U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR NuScale SMR DESIGN

10.2 TURBINE GENERATOR

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of power conversion systems.

Secondary - Organization responsible for the review of turbine-generator controls and overspeed protection systems, and

Organization responsible for the review of the turbine-generator arrangement and missile generation due to overspeed.

I. AREAS OF REVIEW

The turbine generator system (TG) converts the thermal energy from the nuclear steam supply system into electrical energy. The TG consists essentially of (1) the turbine unit and the automatic devices, alarms, and trips that control and regulate turbine action; and (2) the generator unit and its controls. The turbine control system, the steam inlet stop and control valves, the reheat steam and intercept valves, the low-pressure turbine steam inlet control valves, and the extraction steam control valves control the speed of the turbine under normal and abnormal conditions and are thus related to the overall safe operation of the plant.

The TG installed in a nuclear plant is typically equipped with redundant and diverse overspeed protection systems. The main steam stop and control, together with the reheat steam stop and intercept valving arrangements, provide redundancy in the valves essential for overspeed protection. The intent of the review under this Design Specific Review Standard (DSRS) section is to ensure conformance with General Design Criterion (GDC) 4 by verifying that such redundancy in overspeed protection, in conjunction with inservice inspection and testing of the essential valves, makes it very unlikely that a turbine overspeed condition will exceed the design overspeed.

The specific areas of review are as follows:

1. The TG and the components and subsystems are reviewed with respect to the following:

   A. The general arrangement of the turbine and associated equipment with respect to important to safety structures, systems, and components (SSCs) that could be vulnerable to turbine missile impact.

   B. The types and locations of the main steam stop and control valves, reheat stop and intercept valves, extraction non-return valves and associated piping arrangements.

   C. The capability of the turbine generator control and overspeed protection systems to detect a turbine overspeed condition and to actuate appropriate system valves or other protective devices to preclude an overspeed condition that exceeds the design overspeed.

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D. The overspeed protection instrumentation and controls with respect to redundancy, diversity, independence, testability, and reliability.

E. The pneumatic and hydraulic subsystems associated with TG (such as piping, valves, instrumentation and controls), as they relate to redundancy, testability, and reliability to preclude common cause failures.

2. The initial pre-operational plant testing and inspection program and the inservice inspection and operability assurance program covering valves essential for overspeed protection.

3. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC). For design certification (DC) and combined license (COL) reviews, the staff reviews the applicant's proposed ITAAC associated with the SSCs related to this DSRS section in accordance with Standard Review Plan (SRP) Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria." The staff recognizes that the review of ITAAC cannot be completed until after the rest of this portion of the application has been reviewed against acceptance criteria contained in this DSRS section. Furthermore, the staff reviews the ITAAC to ensure that all SSCs in this area of review are identified and addressed as appropriate in accordance with DSRS Section 14.2 and 14.3.7

4. COL Action Items and Certification Requirements and Restrictions. For a DC application, the review will also address COL action items and requirements and restrictions (e.g., interface requirements and site parameters).

   For a COL application referencing a DC, a COL applicant must address COL action items (referred to as COL license information in DCs) included in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

Review Interfaces

Other DSRS sections interface with this section as follows:

1. Acceptability of the seismic and quality group classifications for system components is reviewed under SRP Sections 3.2.1 and 3.2.2.

2. Review of the assessment of the risk to essential plant systems and structures and consideration of turbine orientation as related to turbine missiles is performed under DSRS Section 3.5.1.3. Also, a review of the DSRS Section 3.5.1.3, as it relates to initial plant testing and inspection, inservice inspection, and ITAAC is performed.

3. Review of high- and moderate-energy pipe breaks is performed under DSRS Section 3.6.1. If safety-related systems or portions of systems are located close to the TG, the physical layout of the system is reviewed to ensure that protection has been provided from the effects of high- and moderate-energy TG piping failures or a failure of the connections from the low-pressure turbine section of the main condenser. Section 3.6 of the applications will note the means of providing such protection, and the corresponding DSRS sections will cite procedures for reviewing this information.

4. Review of the components, piping, and structures, which are designed in accordance with applicable codes and standards, is performed under SRP Sections 3.9.1, 3.9.2 and 3.9.3.

