UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

SUPPORTING AMENDMENT NO. 120 TO LICENSE NO. DPR-49

IOWA ELECTRIC LIGHT AND POWER COMPANY
CENTRAL IOWA POWER COOPERATIVE
CORN BELT POWER COOPERATIVE

DUANE ARNOLD ENERGY CENTER

DOCKET NO. 50-331

1.0 INTRODUCTION

By letter dated August 17, 1984, the Iowa Electric Light and Power Company (the licensee) requested changes to the Duane Arnold Energy Center (DAEC) Technical Specifications (TS) to implement Extended Load Line Limits derived from its analysis. Subsequently, by letters dated January 11 and March 15, 1985, the licensee proposed improvements to the Average Power Range Monitor (APRM) and Rod Block Monitor (RBM). The APRM, RBM and TS (ARTS) improvements are intended to increase the plant operating efficiency, update the compliance with the thermal margins requirements, improve the accuracy and response of the pertinent instrumentation, and to improve the man/machine interface.

The licensee has provided Extended Load Line Limit Analysis (ELLLA) as a basis for normal reactor operation in the region of power/flow map above 100 percent power and 100 percent flow limits. The operation in the extended region is achieved by changing the slope of the flow bias algorithms and revising the APRM rod block line. The ARTS improvements involve (1) elimination of APRM trip setdown requirements, (2) changes from flow to power referenced setpoints for the RBM, (3) power and flow dependent limits on Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) and Minimum Critical Power Ratio (MCPR), (4) reconfiguration of Local Power Range Monitor (LPRM), (5) changes in normalization procedure and new trip logic in the RBM providing definition of a limiting rod pattern for RBM bypass decisions, and (6) an altered rod withdrawal error at power analysis.

2.0 EVALUATION

Extended Load Line Limit Analysis

The extended load line limit operation permits higher powers for low flow conditions by changing the slope of the APRM rod block line. The effect is to allow operation at 100 percent power for 87 percent flow or greater and to increase the permitted power at 40 percent flow by about 5 percent to 63.2 percent. We have reviewed the impact of the reactor operation in the extended power/flow region, on the evaluation of transients and core stability.

The transient and accident analyses described in the evaluation of the ARTS program have all assumed operation with the extended load line limit. The changes in core behavior caused by the extended operation range have been accounted for in the revised analyses discussed under ARTS improvement program.

The operation in the extended power/flow region was previously approved for the Hatch, Dresden, and Monticello plants (see Monticello Amendment No. 29). Additionally, the compliance of General Electric Company's (GE) boiling water reactors with thermal-hydraulic stability criteria has been generically confirmed by the staff for operation in the extended power/flow region. We, therefore, conclude that the thermal-hydraulic stability of DAEC Cycle 8 in the extended power/flow region is assured. The operation of DAEC in the proposed extended power/flow region is, therefore, acceptable.

APRM System Improvements

Each APRM channel consists of a number of LPRMs which are chosen in such a way that the channel output is proportional to core power. The APRM signals are compared to a fixed scram trip (at 120% full power) and to a flow biased rod withdrawal block trip. In addition the APRM signals are passed through a filter having a time constant of approximately six seconds to form the simulated thermal power monitor (STPM). The STPM output is then compared to a flow biased scram trip.

Current DAEC Technical Specifications require that the flow biased APRM setpoints be lowered (set down) if the core maximum fraction of limiting power density (CMFLPD) exceeds the fraction of rated power (FRP). This may be accomplished by increasing the APRM channel gain. If CMFLPD exceeds FRP and the core power is raised to its full value the operating limit value for MAPLHGR or MCPR could be exceeded and the assumptions used in the plant transient analyses violated.

In the proposed APRM system the setdown requirement would be removed. It would be replaced by power and flow dependent MAPLHGR and MCPR limits. Analyses have been performed to obtain the multipliers to be applied to the full power values of MAPLHGR and MCPR in order to prevent violation of safety criteria during transients and accidents. The LOCA and limiting transients were reanalyzed without the APRM system setdown requirements.

