Full-Scope Site Level 3 Probabilistic Risk Assessment Project

Description

It has been more than two decades since the U.S. Nuclear Regulatory Commission (NRC) last sponsored a Level 3 probabilistic risk assessment (PRA) study (NUREG-1150[1]), although Level 3 PRAs have since been performed to some extent by nuclear industries in the United States and internationally. Since 1990, there have been numerous technical advances in PRA and related fields, as well as plant modifications, that are not reflected in the NUREG-1150 PRA models. In SECY-11-0089 (ADAMS Accession No. ML11090A041), the staff proposed various options for proceeding with Level 3 PRA activities. In the Staff Requirements Memorandum related to SECY-11-0089 (ADAMS Accession No. ML112640419), the Commission approved a modified version of Option 3 to conduct a full-scope site Level 3 PRA.

The full-scope site Level 3 PRA project includes the following objectives:

- Develop a Level 3 PRA, generally based on current state-of-practice methods, tools, and data,[2] that (1) reflects technical advances since completion of the NUREG-1150 studies, and (2) addresses scope considerations that were not previously considered (e.g., low power and shutdown,[3] multiunit risk, and spent fuel storage).
- Extract new risk insights to enhance regulatory decision making and help focus limited agency resources on issues most directly related to the agency's mission to protect public health and safety.
- Enhance PRA staff capability and expertise and improve documentation practices to make PRA information more accessible, retrievable, and understandable.
- Obtain insight into the technical feasibility and cost of developing new Level 3 PRAs.

Consistent with the objectives of this project, the Level 3 PRA study is generally being based on current state-of-practice methods, tools, and data. However, there are several gaps in current PRA technology and other challenges that require advancement in the PRA state-of-practice. The general approach to addressing these challenges for the Level 3 PRA study is to primarily rely on existing research and the collective expertise of the NRC's senior technical advisors and contractors, and to perform limited new research only for a few specific technical areas (e.g., multi-unit risk).

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1 NUREG-1150, "Severe Accident Risk: An Assessment for Five U.S. Nuclear Power Plants," December 1990 (ADAMS Accession No. ML040140729).

2 "State-of-practice" methods, tools, and data refer to those that are routinely used by the NRC and licensees or have acceptance in the PRA technical community.

3 While NUREG-1150 only addressed reactor operation at-power, the NRC subsequently sponsored two studies that addressed reactor risk for some low power and shutdown modes of operation (NUREG/CR-6143, "Evaluation of potential severe accidents during low power and shutdown operations at Grand Gulf, Unit 1," July 1995, and NUREG/CR-6144," Evaluation of potential severe accidents during low power and shutdown operations at Surry, Unit 1," October 1995).

Based on a set of site selection criteria and with the support of the Nuclear Energy Institute (NEI),[4] Southern Nuclear Operating Company's Vogtle Electric Generating Plant, Units 1 and 2,[5,6] was selected as the volunteer site for the Level 3 PRA study. The Level 3 PRA project team is leveraging the existing and available information on Vogtle and its licensee PRA, in addition to related research efforts (e.g., SOARCA), to enhance the efficiency in performing the study.

The Level 3 PRA project team is using the following NRC tools and models for performing the Level 3 PRA study:

- Systems Analysis Programs for Hands-on Integrated Reliability Evaluation (SAPHIRE), Version 8
- MELCOR Severe Accident Analysis Code
- MELCOR Accident Consequence Code System, Version 2 (MACCS)

In addition, the Level 3 PRA study is being made consistent with many of the modeling conventions used for the Standardized Plant Analysis Risk (SPAR) models.

SAPHIRE is the NRC's standard software application for performing PRAs. This code was developed and is maintained by the NRC through contracts with Idaho National Laboratory. The latest version in use, SAPHIRE 8, has increased capability for handling large complex modes and can be used to analyze both internal and external hazards and all plant operating states.

MELCOR is a fully integrated, engineering-level computer code whose primary purpose is to model the progression of postulated accidents in both light water reactors and in non-reactor systems such as spent fuel pools and dry storage casks. The MELCOR code is routinely used for performing thermal-hydraulic analysis to determine system success criteria and accident sequence timing and to inform severe accident progression analysis.