5. Review of the adequacy of the inservice testing program of the system valves is performed under SRP Section 3.9.6.

6. Review of portions of the TG with respect to the adequacy of design, installation, inspection, and testing of essential components necessary for instrumentation and control functions is performed under the DSRS and SRP Sections in Chapter 7.

7. Review of "Inservice Inspection" and "periodic testing" of the turbine steam admission valves, and also the DC or COL applicant's proposed ITAAC, as they relate to the turbine orientation and turbine missile generation probability, is performed under SRP Section 10.2.3, "Turbine Rotor Integrity."

8. Review of the compatibility of the materials of construction with service conditions is performed under DSRS Section 10.3.6.

9. Acceptability of the initial plant (pre-operational) testing and startup tests is performed under DSRS Section 14.2 and 14.3.7.

10. Review of technical specifications is performed under DSRS Chapter 16.

11. Review of quality assurance is performed under SRP Chapter 17.

12. The identification of risk-significant SSCs is reviewed under SRP Chapter 19.

II. ACCEPTANCE CRITERIA

Requirements

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. Title 10 of the *Code of Federal Regulations* (CFR), Part 50, Appendix A, GDC 4, "Environmental and dynamic effects design bases."

2. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a facility that incorporates the DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act (AEA), and the U.S. Nuclear Regulatory Commission's (NRC's) regulations.

3. 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the COL, the provisions of the AEA, and the NRC's regulations.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are set forth below. The DSRS is not a substitute for the NRC's regulations, and compliance with it is not required. As an alternative, and as described in more detail below, an applicant may identify the differences between a DSRS section and the design features (DC and COL applications only), analytical techniques, and procedural measures proposed in an application and discuss how the proposed alternative provides an acceptable method of complying with the NRC regulations that underlie the DSRS acceptance criteria.

1. Compliance with GDC 4, as it relates to the review performed under this DSRS section, involves protecting SSCs important to safety from the effects of turbine missiles by providing a turbine overspeed protection system (with suitable redundancy and diversity) to minimize the probability of generation of turbine missiles. Specific criteria necessary to meet the requirements of GDC 4 are as follows:

   A. A turbine control and overspeed protection system should control turbine action under all normal or abnormal operating conditions and should ensure that a full-load turbine trip will not cause the turbine to overspeed beyond acceptable limits. Under these conditions, the control and protection system should permit an orderly reactor shutdown by use of either the turbine bypass system and main steam relief system or other engineered safety systems. The overspeed protection system should meet the single failure criterion and should be testable when the turbine is in operation.

   B. The turbine main steam stop and control valves, the reheat steam stop and intercept valves, and steam extraction non-return valves should protect the turbine from exceeding set speeds and should protect the reactor system from abnormal surges. Reheat steam stop and intercept valves, and steam extraction non-return valves should be capable of closure concurrent with the main steam stop valves, or of sequential closure within an appropriate time limit, to ensure that turbine overspeed is controlled within acceptable limits. The valve arrangements and valve closure times should be structured so that a failure of any single valve to close will not result in excessive turbine overspeed in the event of a TG trip signal.

   C. The TG should have the capability to permit periodic testing of turbine steam admission valves, including the extraction non-return valves, overspeed control, and air/hydraulic components while the unit is operating at rated load.

2. An inservice inspection program for main steam valves should be established and should include the following provisions:

   A. At intervals of approximately 3 1/3 years, during refueling or maintenance shutdowns coinciding with the inservice inspection schedule required by Section XI of the American Society of Mechanical Engineers Code for reactor components, at least one main steam stop valve, one main steam control valve, one reheat stop valve, one reheat intercept valve, and extraction non-return valves in the high energy extraction steam lines to the deaerator and feedwater heaters should be dismantled, and visual and surface examinations should be conducted of valve seats, disks, and stems. If this process detects unacceptable flaws or excessive corrosion in a valve, all other valves of that type should be

dismantled and inspected. Valve bushings should be inspected and cleaned and bore diameters should be checked for proper clearance.

