

MULTI-MODULE RISK: NRC DRAFT TECHNICAL GUIDANCE

Introduction

The NRC has been discussing the risk of accidents involving multiple units of an operating nuclear power plant (i.e., multi-unit risk) for many years. And while there has been discussion of the issues regarding licensing small modular nuclear power reactors (SMRs), there has been limited discussion on the risk of accidents involving multiple modules (i.e., multi-module risk) in these types of facilities. In 2011, the staff, in SECY-11-0079, “License Structure for Multi-Module Facilities Related to Small Modular Nuclear Power Reactors,” discussed three options for licensing SMRs and committed to further develop the specific aspects of alternative 3 and submit a specific proposal to the Commission for its consideration and approval. The staff is actively monitoring SMR developments and waiting for SMR applicants to identify their preferred plans for licensing before moving forward with any action. By contrast, there has not been a comparable discussion on the technical approach to addressing risks associated with coupling between modules not found in large light water reactor plants.

Multi-module risk, and the analysis of that risk, is an issue for a nuclear power station¹ consisting of more than one nuclear power module. A nuclear power module is a nuclear power reactor and its associated safety and control features. A multi-module nuclear power station, or nuclear power plant, is one that is composed of multiple nuclear power modules wherein: a) each module can be safely operated independent of other modules, and b) all modules are located within a common building structure such that a module can be physically impacted by events occurring at another module due to proximity and lack of a physical barrier providing separation.² It is also important to note that for the purposes of this white paper, the only radiological source that was considered were reactor cores, not onsite spent fuel storage or other potential radiological sources.

The staff has developed draft technical criteria for evaluating multi-module risk, which are described in this paper. In the background section, this paper describes the history of considerations of multi-unit risk at the NRC, which provides a foundation for consideration of multi-module risk.

Background

Before considering the technical criteria for evaluating multi-module risk, it is important to understand the issue of multi-unit risk because it provides a foundation for looking at multi-module risk. While multi-unit risk and multi-module risk are similar, they have several distinctions. Multi-unit nuclear power plants, for example, have separate licensed crews for each unit and are designed such that one unit does not cause initiating events on the other unit.

¹ It should be noted that in this paper, nuclear power station is used, as opposed to site. In 10 CFR, “station” is used to describe multiple units at one location, while “site” is used to describe the “actual physical, environmental, and demographic features” of a location.

² For reference: 10 CFR 50 Appendix A: Nuclear power unit. A nuclear power unit means a nuclear power reactor and associated equipment necessary for electric power generation and includes those structures, systems, and components required to provide reasonable assurance the facility can be operated without undue risk to the health and safety of the public.

10 CFR 52.1 Modular design means a nuclear power station that consists of two or more essentially identical nuclear reactors (modules) and each module is a separate nuclear reactor capable of being operated independent of the state of completion or operating condition of any other module co-located on the same site, even though the nuclear power station may have some shared or common systems.

Designers of multi-module SMR plants are considering having a single operator monitoring many modules, and, due to sharing of systems or structures, an accident condition in a single module could potentially cause an initiating event on adjacent modules.

Consideration of Multi-Unit Design in the Commission's Regulations

10 CFR 50, Appendix A, General Design Criteria (GDC) 5, "Sharing of Structures, Systems, and Components," states that structures, systems, and components (SSCs) important to safety shall not be shared among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, the shutdown and cooldown of the remaining units.

In Subpart A to 10 CFR Part 100, "Reactor Site Criteria", which applied to siting of nuclear power plants prior to January 10, 1997, 10 CFR 100.11(b) gave additional considerations related to multi-unit nuclear power plants as follows:

(b) For sites for multiple reactor facilities consideration should be given to the following:

(1) If the reactors are independent to the extent that an accident in one reactor would not initiate an accident in another, the size of the exclusion area, low population zone and population center distance shall be fulfilled with respect to each reactor individually. The envelopes of the plan overlay of the areas so calculated shall then be taken as their respective boundaries.

(2) If the reactors are interconnected to the extent that an accident in one reactor could affect the safety of operation of any other, the size of the exclusion area, low population zone and population center distance shall be based upon the assumption that all interconnected reactors emit their postulated fission product releases simultaneously. This requirement may be reduced in relation to the degree of coupling between reactors, the probability of concomitant accidents, and the probability that an individual would not be exposed to the radiation effects from simultaneous releases. The applicant would be expected to justify to the satisfaction of the Commission the basis for such a reduction in the source term.

(3) The applicant is expected to show that the simultaneous operation of multiple reactors at a site will not result in total radioactive effluent releases beyond the allowable limits of applicable regulations.

Such requirements regarding multi-unit accident considerations are not included in 10 CFR Part 100, Subpart B, which is applicable to siting of nuclear power plants after January 10, 1997, nor are they included in the safety assessment technical information requirements for applications under 10 CFR 50 or 10 CFR Part 52.

