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

July 21, 2015

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

SUBJECT: NINE MILE POINT NUCLEAR STATION UNIT 2 MAXIMUM EXTENDED LOAD LINE LIMIT ANALYSIS PLUS (MELLLA+) LICENSE AMENDMENT REQUEST

Dear Chairman Burns:

During the 626th meeting of the Advisory Committee on Reactor Safeguards, July 8-9, 2015, we completed our review of the license amendment request and the associated NRC staff draft safety evaluation to allow operation of Nine Mile Point Nuclear Station Unit 2 (NMP2) in the expanded Maximum Extended Load Line Limit Analysis Plus (MELLLA+) domain under the NRC-approved extended power uprate (EPU) conditions of 3988 MWt. This matter was reviewed by our Power Uprates Subcommittee on June 22, 2015. During these reviews, we had the benefit of discussions with representatives of the staff, Exelon Generation Company, LLC (Exelon or the licensee) and their contractors. We also had the benefit of the documents referenced.

RECOMMENDATION AND CONCLUSION

1. The Exelon application for NMP2 operation in the MELLLA+ domain should be approved, subject to the limitations and conditions identified in the staff's draft safety evaluation.

2. Plant features, such as automated actions to initiate feedwater flow reduction and increased boron-10 enrichment in the standby liquid control system (SLCS), enhance protection against anticipated transient without scram (ATWS) instabilities during MELLLA+ operation.

BACKGROUND

NMP2 is a BWR/5 with a Mark II containment. The plant began operation in 1987 with an original licensed thermal power of 3323 MWt. On December 22, 2011, NRC granted an EPU to increase the thermal power of NMP2 to its current licensed thermal power (CLTP) of 3988 MWt. NMP2 currently operates in the Maximum Extended Load Line Limit Analysis (MELLLA) domain. MELLLA+ operation would expand the NMP2 operating domain to core flows as low as

85% of the rated value at CLTP. This expanded domain increases operating flexibility by allowing control of reactivity at higher powers with changes in recirculation flow rather than control rod insertion or withdrawal. NMP2 has a high thermal power with a power density of 59 kW/liter and can operate at a thermal power to flow ratio exceeding 50 MWt/Mlbm/hr. These features make NMP2 susceptible to power oscillations when operating in the MELLLA+ domain. As a result, enhanced protection against instabilities must be instituted to enable such operation safely.

In support of the license amendment request, Exelon submitted safety analysis report NEDC-33576P. This report documents results from evaluations to support MELLLA+ operation. The licensee evaluated the applicability of generic GE-Hitachi assessments to NMP2. In cases where such generic assessments were not applicable, the licensee provided plant-specific evaluations. NMP2 uses GE14 fuel, which is approved for MELLLA+ operation. 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.

DISCUSSION

Broadening the NMP2 operating domain by allowing operation at lower flow without requiring additional compensating measures could reduce the plant's safety margin. The licensee adopted the applicable generic license conditions and limitations for MELLLA+ operation. In addition, continued application of the existing NMP2 license condition and technical specification changes are proposed to support this MELLLA+ application. Acceptable safety margins will also be maintained by a combination of measures based on generic and plant-specific evaluation results:

- Maintaining feedwater temperature above 420.5 °F at rated steady-state power conditions
- Increasing isotopic enrichment of boron-10 in the SLCS
- Increasing the discharge pressure for the SLCS pumps
- Increasing safety margins to assure fuel integrity and adequate core cooling
- Increasing safety margins to compensate for implementation of the DSS-CD methodology
- Utilizing automated feedwater flow reduction
- Prohibiting single-loop operation in the MELLLA+ domain
- Demonstrating operator response times for critical actions during ATWS events

Our review focused on the effect of MELLLA+ operation on fuel and nuclear design, thermal and hydraulic design, plant systems response, and transient and accident analyses. Our review also examined uncertainties in operator response times and parameters that affect predictions of ATWS instabilities.

