
    - In the final stages of publication
- The above work has both confirmed existing SPAR modeling assumptions and supported specific SPAR modeling changes

Questions or feedback at this point?

Plans for Project Scope

- The current GGNS SPAR model includes Level 1 at-power internal event, high wind, and seismic initiators, as well as low power and shutdown internal events.
- The approach here is to:
  - perform plant-specific thermal-hydraulic (MELCOR) analysis for Grand Gulf,
  - apply the findings to the GGNS SPAR model, and
  - extend the insights of the analyses to other plants' SPAR models (leveraging expertise at NRC and Idaho National Labs), considering the important differences in design and operation that exist between the plants.
- The project will rely on the best available information in developing the MELCOR thermal-hydraulic model and performing the thermal-hydraulic analysis, including:
  - Licensing information previously submitted to the NRC (e.g., the Updated Final Safety Analysis Report; Order EA-12-049 and Order EA-13-109 Overall Integrated Plan and Updates);
  - Generic BWR technology design and operation information;
  - Information provided by the plant voluntarily for the conduct of this project.

High-level Issues to be Investigated

- Intent is not to comprehensively confirm all success criteria in the chosen plant's SPAR model:
  - Focus on issues of known importance:
    - Issues that were central to past risk analyses
    - Issues that are expected to be central to future risk analyses
    - Changes in plant design and operation
  - Develop a basis for confirming or modifying that issue's treatment in a set of SPAR models.
- Since the focus is on issues important to event and conditions assessment, the issues may or may not be important to the estimated baseline plant risk.
- Two specific topics being considered:
  1. RCIC/LPCI operation at various levels of depressurization
  2. FLEX Support Guidelines (FSGs) applied to loss-of-ac-power and other scenarios

MELCOR Model Development

- MELCOR is a “systems level” thermal-hydraulic and severe accident modeling code developed by Sandia National Labs under NRC sponsorship (melcor.sandia.gov)
- A MELCOR model is similar to the software used for NPP simulator functionality, except that for typical MELCOR models there is much more capability in modeling the response after fuel heat-up and less capability with respect to modeling support systems, normal operation, and the human-machine interface
- Will be modifying an existing model that has been well exercised in other BWR Mark III assessments (ORNL/TM-12771 and NUREG/CR-5529)
- Example plant features to be modeled include:
  - Structures: primary and secondary containment, condensate storage tank
  - Systems: NSSS, RCIC, HPCI, CRDHS, RHR, ADS, RPS, and ESF
  - Components: SRVs, MSIVs, flow restrictors, vessel internals
  - Phenomena: drywell leakage, suppression pool heatup, core cooling
  - Operator actions: manual RPV depressurization, containment venting
- Shakedown, and limited validation, will be performed
  - For example, comparison against generic BWR or plant-specific Order EA-12-049 (mitigating strategies) and Order EA-13-109 (hardened containment venting system) analysis

Plant Selection

- NRC's risk analysts were canvassed for input on issues relative to various NPP design types
- Within the BWR/5 and BWR/6 design classes, the suite of plants were considered with regard to:
  - Thermal power level
  - SPAR internal events station blackout contribution
  - SPAR model scope
  - Design and operational considerations
    - For example, similarity of cross-tying capabilities, number of trains of emergency power
  - Utility activeness in risk-informed activities
- Ultimately, GGNS was chosen as a plant that provided a good balance of the various considerations
- NRC approached GGNS about voluntarily supporting the project, and they have agreed

Questions or feedback at this point?

LPCI operation at various levels of depressurization

- Topic to be explored:
  - The success criteria for when low-pressure injection can preclude core damage is unclear
  - Currently, the SPAR models require depressurization when there is a single stuck open relief valve, but do not require depressurization when there are two stuck open valves – the team would like to confirm these assumptions
- Example modeling assumptions of interest:
  - Number of SRVs that actuate
  - SRV discharge path characteristics that affect flow rates and depressurization
  - Credit for LPCI flow prior to and following depressurization
  - Credit for CRDHS flow prior to and following depressurization
  - Source, and achieved flow, of low-pressure injection
- Preliminary sequences of interest:
  - A transient sequence
  - A loss of coolant accident sequence
- A handful of variations will be run on each sequence.

FLEX Support Guideline Strategies for Loss-of-ac Power and Other Scenarios

- Topic to be explored:
  - New capabilities are being put in to place under Order EA-12-049 and Order EA-13-109, relating to mitigating strategies and hardened containment venting in response to Fukushima lessons-learned
  - Other NRC activities address regulatory licensing and oversight aspects of these new capabilities, and other NRC activities address when and how these capabilities will be considered in risk-informed activities
  - **The current activity is focused solely on scoping success criteria and sequence timing issues that may be informative for future NRC risk modeling**
  - NRC is aware that some licensees are crediting this equipment in some specific risk-informed licensee activities, and welcomes input on success criteria-related challenges that have been identified
  - This was looked at for BWR 3/4 – the NRC would like to expand this knowledge to BWR 5/6

FLEX Support Guideline Strategies for Loss-of-ac Power and Other Scenarios (2)

- Example modeling assumptions of interest:
  - Time of loss-of-ac (e.g., diesel generator failure-to-run) and time of battery depletion
  - Time of RCIC failure and effect of the mode of failure (e.g., flow terminates versus fails with flow as-is)
  - Estimate of suppression pool temperature (including RCIC net positive suction head and bearing temperature effects)
  - Number of relief valves actuating during depressurization and timing of action (also relates to earlier topic)
  - Flow rate achieved by ac-independent injection, and timing of injection
- Preliminary sequences of interest:
  - A loss of offsite power scenario
  - A scenario that does not involve loss of offsite power
- As before, a handful of variations will be run on each sequence.

Going Forward

- Near-term effort will be focused on:
  - Coordinating with GGNS to receive additional plant-specific information
  - Fleshing out the specific calculations to be performed
  - Developing the plant-specific MELCOR model, and performing model shakedown/validation
- We plan to hold another public meeting once analysis is imminent with details on the sequences to be used
- The analysis will be documented in a NUREG