UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

June 24, 2015

The Honorable Stephen G. Burns
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: GRAND GULF NUCLEAR STATION MAXIMUM EXTENDED LOAD LINE LIMIT ANALYSIS PLUS (MELLLA+) LICENSE AMENDMENT REQUEST

Dear Chairman Burns:

During the 625th meeting of the Advisory Committee on Reactor Safeguards, June 10-12, 2015, we completed our review of the license amendment request and the associated NRC staff draft safety evaluation to allow operation of Grand Gulf Nuclear Station Unit 1 (GGNS) in the expanded Maximum Extended Load Line Limit Analysis Plus (MELLLA+) domain under the NRC-approved extended power uprate (EPU) conditions of 4408 MWt. This matter was also reviewed during our 624th meeting on May 7, 2015, and by our Subcommittee on Power Uprates on March 17, 2015. During these reviews, we had the benefit of discussions with representatives of the staff, Entergy Operations, Inc. (Entergy or the licensee) and their contractors. We also had the benefit of the documents referenced.

RECOMMENDATION AND CONCLUSION

1. The Entergy application for GGNS operation in the MELLLA+ domain should be approved, subject to the conditions and limitations identified in the staff's draft safety evaluation.

2. The proposed GGNS operator response time and other measures, including the limitations and conditions adopted by the licensee, provide reasonable assurance of adequate protection from instabilities during MELLLA+ operation.

BACKGROUND

GGNS is a BWR/6 with a Mark III containment. The plant began operation in 1985 with an original licensed thermal power of 3833 MWt. On July 18, 2012, the NRC granted Entergy an EPU to increase the thermal power of GGNS to its current licensed thermal power (CLTP) of 4408 MWt. GGNS currently operates in the Maximum Extended Load Line Limit Analysis (MELLLA) domain. MELLLA+ expands the operating domain to permit core flows as low as 80% of the rated value at CLTP. The MELLLA+ expanded domain increases operating flexibility by allowing control of reactivity at maximum power with changes in flow rather than control rod insertion or withdrawal. Implementation of MELLLA+ could lead to operation closer to system stability boundaries. As a result, enhanced protection against instabilities must be instituted to enable such operation safely.

In support of the license amendment request, Entergy submitted safety analysis report NEDC-33612P. This report documents results from safety evaluations to support MELLLA+ operation at CLTP. The licensee evaluated the applicability of generic General Electric-Hitachi (GEH) assessments to GGNS. In cases where such generic assessments were not applicable, the licensee provided plant-specific evaluations. The licensee plans to apply the Detect and Suppress Solution - Confirmation Density (DSS-CD) methodology to protect against the increased susceptibility to instabilities in the MELLLA+ operating domain.

GGNS has a large core (4408 MWt) and a high power density (62 kW/liter). It can operate at a thermal power to flow ratio exceeding 50 MWt/Mlbm/hr. It uses GEH Global Nuclear Fuel 2 (GNF2) which is optimized for performance at full power and full flow conditions. These features of GGNS make it susceptible to power oscillations at low flow conditions.

The licensee adopted the applicable generic license conditions and limitations. In addition, the licensee has proposed two plant-specific license conditions and three amendments in support of this MELLLA+ application.

DISCUSSION

Broadening the GGNS operating domain by allowing operation at lower flow without requiring additional compensating measures could reduce the plant's safety margin. However, limitations and conditions adopted by the licensee maintain acceptable safety margins and satisfy regulatory criteria under MELLLA+ operation. Acceptable safety margins will be maintained by a combination of measures based on generic and plant-specific evaluation results:

- Changes in setpoints and operating limits to assure fuel integrity and adequate core cooling
- Penalties imposed to maintain margins associated with implementing the approved DSS-CD methodology
- Not allowing operation in the MELLLA+ domain when a feedwater heater is out of service
- Not allowing single loop operation in the MELLLA+ domain
- Demonstrated operator response time to limit instabilities during anticipated transient without scram (ATWS) events
- Limitations due to predicted critical power ratio (CPR) reductions associated with GNF2 fuel performance at low flow
- Increased discharge pressure for the standby liquid control system pumps to accommodate higher peak pressures predicted for the limiting ATWS event.