With respect to annual limits on doses to the public from radioactive effluent releases, 10 CFR 20.1301(e) requires that NRC-licensed facilities comply with the United States Environmental Protection Agency (EPA) generally applicable environmental radiation standards of 40 CFR Part 190 for facilities that are part of the fuel cycle. 10 CFR 20.1301(e) requires that all potential

sources of external radiation and radioactivity be considered, including liquid and gaseous effluents and external radiation exposures from buildings, storage tanks, radioactive waste storage areas, and N-16 skyshine from BWR turbine buildings. The EPA standards apply to the entire nuclear power station, whether with single or multiple units.

Consideration of Operating Experience at Multi-Unit Power Plants

In response to the accident at Three Mile Island, the NRC staff issued an action plan (NUREG-0660). Item II.B.8 of that plan involved a two-phase rulemaking proceeding on degraded-core accidents. In the second phase (termed “long-term rulemaking”), the staff identified the need to consider the effects of an accident in a reactor plant on an adjacent plant in a multiple reactor site. This issue was subsequently removed from the plan at the Commission’s direction, as discussed in the Staff Requirements Memorandum (SRM) to SECY-82-1B.

After the Chernobyl accident, the 1989 NRC lessons learned report included four recommendations that address multi-unit accidents. Many of these recommendations came about because noble gases and airborne volatiles were found to have been transported from the damaged unit to the other three units onsite through a shared ventilation system during the accident. In light of this, the staff recommended that control room habitability, contamination outside of the control room, smoke control, and shared shutdown systems be looked at more fully in the U.S. through the NRCs generic safety issues (GSI) program (see NUREG-0933, “Resolution of Generic Safety Issues” - Formerly entitled “A Prioritization of Generic Safety Issues,” Chernobyl Issue CH2.3,” Multiple-Unit Protection”). The control room habitability issue was moved into GSI 83. The other concerns were closed in 2011 via SECY-11-0101, as they were considered licensing issues.

Commission Policy Related to Multi-Unit Risk

The Commission’s Safety Goals, which define acceptable risk, are applied on a per-reactor basis. The staff in NUREG-0880 (ADAMS Accession No. ML071770230) summarized comments made by the public as the Safety Goals were being formulated in the early 1980s. NUREG-0880 states:

“Some commenters objected to the originally proposed individual and societal numerical guidelines because they were to be applied on a per-site basis. This would have resulted in tighter requirements being imposed on plants at multi-unit sites than at single-unit sites. The Commission decided not to impose a regulatory bias against multi-unit sites. Therefore, the quantitative design objectives were changed from risks per site to risk per plant.”

In SECY-02-0139, “Plan for Resolving Policy Issues Related to Licensing Non-Light Water Reactor Designs,” and SECY-03-0047, “Policy Issues Related to Licensing Non-Light-Water Reactor Designs,” the staff recommended that in order to license non-light water reactor designs, rulemaking should be considered. The staff further recommended that this rulemaking should consider the integrated risk from multiple units. Then, in SECY-05-0130, “Policy Issues Related to New Plant Licensing and Status of the Technology-Neutral Framework for New Plant

Licensing,” the staff recommended to the Commission that they endorse an integrated risk analysis. The staff presented the Commission with three options to deal with this integrated risk: (1) take no action and continue evaluating risk from each reactor separately, (2) quantify the integrated risk at the station for new reactors that were being built without including the risk of currently operating reactors on the site, or (3) quantify the risk for all reactors at a station. The SECY also recommended that any modular reactor designs should account for the integrated risk posed at multi-unit facilities. The staff recommended that the Commission choose Option 2, which would require nuclear power plants to quantify the risk of all *new* units on a reactor site. In the SRM to SECY-05-0130, the Commission rejected Option 2 and directed the staff to issue an Advanced Notice of Proposed Rulemaking (ANPR) to inform the public and request comments for staff consideration of the spectrum of issues relating to risk informing the reactor requirements.

In 2006, the NRC staff issued SECY-06-0007, “Staff Plan to Make a Risk-Informed and Performance-Based Revision to 10 CFR Part 50,” which included a draft of the ANPR directed by the SRM for SECY-05-0130, and noted that it would be discussing the issue of integrated risk with external stakeholders. In the SRM on SECY-06-0007, the Commission approved the staff’s recommendation to issue the ANPR. Following the ANPR and other agency activities, the staff issued NUREG-1860, “Feasibility Study for a Risk-Informed and Performance-Based Regulatory Structure for Future Plant Licensing,” which presented an approach to integrated risk that did not provide prescriptive guidelines, but instead only necessitated that the risk from new reactors be “limited.” Additionally, NUREG-1860 stated that the integrated risk from new reactors should not exceed the quantitative health objectives (QHOs) given in the Commission’s 1986 Safety Goal Policy Statement.