Fuel and Nuclear Design

Operation in the MELLLA+ domain could subject the fuel to increased temperatures and stresses during some transient events. Such effects are mitigated by imposing more restrictive plant operating limits to prevent cladding damage.

NMP2 analyses assess the effects of the proposed operating domain extension on the fuel assemblies, control systems, and reactor core. In addition, the licensee provided fuel- and cycle-dependent analyses, including the plant-specific thermal limits assessment, to ensure that margins are maintained. These analyses predict that the impact on fuel, when operating with the more restrictive operating limits at the lower MELLLA+ flows, is acceptable.

Plant-specific power distribution assessments are required to consider the effect of additional uncertainties when the core power to flow ratio exceeds 50 MWt/Mlbm/hr. Exelon addressed this requirement by assuming more conservative NMP2 cycle-specific safety limit minimum critical power ratios (SLMCPRs) in their evaluations for steady-state operation. The higher SLMCPRs must be applied for each cycle-specific reload analysis report.

The operating limit minimum critical power ratio (OLMCPR) and the maximum average planar linear heat generation rate (MAPLHGR) are set to assure that specified fuel design limits are not exceeded during anticipated transients and loss of coolant accidents (LOCAs), respectively. Evaluations of Anticipated Operating Occurrences demonstrate that conditions at CLTP with 105% flow, which was approved for the EPU, are more limiting for OLMCPR than conditions possible in MELLLA+ operation at CLTP with 85% core flow. The licensee selected MAPLHGRs by examining the effects of MELLLA+ operation during large and small break LOCAs assuming different power and flow conditions with top-peaked and mid-peaked power shapes. Predictions for peak cladding temperature (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. Calibrations are prohibited in a small region of the MELLLA+ domain where calculations indicate that hot channel bypass voiding could exceed levels that could affect neutron monitoring system instrumentation accuracy.

Thermal and Hydraulic Design

The proposed MELLLA+ power-flow operating domain is similar to the domain currently in use at NMP2. 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 NMP2 operation at power-to-flow conditions that exceed 50 MWt/Mlbm/hr, plant-specific evaluations apply the increased SLMCPR penalties. The staff compared plant-specific evaluations with power range measurement data from three previous fuel cycles and found the proposed penalties acceptable.

The licensee will implement the DSS-CD methodology to help protect NMP2 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 and a higher scram setpoint. 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 major plant modifications were made for MELLLA+ operation. It is proposed to revise the technical specification for the SLCS pumps discharge pressure to ensure boron injection at the higher peak pressures predicted for a limiting ATWS event. In addition, a technical specification was previously revised to increase the boron-10 enrichment of the solution used in the SLCS. Together, these changes significantly decrease the time to shut down the reactor.

Evaluations indicate that the MELLLA+ operating domain does not increase heat addition to the suppression pool following the limiting LOCA and transient events. Peak values for long-term suppression pool temperatures and containment pressures are not predicted to increase. Lower suppression pool temperatures are predicted following an ATWS event because of the increased SLCS boron-10 enrichment.

Plant-specific analyses were performed to evaluate overpressure protection. For NMP2, the limiting overpressure event is main steam isolation valve closure with scram on a high flux signal. The predicted peak pressure response is dependent on several input values, including setpoints and drift tolerances of safety relief valves based on NMP2 valve performance testing. Analyses indicate that the reactor vessel bottom head peak pressure is unchanged for this event. Vessel pressure limits are met without requiring an increase in the number of operable safety relief valves.

MELLLA+ conditions could increase the steam moisture content due to reduced steam separator efficiencies at lower flows. Potential effects of increased moisture carry-over from the steam dryer were evaluated using generic analyses combined with measurements. Exelon will continue these measurements and incorporate any trends into their existing monitoring programs.