Our review focused on the effect of MELLLA+ operation on fuel and nuclear design, thermal and hydraulic design, plant system response, and transient and accident analyses. Our review also emphasized evaluations of plant response during anticipated operational occurrences (AOOs), operator response time, and uncertainties in predicting ATWS instabilities.

Fuel and Nuclear Design

The MELLLA+ analyses indicate that GNF2 fuel could be subjected to increased temperatures and stresses during some events. To mitigate these effects, more restrictive setpoints are adopted that affect plant operating limits, such as the safety limit minimum critical power ratio (SLMCPR), a limit established to prevent cladding damage due to fuel overheating.

GGNS analyses examined effects of the proposed operating domain extension on the nuclear design of the fuel assemblies, control systems, and reactor core. In addition, the licensee committed to provide fuel- and cycle-dependent analyses, including the plant-specific thermal limits assessment, to ensure that margins are maintained during each core reload.

Plant-specific power distribution assessments are required to ensure that uncertainties determined via neutronic methods have not increased in expanded operating domains in which the core thermal power to core flow ratio exceeds 50 MWt/Mlbm/hr. Entergy addressed this limitation by adding conservatism to the GGNS cycle-specific SLMCPR value. This SLMCPR adder for EPU/MELLLA+ must be applied in the stability analyses for each cycle-specific reload licensing analysis report.

The operating limit minimum critical power ratio (OLMCPR) and the maximum average planar linear heat generation rate are set to assure that specified acceptable fuel design limits are not exceeded during normal operation, anticipated transients, and loss of coolant accidents (LOCAs).

Analyses demonstrate that for the turbine trip and load rejection AOOs, the calculated change in CPR is more limiting at lower flows. This behavior is attributed to GNF2 fuel thermal hydraulic performance. GNF2 fuel includes mixing vanes to optimize CPR performance, but this advantage is realized only at full power and full flow conditions. Stability calculations consider CPR performance at low flow conditions. Therefore, additional OLMCPR margin is required for GGNS to operate in the MELLLA+ domain. This requirement is also applied in the reload analysis process.

The effects of MELLLA+ operation on fuel peak cladding temperature (PCT) were evaluated. The licensee performed LOCA analyses for large and small breaks assuming different power and flow conditions with top-peaked and mid-peaked power shapes. The limiting 10 CFR 50, Appendix K, large break single failure for GGNS MELLLA+ operation remains the recirculation suction line break with high pressure core spray failure. Predictions for PCT, local cladding oxidation, and core-wide metal-water reactions are bounded by predictions for EPU conditions and therefore satisfy 10 CFR 50.46 acceptance criteria.

Power manipulations within the MELLLA+ operating domain may be controlled by either recirculation flow or control rod movement. Other than required limitations and conditions associated with implementing the approved DSS-CD Long Term Solution, no changes will be made to the neutron monitoring system or the recirculation flow instrumentation for MELLLA+ operation. Evaluations by Entergy indicate that bypass voiding under MELLLA+ conditions remains below levels that could affect instrumentation calibration.

Thermal and Hydraulic Design

The proposed MELLLA+ power-flow operating domain is similar to the domain currently in use by GGNS. The primary difference occurs at higher power-to-flow operating conditions. Higher void fractions associated with higher operating power at lower flow can affect plant response during ATWS events. A penalty is imposed on the calculated SLMCPR to account for uncertainties in predicted power distributions at higher void fraction conditions. For GGNS operation at power-to-flow conditions that exceed 50 MWt/Mlbm/hr, plant-specific evaluations apply the increased SLMCPR penalties. Plant-specific evaluations and power range measurement data from three previous fuel cycles were compared by the staff and found to be acceptable, deviating by less than two percent.