B. Main steam stop and control valves, and all other steam admission valves, including extraction non-return valves, should be exercised at a frequency recommended by the turbine vendor or valve manufacturer.

3. The arrangement of connection joints between the low-pressure turbine exhaust and the main condenser should prevent adverse effects on any important to safety equipment in the turbine room in the event of a rupture.

Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this DSRS section is discussed in the following paragraphs:

1. Compliance with GDC 4 requires, in part, that SSCs important to safety are appropriately protected against dynamic effects, including missiles.

   GDC 4 applies to this DSRS section because missiles resulting from a failure of the TG can potentially cause a loss of function of any important to safety SSCs, thus compromising the safety of the nuclear power plant. Specifically, turbine overspeed is a potential initiating event that could cause turbine blades to fail and become a source of missiles. Implementation of a turbine overspeed protection system serves to control turbine action under all operating conditions, thereby ensuring that a full-load turbine trip will not cause the turbine to overspeed beyond acceptable limits.

III. REVIEW PROCEDURES

These review procedures are based on the identified DSRS acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II.

The review for COL and DC applications will determine whether the content and intent of the applicant's technical specifications agree with the requirements for system testing, minimum performance, and surveillance developed as a result of the staff's review.

The specified review procedures are for a typical TG. Any variance in the review to account for a proposed unique design will ensure that the system meets the criteria of Subsection II. The reviewer evaluates the TG, subsystems, and components of the unit that are considered essential for the safe integrated operation of the reactor facility.

1. Selected Programs and Guidance - In accordance with the guidance in NUREG-0800, "Introduction - Part 2: Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: Integral Pressurized Water Reactor Edition" (NUREG-0800 Intro Part 2) as applied to this DSRS Section, the staff will review the information proposed by the applicant to evaluate whether it meets the acceptance criteria described in Subsection II of this DSRS. As noted in NUREG-0800 Intro Part 2, the NRC requirements that must be met by an SSC do not change under the SMR framework. Using the graded approach described in NUREG-0800 Intro Part 2, the NRC staff may determine that, for certain structures, systems, and components (SSCs), the applicant's basis for compliance with other selected NRC requirements may help demonstrate

satisfaction of the applicable acceptance criteria for that SSC in lieu of detailed independent analyses. The design-basis capabilities of specific SSCs would be verified where applicable as part of completion of the applicable ITAAC. The use of the selected programs to augment or replace traditional review procedures is described in Figure 1 of NUREG-0800, Introduction - Part 2. Examples of such programs that may be relevant to the graded approach for these SSCs include:

- 10 CFR Part 50, Appendix A, General Design Criteria (GDC), Overall Requirements, Criteria 1 through 5
- 10 CFR Part 50, Appendix B, Quality Assurance (QA) Program
- 10 CFR 50.49, Environmental Qualification of Electrical Equipment (EQ) Program
- 10 CFR 50.55a, Code Design, Inservice Inspection and Inservice Testing (ISI/IST) Programs
- 10 CFR 50.65, Maintenance Rule requirements
- Reliability Assurance Program (RAP)
- 10 CFR 50.36, Technical Specifications
- Availability Controls for SSCs Subject to Regulatory Treatment of Non-Safety Systems (RTNSS)
- Initial Test Program (ITP)
- Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)

This list of examples is not intended to be all-inclusive. It is the responsibility of the technical reviewers to determine whether the information in the application, including the degree to which the applicant seeks to rely on such selected programs and guidance, demonstrates that all acceptance criteria have been met to support the safety finding for a particular SSC.

2. In accordance with 10 CFR 52.47(a)(8),(21), and (22), and 10 CFR 52.79(a)(17), (20) and (37), for design certification or combined license applications submitted under Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues and medium- and high-priority generic safety issues which are identified in the version of NUREG-0933 current on the date up to 6 months before the docket date of the application and which are technically relevant to the design; (2) demonstrate how the operating experience insights have been incorporated into the plant design; and, (3) provide information necessary to demonstrate compliance with any technically relevant portions of the Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v) for a DC application, and except paragraphs (f)(1)(xii), (f)(2)(ix), (f)(2)(xxv), and (f)(3)(v) for a COL application. These cross-cutting review areas should be addressed by the reviewer for each technical subsection and relevant conclusions documented in the corresponding safety evaluation report (SER) section.