Transient and Accident Analyses

The licensee provided evaluations to assess 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 (85%) conditions. Plant-specific analyses show that reactor vessel peak pressures remain within applicable limits, PCTs remain below the 2200 °F acceptance criterion, suppression pool peak temperatures are less than design limits, and containment peak pressures remain less than the containment design pressure.

For more limiting ATWS events, the licensee applied a licensing basis methodology using the ODYN code. In MELLLA+ operation, the calculations assume 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 resulted in suppression pool temperatures that exceed the HCTL. The licensee increased the enrichment of boron-10 in the SLCS. This increases the effectiveness of boron injection by the SLCS, allows shutdown to occur earlier, and reduces integrated heat loads to the containment. With the increased boron-10 enrichment, ODYN calculations indicate that the suppression pool temperature remains below the HCTL, and a best estimate TRACG04 calculation is not required to establish a suitable depressurization approach.

The licensee evaluated stability during ATWS events. NMP2 has a control system that automates many of the critical actions. For example, following detection of ATWS events in which a high pressure signal is generated, this system initiates several automatic actions:

- Recirculation pump trip occurs immediately.
- Feedwater flow reduction occurs with a 25 second delay.
- SLCS boron injection occurs with a 98 second delay.

MELLLA+ operating domain expansion does not affect any of these actions. For these events, TRACG04 calculations indicate that applicable limits are satisfied.

Operator actions are needed to mitigate ATWS events that do not cause a high pressure signal. Though no operator actions will be added, deleted, or changed, the licensee has identified two required operator actions as critical:

- Initiation of manual scram
- Initiation of manual water level reduction

The time to accomplish feedwater flow reduction was determined by having several crews exercise the procedural steps in the plant simulator. Times to accomplish these actions ranged from 150 to 230 seconds. Margin was added to allow for such real-world issues as plant conditions, time during shift, time of day, and time to recognize the event. The required time including margins was set at 270 seconds. During an audit, the staff observed an NMP2 crew successfully accomplish these actions within 200 seconds. The licensee has a process that ensures operators will continue to be trained regarding changes to plant procedures and other aspects associated with the MELLLA+ operating domain expansion.

A trip of two reactor recirculation pumps with failure to scram is the limiting ATWS instability event without a high pressure signal. Calculations assuming operator action to reduce feedwater flow at 270 seconds indicate that the plant will enter a period of flow and power oscillations lasting approximately 150 seconds. The calculated PCTs increase during this period, but still remain below the minimum temperature for stable film boiling (T_{min}) which is well below the 2200 °F acceptance criterion. As more dryout, post-dryout, and rewetting data become available at higher rod temperatures and oscillatory flows, the staff should confirm the adequacy of a fixed T_{min} in transient flow boiling calculations and post-dryout temperature predictions. Nonetheless, the calculated margins to the PCT acceptance criteria for this event with the proposed mitigation actions at NMP2 are sufficiently large to account for uncertainties in the modeling approach.

To provide additional insights related to the available margins, the licensee evaluated plant response for a limiting ATWS instability event. For a turbine trip with bypass event, it was assumed that automated actions to initiate feedwater flow reduction failed. Calculations evaluated various times for operator actions to reduce feedwater flow and various feedwater temperature reduction rates. Results indicate that PCTs remain below T_{min} which is well below the 2200 °F acceptance criterion. Once again, the margins are sufficient to account for uncertainties in the modeling approach.

SUMMARY

There is reasonable assurance that the health and safety of the public will not be adversely affected by operation of NMP2 in the expanded MELLLA+ domain. The Exelon application for NMP2 operation in the expanded MELLLA+ domain using GE14 fuel should be approved, subject to the conditions and limitations identified in the staff's draft safety evaluation. If Exelon pursues the use of an alternative fuel design or different stability analysis methods for NMP2, additional evaluations will be required.

Sincerely,

/RA/

John W. Stetkar
Chairman

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Sincerely,

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John W. Stetkar
Chairman

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