MACCS2 is a general-purpose tool used to evaluate the public health effects and economic costs of mitigation actions for severe accidents at diverse reactor and non-reactor facilities. This code was developed and is maintained by the NRC through contracts with Sandia National Laboratory. The principal phenomena considered are atmospheric transport and deposition under time-variant meteorology, short- and long-term mitigation actions and exposure pathways, deterministic and stochastic health effects, and economic costs.

SPAR models are in-house PRA models that NRC staff use to support various risk-informed activities. The SPAR models use a standard set of event trees for each plant design class and standardized input data for initiating event frequencies, equipment performance, and human performance, although these input data may be modified to be more plant-specific, when needed.

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[4] T.J. McGinty, U.S. Nuclear Regulatory Commission, letter to A. Marion, Nuclear Energy Institute, "Request for Assistance in Identifying a Licensee Volunteer for the Full-Scope Site Level 3 Probabilistic Risk Assessment Study," December 6, 2011 (ADAMS Accession No. ML113330813).

[5] A. Marion, Nuclear Energy Institute, "Response to December 6, 2011 Letter Requesting Support in Identifying a Licensee Volunteer for the Full-Scope Site Level 3 Probabilistic Risk Assessment Study," February 14, 2012 (ADAMS Accession No. ML12059A329).

[6] Southern Nuclear Operating Company has received a combined license for two additional nuclear reactors at the Vogtle site. The two new reactors are not within the scope of this study.

Besides the technical capabilities of these NRC tools, they offer the advantages that they are generally available, the staff is familiar with their use, and, if necessary, the staff has the ability to modify these tools. This latter advantage is of particular importance given the potential size of the Level 3 PRA study models, which has already led to the need to modify parts of the SAPHIRE code, and expanded scope items such as multi-unit risk, spent fuel pools, and dry storage casks. Similarly, there is advantage to using the SPAR model conventions to make the Level 3 PRA study more useable by a wider array of agency risk analysts.

Completed Milestones

Project infrastructure

- Established Level 3 PRA Technical Advisory Group (TAG) (March 2012)
- Provided initial Level 3 PRA project plan to Commission (ADAMS Accession No. ML121320310) (March 2012)
- Submit Commssion paper on application of Level 3 PRA results (ADAMS Accession No. ML12202B170) (September 2012)
- Developed draft technical analysis approach plan (TAAP), Rev. 0b (ADAMS Accession No. ML13296A064) (October 2013)

Significant meetings

- Held public meeting on site selection criteria (November 2011)
- Briefed ACRS Reliability and Risk Subcommittee on initial Level 3 PRA project plan (March 2012)
- Brief Commission Technical Advisors on Level 3 PRA project (September 2012)
- Held public meeting on TAAP for reactor PRA (November 2012)
- Briefed ACRS Reliability and Risk Subcommittee on TAAP for reactor PRA (December 2012)
- Briefed ACRS Reliability and Risk Subcommittee on TAAP for spent fuel pool and dry cask storage PRA (May 2013)
- Briefed ACRS Reliability and Risk Subcommittee on (1) TAAP for integrated site risk and human reliability analysis, and (2) development and initial results of Level 1, at-power, internal event model (July 2013)
- Brief Commission Technical Advisors on Level 3 PRA project (October 2013)
- Briefed ACRS Reliability and Risk Subcommittee on Level 3 PRA project status (February 2014)
- Briefed ACRS Full Committee on Level 3 PRA project status (June 2014)
- Brief Commission Technical Advisors on Level 3 PRA project (September 2014)
- Briefed ACRS Reliability and Risk Subcommittee on Level 3 PRA project status (October 2014)

Technical accomplishments

- Completed SCALE analysis for the reactor and spent fuel pool, to support plant-specific MELCOR and MACCS2 calculations (April 2013)
- Completed reactor, at-power, Level 1 PRA for internal events and internal floods (June 2014) and ASME/ANS PRA Standard based peer review (July 2014)

- Completed reactor, at-power, Level 1 PRA for high winds (September 2014)
- Completed screening evaluation of "other" hazards[7] for reactor, at-power (September 2014)
- Completed reactor, at-power, Level 2 PRA for internal events and internal floods (September 2014)

[7] "Other" hazards includes hazards other than internal events, internal floods, internal fires, high winds, and seismic events.