3. The reviewer confirms that the system description and schematics provided in the safety analysis report show the TG. The general arrangement of the TG and associated equipment with respect to any important to safety SSCs is noted.

4. The reviewer verifies the adequacy of the control and overspeed protection system and determines the following:

   A. Support systems, subsystems, control systems, and alarms and trips will function for all abnormal conditions, including a single failure of any component or

subsystem, and will preclude an unsafe turbine overspeed. The design of the in-depth defense provided by the turbine generator protection system to preclude excessive overspeeds should include diverse protection means.

B. For normal speed-load control, the speed governor action of the electrohydraulic control system fully cuts off steam at approximately 103 percent of rated turbine speed by closing the control and intercept valves.

C. A mechanical overspeed trip device will actuate the control, stop, and intercept valves at approximately 111 percent of rated speed. If an alternative to the mechanical overspeed trip device is proposed, the design must include high quality and reliable components and demonstrate adequate diversity to preclude common cause failures of redundant overspeed protection systems.

D. An independent and redundant backup electrical overspeed trip circuit senses the turbine speed by magnetic pickup and closes all valves associated with speed control at approximately 112 percent of rated speed. This backup electrical overspeed trip system may use the same sensing techniques as the electrohydraulic control system. However, the circuitry is reviewed to confirm that the control signals from the two systems are isolated from, and independent of, each other.

E. The pneumatic and hydraulic subsystems associated with TG, such as piping and valves and other components, are reviewed to preclude Common Cause Failiures (CCFs).

5. The main steam stop, control, reheat stop, and intercept valving arrangements and the valve closure times are reviewed to ensure that no single valve failure can disable or otherwise compromise the overspeed control function.

6. The capability to test essential components during TG operation is reviewed. These essential components include, but are not limited to: the turbine and reheat steam inlet and control valves, the extraction steam non-return valves and the solenoid valves in the associated pneumatic/hydraulic subsystems for reliable operation of the TG.

7. The proposed inservice inspection program for essential speed control valves is reviewed to verify that it includes the provisions of Subsection I of this DSRS section.

For review of a DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements and site parameters), set forth in the final safety analysis report (FSAR) meets the acceptance criteria. DCs have referred to the FSAR as the DCD. The reviewer should also consider the appropriateness of identified COL action items. The reviewer may identify additional COL action items; however, to ensure these COL action items are addressed during a COL application, they should be added to the DC FSAR.

For review of a COL application, the scope of the review is dependent on whether the COL applicant references a DC, an ESP or other NRC approvals (e.g., site suitability report or topical report).
For both DC and COL applications, SRP Section 14.3 should be followed for the review of ITAAC. The review of ITAAC cannot be completed until after the completion of this section.

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the staff's technical review and analysis support conclusions of the following type to be included in the staff's SER. The reviewer also states the bases for those conclusions.

1. The TG includes all components and equipment normally provided, such as turbine main steam stop and control valves, reheat steam stop and intercept valves, and the extraction non-return valves. The scope of review of the TG for the plant includes layout drawings, schematics, and/or piping and instrumentation drawings (P&IDs), and descriptive information for the system and for control and supporting systems that are essential to its operation.

2. The basis for acceptance of the TG was conformance of the design to 10 CFR Part 50, Appendix A, GDC 4. The staff concludes that the plant design is acceptable and meets the requirements of GDC 4 with respect to the protection of important to safety SSCs from the effects of turbine missiles. The applicant has met this requirement by providing a turbine overspeed protection system to control the turbine action under all operating conditions, which ensures that a full-load turbine trip will not cause the turbine to overspeed beyond acceptable limits and will not result in turbine missiles.

3. The staff concludes that the TG design conforms to GDC 4, staff positions, and industry standards and that it can perform its designed safety functions.

For DC and COL reviews, the findings will also summarize the staff's evaluation regarding DC requirements and restrictions (e.g., interface requirements and site parameters) and COL action items relevant to this DSRS section.