Evaluations of GGNS response for ATWS events with timely operator actions result in predicted cladding temperatures that are well below the regulatory limit. As discussed below, comparisons between TRACE and TRACG04 calculations for a generic plant provide confidence that TRACG04 models are acceptable for this application.

Operation in the MELLLA+ domain has the potential to result in unstable power oscillations during AOOs. The licensee will implement the DSS-CD methodology to help protect GGNS from a coupled neutronic thermal-hydraulic instability. The DSS-CD methodology uses a confirmation density algorithm to detect the inception of power oscillations and generate a power suppression signal prior to significant oscillation amplitude growth and minimum critical power ratio degradation. False scrams are minimized by requiring density confirmation from multiple power range monitors, which could result in the growth of slightly larger instabilities prior to scram. To compensate, the licensee has imposed penalties and increased the required initial minimum critical power ratio margin. Furthermore, backup scram protection options include an automatic backup scram system and manual reactor scram.

Plant Systems

No safety systems were modified for MELLLA+ operation. However, standby liquid control system discharge pressures and relief valves were modified to ensure that boron injection is not impeded at the higher peak pressures predicted for a limiting ATWS event.

Plant-specific analyses were performed to address overpressure protection. For GGNS, the limiting overpressure event is main steam isolation valve closure with scram on high flux. Analyses indicate that the reactor vessel bottom head peak pressure is unchanged for this event. Vessel pressure limits are met without requiring any increase in the number of operable safety relief valves. The predicted peak pressure response is dependent on several input values, including the upper limit for the setpoints and assumed drift tolerance of the safety relief valves, based on valve performance testing at GGNS.

MELLLA+ conditions could increase the steam moisture content due to reduced steam dryer efficiencies at lower flows. Potential effects of increased moisture carry-over from the steam dryer on flow-induced vibrations, flow-accelerated corrosion, effluent releases, and steam line components were evaluated using generic analyses combined with measurements to assess the moisture content. Entergy has committed to continue obtaining these measurements and incorporate any trends into their existing monitoring programs.

Transient and Accident Analyses

The licensee completed evaluations to assess the impact of MELLLA+ operation on the radiological consequences of design basis accidents and other special events, such as station blackout. The evaluation concluded that MELLLA+ operation is bounded by events in the MELLLA domain.

In addition, the licensee analyzed several ATWS events at CLTP for increased core flow (105%) and at MELLLA+ for reduced core flow (80%) conditions. Plant-specific analysis results show that reactor vessel peak pressure remains within applicable limits, PCT remains below the 2200 °F acceptance criterion, suppression pool peak temperature is less than design limits, and containment peak pressure remains less than containment design pressure. For more limiting licensing basis ATWS events, the licensee applied two approaches: the licensing basis methodology using the ODYN code, and a best estimate methodology using the TRACG04 code.

In the licensing basis calculations for MELLLA+ operation, reactor vessel water level is controlled at five feet above the top of the fuel, and the suppression pool is allowed to heat up even after the heat capacity temperature limit (HCTL) is reached. ODYN calculations for both CLTP and MELLLA+ conditions result in suppression pool temperatures that exceed the HCTL and would require depressurization. Because the ODYN calculated temperatures exceed the HCTL, a best estimate calculation is required.

For the best estimate calculation using TRACG04, it is assumed that there is manual emergency depressurization within 40 seconds after the HCTL is reached. With this assumption, reactor vessel peak pressure is calculated to remain below the 1500 psig ASME Service Level C limit. This calculation also indicates that the outcome depends on the assumed initial suppression pool temperature (i.e., HCTL may or may not be reached, and emergency depressurization may not be required).

The licensee evaluated stability during ATWS events, including those initiated by turbine trip or recirculation pump trip. Analysis results show that mitigating actions in the emergency operating procedures (e.g., flow runback to uncover the feedwater spargers and early boron injection) are effective in the MELLLA+ operating domain if operator actions are accomplished within a specified time. TRACG04 calculations indicate that all applicable criteria are satisfied if operators initiate feedwater flow reduction within 90 seconds after ATWS initiation. Although calculations of channel powers indicate that large out-of-phase oscillations may occur, prompt operator actions preclude the PCT from reaching the minimum temperature for stable film boiling (T_{min}), which is well below the 2200 °F acceptance criterion. This conservative temperature limit avoids issues related to uncertainties in rewetting and quenching.

