DRAFT for Comment

U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR mPOWER™ iPWR

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 (TGS) converts the energy in steam from the nuclear steam supply system into electrical energy. The TGS 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, steam inlet stop and control valves, reheat steam and intercept valves, and low-pressure turbine steam inlet control valves, and 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 TGS installed in a nuclear plant is typically equipped with redundant and diverse overspeed protection systems. The main steam stop and control and reheat steam stop and intercept valving arrangements typically provide redundancy in the valves essential for overspeed protection. The intent of the review under this DSRS section is to verify that such redundancy in overspeed protection, in conjunction with inservice inspection and testing of the essential valves, makes a turbine overspeed condition that exceeds the design overspeed very unlikely and to ensure conformance with General Design Criterion (GDC) 4.

The specific areas of review are as follows:

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

   A. The general arrangement of the turbine and associated equipment with respect to safety-related and risk-significant SSCs that could be vulnerable to turbine missile impact.

   B. The types and locations of 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.

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

E. The pneumatic and hydraulic subsystems associated with TGS, such as; piping and valves, instrumentation and controls, as it relates to redundancy, testability, and reliability to preclude common cause failures.

2. A review is conducted of the initial plant/pre-operational testing and inspection, inservice inspection and operability assurance program for valves essential for overspeed protection.

3. Inspections, Tests, Analyses, and Acceptance Criteria. For design certification (DC) and combined license (COL) reviews, the staff reviews the applicant's proposed Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) associated with the structures, systems, and components (SSCs) related to this DSRS section in accordance with DSRS 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 SRP Section 14.3.

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.

   COL applications for a new light-water reactors (LWRs) are based on Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

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 DSRS 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 Section 3.5.1.3, as it relates to initial plant testing, inspection, inservice inspection, and ITAACs 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 TGS, the physical layout of the system is reviewed to ensure that protection has been provided from the effects of high- and moderate-energy TGS piping failures or a failure of the connections from the low-pressure turbine section of the main condenser. Section 3.6 of the COL 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 DSRS Sections 3.9.1 through 3.9.3.

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

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

7. Acceptability of the fire protection system is reviewed under SRP Section 9.5.1.

8. Review of “Inservice Inspection” and “periodic testing” of the turbine steam admission valves, and also the DC or COL applicant’s proposed ITAACs as they relate to the turbine orientation and turbine missile generation probability is performed under DSRS Section 10.2.3, “Turbine Rotor Integrity.

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

10. A determination is made of the acceptability of the initial plant (pre-operational) testing and startup tests under review for DSRS Chapter 14.

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

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

13. 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. General Design Criterion (GDC) 4 as it relates to the TGS for the protection of 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.

2. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed inspections, tests, analyses, and acceptance criteria (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 design certification has been constructed and will be operated in conformity with the design certification, the provisions of the Atomic Energy Act, and the 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 combined license, the provisions of the Atomic Energy Act, 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 as follows for review described in this DSRS section. The DSRS is not a substitute for the NRC's regulations, and compliance with it is not required. Identifying the differences between this DSRS section and the design features, analytical techniques, and procedural measures proposed for the facility, and discussing how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria, is sufficient to meet the intent of 10 CFR 52.47(a)(9), "Contents of applications; technical information."

1. 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 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 TGS trip signal.

C. The TGS 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 (ASME) 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 safety-related 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 TGS can potentially cause a loss of function of safety-related structures or components, 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.

   Meeting this requirement provides assurance that missiles resulting from a TGS failure will not result in a loss of function of safety-related portions of the nuclear power plant.

III. REVIEW PROCEDURES

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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 procedures for COL, DC, or ESP applications determine that 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 TGS. 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 TGS, subsystems, and components of the unit that are considered essential for the safe integrated operation of the reactor facility by evaluation where necessary or the application of programmatic requirements that address the following:

1. Programmatic Requirements - In accordance with the guidance in NUREG – 0800 *"Introduction," Part 2* as applied to this DSRS Section, the staff will review the programs proposed by the applicant to satisfy the following programmatic requirements. If any of the proposed programs satisfies the acceptance criteria described in Subsection II, it can be used to augment or replace some of the review procedures. It should be noted that the wording of "to augment or replace" applies to nonsafety-related risk-significant SSCs, but "to replace" applies to nonsafety-related nonrisk-significant SSCs according to the "graded approach" discussion in NUREG-0800 "Introduction," Part 2. Commission regulations and policy mandate programs applicable to SSCs that include:

    A. Maintenance Rule SRP Section 17.6 (DSRS Section 13.4, Table 13.4, Item 17, Regulatory Guides 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants." and RG 1.182; "Assessing and Managing Risk Before Maintenance Activities at Nuclear Power Plants".
    B. Quality Assurance Program SRP Sections 17.3 and 17.5 (DSRS Section 13.4, Table 13.4, Item 16).
    C. Technical Specifications (DSRS Section 16.0 and SRP Section 16.1) – including brackets value for DC and COL. Brackets are used to identify information or characteristics that are plant specific or are based on preliminary design information.
    D. Reliability Assurance Program (SRP Section 17.4).
    E. Initial Plant Test Program (Regulatory Guide 1.68, "Initial Test Programs for Water-Cooled Nuclear Power Plants, "DSRS Section 14.2, and DSRS Section 13.4, Table 13.4, Item 19).
    F. ITAAC (DSRS Chapter 14).

2. The reviewer confirms that the system description and schematics provided in the SAR show the TGS. The general arrangement of the TGS and associated equipment with respect to safety-related and risk-significant SSCs is noted.

3. 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 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.

4. 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.

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

6. 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.

7. 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 design control document (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.

8. For review of a COL application, the scope of the review is dependent on whether the COL applicant references a DC, an early site permit (ESP) or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

9. For review of both DC and COL applications, DSRS 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 review and calculations (if applicable) support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

1. The TGS 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 TGS 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 TGS in the NRC review was conformance of the designs, design criteria, and design bases to the Commission's regulations, as cited in the GDC of Appendix A to 10 CFR Part 50. The staff concludes that the plant design is acceptable and meets the requirements of GDC 4 with respect to the protection of safety-related or risk-significant 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 TGS design conforms to all applicable GDC, 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 of 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, including design acceptance criteria, as applicable.

V. IMPLEMENTATION

The staff will use this DSRS section in performing safety evaluations of mPower^{TM}-specific DC, COL, or early site permit (ESP) applications submitted by applicants pursuant to 10 CFR Part 52. The staff will use the method described herein to evaluate conformance with Commission regulations.

Because of the numerous design differences between the mPower^{TM} and large light-water nuclear reactor power plants, and in accordance with the direction given by the Commission in 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), to develop risk-informed licensing review plans for each of the small modular reactor (SMR) reviews including the associated pre-application activities, the staff has developed the content of this DSRS

section as an alternative method for mPower™ -specific DC, COL, or ESP applications submitted pursuant to 10 CFR Part 52 to comply with 10 CFR 52.47(a)(9), "Contents of applications; technical information."

This regulation states, in part, that the application must contain "an evaluation of the standard plant design against the Standard Review Plan (SRP) revision in effect 6 months before the docket date of the application." The content of this DSRS section has been accepted as an alternative method for complying with 10 CFR 52.47(a)(9) as long as the mPower™ DCD FSAR does not deviate significantly from the design assumptions made by the NRC staff while preparing this DSRS section. The application must identify and describe all differences between the standard plant design and this DSRS section, and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria. If the design assumptions in the DC application deviate significantly from the DSRS, the staff will use the SRP as specified in 10 CFR 52.47 (a)(9). Alternatively, the staff may revise the DSRS section in order to address new design assumptions. The same approach may be used to meet the requirements of 10 CFR 52.17 (a)(1)(xii) and 10 CFR 52.79 (a)(41), for ESP and COL applications, respectively.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Dynamic Effects Design Bases."

2. Regulatory Guide 1.68, "Initial Test Programs for Water-Cooled Reactor Power Plants."

3. Regulatory Guide 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants."

4. Regulatory Guide 1.182, "Assessing and Managing Risk Before Maintenance Activities at Nuclear Power Plants."

5. Regulatory Guide 1.215, "Guidance for ITAAC Closure Under 10 CFR Part 52."

6. Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

7. American Society of Mechanical Engineers, Boiler and Pressure Code. Section XI, "Rules for Inservice Inspection of Nuclear Power Plants Components."