In addition, to the extent that the review is not discussed in other SER sections, the findings will summarize the staff's evaluation of the ITAAC, as applicable.

V. IMPLEMENTATION

The regulations in 10 CFR 52.17(a)(1)(xii), 10 CFR 52.47(a)(9), and 10 CFR 52.79(a)(41) establish requirements for applications for ESPs, DCs, and COLs, respectively. These regulations require the application to include an evaluation of the site (ESP), standard plant design (DC), or facility (COL) against the Standard Review Plan (SRP) revision in effect six months before the docket date of the application. While the SRP provides generic guidance, the staff developed the SRP guidance based on the staff's experience in reviewing applications for construction permits and operating licenses for large light-water nuclear power reactors. The proposed small modular reactor (SMR) designs, however, differ significantly from large light-water nuclear reactor power plant designs.

In view of the differences between the designs of SMRs and the designs of large light-water power reactors, the Commission issued SRM- COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010 (ML102510405) (SRM). In the SRM, the Commission directed the staff to develop risk-informed licensing review plans for each of the SMR design reviews, including plans for the associated pre-application activities. Accordingly, the staff has developed the content of the DSRS as an alternative method for the evaluation of a NuScale-specific application submitted pursuant to 10 CFR Part 52, and the staff has determined that each application may address the DSRS in lieu of addressing the SRP, with specified exceptions. These exceptions include

particular review areas in which the DSRS directs reviewers to consult the SRP and others in which the SRP is used for the review. If an applicant chooses to address the DSRS, the application should identify and describe all differences between the design features (DC and COL applications only), analytical techniques, and procedural measures proposed in an application and the guidance of the applicable DSRS section (or SRP section as specified in the DSRS), and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria.

The staff has accepted the content of the DSRS as an alternative method for evaluating whether an application complies with NRC regulations for NuScale SMR applications, provided that the application does not deviate significantly from the design and siting assumptions made by the NRC staff while preparing the DSRS. If the design or siting assumptions in a NuScale application deviate significantly from the design and siting assumptions the staff used in preparing the DSRS, the staff will use the more general guidance in the SRP as specified in 10 CFR 52.17(a)(1)(xii), 10 CFR 52.47(a)(9), or 10 CFR 52.79(a)(41), depending on the type of application. Alternatively, the staff may supplement the DSRS section by adding appropriate criteria in order to address new design or siting assumptions.

VI. REFERENCES

1. 10 CFR Part 20, “Standards for Protection Against Radiation.”

2. 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities.”

3. 10 CFR Part 52, “Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants.”

4. GDC 61, “Fuel Storage and Handling and Radioactivity Control.”

5. GDC 19, “Control Room.”

6. GDC 4, “Environmental and Dynamic Effects Design Bases.”

7. RG 1.7, “Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident.”

8. RG 1.112, “Calculations of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors.”

9. RG 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors.”

10. ANSI/ANS Standard 18.1-1999, “Source Term Specification,” American National Standards Institute/American Nuclear Society.”

11. NUREG-0737, “Clarification of TMI Action Plan Requirements.”

12. 40 CFR Part 190, “Environmental Radiation Protection Standards For Nuclear Power Operations.”

13. RG 1.89, “Environmental Qualification of Certain Electric Equipment Important to Safety

for Nuclear Power Plants."

14. RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants."

15. RG 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants."

16. RG 1.29, "Seismic Design Classification."

17. RG 1.117, "Tornado Design Classification."

18. RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

19. EPRI, "Pressurized Water Reactor Primary Water Chemistry Guidelines."

20. EPRI, "Pressurized Water Reactor Primary Water Zinc Application Guidelines."

21. EPRI, "Advanced Light Water Reactor Utility Requirements Document, Volume III, ALWR Passive Plant."

22. NUREG-1242, "NRC Review of Electric Power Research Institute's Advanced Light Water Reactor Utility Requirements Document, Passive Plant Designs" Volume 3, Part 1 and Volume 3, Part 2 (ADAMS Accession Nos. ML070600372 and ML070600373).

23. EPRI, "Cobalt Reduction Guidelines."

24. RG 8.8, "Information Relevant to Assuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as is Reasonably Achievable."