The staff and GEH devoted substantial effort to understand differences in ATWS instability predictions by the TRACE and TRACG04 codes for a generic BWR. They concluded that differences in code predictions were due primarily to the models each code uses to predict T_{min} and fuel clad quenching. Nevertheless, if it is assumed that operators successfully initiate feedwater flow reduction within 90 seconds, TRACG04 calculations for GGNS predict that ATWS instability oscillations are mitigated and PCTs remain well below $T_{min.}$

The 90-second operator response time to reduce water level is less than the 120 seconds assumed in the approved generic GEH MELLLA+ methodology. Prompt operator actions to reduce feedwater flow are essential for rapid water level decreases that introduce negative reactivity and minimize the amplitude of unstable power oscillations. Hence, the licensee provided a commitment to train and test licensed reactor operators to initiate this action within the allotted time. The licensee will validate that all operating crews have successfully completed this training prior to GGNS operation in the MELLLA+ domain. In addition, a continuing commitment ensures that all subsequent crews will successfully complete training for MELLLA+ operation.

Feasibility evaluations performed on the plant simulator suggest that this operator response time is achievable. The absence of explicit uncertainty evaluations of the response times, however, prevents a quantitative assessment of the available margin associated with these actions. As specified in NEDC-33006P-A, ATWS analyses should include consideration of the uncertainties in the key input parameters. Thus, we considered additional information provided by the licensee for assessing uncertainties in estimates for PCT compared to T_{min} and the onset of oscillations. In particular, we explored the effects of conservatisms assumed in the licensing basis case, the most unrealistic of which was the rate of reduction in feedwater temperature during the turbine trip ATWS event. When this assumption was changed to a physically realizable rate, sufficient margin appeared to be available despite the uncertainties. This additional information led us to conclude that there is acceptable margin for GGNS operation in the MELLLA+ domain. We note that this conclusion is based on a specific plant configuration and maximum achievable feedwater cooling rate. Different plant configurations or cooling rates could affect this conclusion.

SUMMARY

In summary, there is reasonable assurance that the health and safety of the public will not be adversely affected by the licensee's operation in the expanded MELLLA+ operating domain. The Entergy application for GGNS operation in the expanded MELLLA+ domain using GNF2 fuel should be approved, subject to the conditions and limitations identified in the staff's draft safety evaluation. If Entergy pursues the use of an alternative fuel design or different analysis method for GGNS, additional evaluations will be required.

Sincerely,

/RA/

John W. Stetkar
Chairman

REFERENCES

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2. NRC, “Safety Evaluation By the Office of Nuclear Reactor Regulation Related to Amendment No. to Facility Operating License No. NPF-29 Entergy Operations, Inc. Grand Gulf Nuclear Station, Unit 1 Docket No. 50-416,” February 24, 2015 (ML15036A258)

3. GEH, NEDC-33612P, “Safety Analysis Report for Grand Gulf Nuclear Station Maximum Extended Load Line Limit Analysis Plus,” September 2013 (ML13269A139)

4. GEH, NEDC-33006P-A, “General Electric Boiling Water Reactor Maximum Extended Load Line Limit Analysis Plus,” Revision 3, June 2009 (ML091800530)

5. GEH, NEDC-33075P-A, “Detect And Suppress Solution-Confirmation Density Licensing Topical Report,” Revision 8, November 2013 (ML13324A098)

6. GEH, NEDE-33147P-A, “DSS-CD TRACG Application,” Revision 4, August 2013, (ML13224A306)

7. GEH, NEDC-33173P-A, “Applicability of GE Methods to Expanded Operating Domains,”, Revision 4, November 2012 (ML123130130)

8. NRC, RS-001, “Review Standard for Extended Power Uprates,” December 2003 (ML033640024)

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