After NUREG-1860 was issued there was little activity on the subject of multi-unit risk. Then in 2011, the staff provided an information paper (SECY-11-0079, “License Structure for Multi-Module Facilities Related to Small Modular Nuclear Power Reactors”) that discussed three options for licensing SMRs: (1) single license for the facility, (2) master facility license, and (3) individual reactor module licenses. This SECY addressed the process for licensing multi-module plants, including legal considerations. It did not deal with the technical challenges associated with multi-module plants, including the challenge of looking at multi-module risk. Additionally, the SECY committed to further develop the specific aspects of alternative 3 and submit a specific proposal to the Commission for its consideration and approval. Despite the fact that a decision has not been made for licensing SMRs, the staff has concluded that technical acceptance criteria for risk from multiple modules needs to be considered, no matter how SMRs will be licensed.

Current Activity Related to Multi-Unit and Multi-Module Risk

The NRC Office of Nuclear Regulatory Research (RES) is in the intermediate stages of an effort to create an integrated Level 3 PRA that includes the effects of multiple units, as well as the risk from all radiation sources onsite, such as the spent fuel pool. SMR applicants are considering multi-module risk as part of their submittal, and the NRC staff has created an Issue Identification and Ranking Project to identify other multi-module issues.

Discussion

Draft Revision 3 to NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Chapter 19.0, "Severe Accidents", states that for applicants seeking approval of an application for a plant containing multiple modules, the staff will review an applicant's assessment of risk from accidents that could affect multiple modules. However, technical acceptance criteria for such a review have not yet been established. As such, an NRC staff working group was formed and has prepared this white paper, which describes proposed regulatory guidance on acceptance criteria for multi-module risk and summarizes the rationale of the working group.

The Commission's goals for core damage frequency (CDF) and large release fraction (LRF) applied in new reactor licensing, and the guidance for using a focused PRA for the regulatory treatment of non-safety systems (RTNSS) do not address multi-module risk. Consequently, the working group evaluated what, if any, metric should be used for evaluating risk of multi-module plants. For example, for a plant that could have five modules, it was not clear if the risk should be assessed in terms of CDF and LRF for each module or for the plant. The purpose of this staff effort was not to decide how multi-module risk should be calculated by the applicant, but rather to develop proposed technical criteria for evaluating the applicant's multi-module risk assessment. However, after considering the pros and cons of characterizing criteria in terms of risk metrics, the staff rejected this approach and chose a more qualitative approach that complements the Commission's objectives for use of PRA and severe accident evaluation in the design, certification, and licensing of new and advanced reactors. The staff wanted to stay within the current regulatory framework, while providing additional guidance to SMR applicants prior to submittal of their application for design certification. The staff understands that because of the expectation of low risk profiles for the proposed SMRs, numerical criteria would be difficult to develop and substantiate. The staff believes the proposed criteria described below ensure that relevant risk insights related to multi-module design and operation are captured and well understood by the staff, applicants, and the public.

The working group did not explicitly address external hazards, as it is anticipated that RES's Level 3 PRA project will provide insights on these unique hazards. Additionally, the working group is keeping apprised of the activities that are ongoing with the International Atomic Energy Agency (IAEA), including the Technical Approach to Multi-Unit Probabilistic Safety Assessment Safety Report, which should be completed in 2014.

Proposed Criteria

The multi-module risk working group developed the following proposed criteria with the expectation that they will be incorporated into the Standard Review Plan, Section 19.0:

[For small, modular integral pressurized water reactor designs, the staff reviews the results and description of the applicant's risk assessment for a single reactor module; and, if the applicant is seeking approval of an application for a plant containing multiple modules, the staff reviews the applicant's assessment of risk from accidents that could

affect multiple modules]³ to ensure appropriate treatment of important insights related to multi-module design and operation.

The staff will verify that the applicant has:

- i. Used a systematic process to identify accident sequences, including significant human errors, that could lead to multiple module core damages or large releases and described them in the application
- ii. Selected alternative features, operational strategies, and design options to prevent these sequences from occurring and demonstrated that these accident sequences are not significant contributors to risk. Operational strategies should also provide reasonable assurance that there is sufficient ability to mitigate multiple core damages accidents.

Conclusion

By building on the agency's past and current work in the multi-unit arena, the NRC staff developed technical criteria for evaluating multi-module risk. These technical criteria would ensure that multi-module plants are designed and operated in such a way to prevent multiple core damages, to demonstrate that the accident sequences are not significant contributors to risk and large release events, and, if these events should occur, to mitigate their impact on the public health and safety. Additionally, these criteria ensure that relevant risk insights related to multi-module design and operation are captured and well understood by the staff, applicants, and the public

³ The bracketed text is currently in draft Revision 3 of SRP 19.0. The additional text would be a supplement to the current wording.