Previous analyses of the LOCA at less than rated flow have been performed under the assumptions that the extended load line was in effect and that the APRM setdown was present. These analyses showed that below 70 percent power a five percent reduction in MAPLHGR limits was required. However, the reanalysis performed for Cycle 8 (approved by the staff in Amendment No. 115) showed increased margins to LOCA limits at both full and reduced flow. The analyses showed that the required reduction for low flows in the absence of the APRM setdown is bounded by that required for reasons other than LOCA.

In order to restore safety margins which might be reduced when the APRM setdown is removed, the limiting transients were reanalyzed assuming the absence of this feature. The analyses assumed operation within the proposed extended power/flow domain with flows up to 105 percent of rated flow. Analyses of the transient events were made as a function of initial power and flow and the results used to determine multipliers to be applied to full power-full flow values of MCPR and MAPLHGR. The power dependence was most sensitive at full flow and the feedwater controller failure was the transient showing the largest sensitivity. This event was then used to construct a curve of MCPR multiplier, K_p, and MAPLHGR multiplier, $MAPFAC_p$, as a function of core power. Conservative curves were drawn in order to bound future cycles.

Flow dependence of MCPR and MAPLHGR was determined from analyses of flow runout events in which the core flow is ramped rapidly upward to the maximum value permitted by the setting of the recirculation pump scoop. The flow multipliers, K_f and $MAPFAC_f$, are thus a function of the initial flow and the maximum flow and a family of curves is drawn. The multipliers are chosen so that a flow runout to the maximum flow will not result in a violation of MCPR or LHGR safety limits. The $MAPFAC_f$ curves are combined with the results of LOCA analysis described above and the combined family of curves is used in the Technical Specifications. For inclusion in the Technical Specifications, the K_f curve family is transposed to a $MCPR_f$ family by assuming a value of 1.2 for the full flow MCPR. This is the lowest value that may be used for DAEC.

The above discussion applies to the power range from 30 to 100 percent of full power. Below 30 percent of full power the turbine stop and control valve scrams are bypassed and the analyses do not apply. Below 25 percent of full power no MCPR and MAPLHGR limits are defined. In the interval between 25 and 30 percent of full power flow dependent effects are taken into account by having two power dependent curves - one for flows greater than 50 percent of rated and one for lower flows. Analyses are then performed to obtain limiting MCPR and MAPLHGR values in these domains.

Approved methods were used to perform the analyses described above except for those used for the loss of feedwater heater event. For that event the trend analysis was performed with the BWR simulator code. However, this event is not limiting and safety analyses for the event are done by approved methods described in GESTAR II. We find this acceptable.

We conclude that deletion of the APRM setdown requirement is acceptable when it is replaced by the power and flow dependent operating limits described above.

Rod Block Monitor System Improvements

The Rod Block Monitor (RBM) System is used to prevent violation of fuel thermal-hydraulic limits in the event of inadvertent continuous withdrawal of a control rod. When a rod is selected for withdrawal the surrounding LPRM strings are selected. Their response to the withdrawal is monitored and a withdrawal block is initiated by the RBM if that response exceeds certain limits. These limits are selected so that no violation of fuel limits occurs. The RBM has two independent channels either of which will initiate a rod block if tripped.

The proposed Rod Block Monitor improvements include:

1. Reordering of the assignment of LPRM detectors to the two RBM channels in order to increase instrument sensitivity and provide more uniformity of response between the two channels.

2. Changing the baseline normalization of the RBM from an APRM channel to a fixed signal in order to reduce the number of unnecessary rod blocks.

3. Replacing the flow-biased trip setpoints with fixed power-dependent trip setpoints.

4. Elimination of the resettable trips in order to make operation simpler.

In addition the electronics hardware has been updated to increase the reliability of operation.

The change in LPRM assignments is described in the licensee's request and a comparison of the RBM channel responses to those of the current design is made. The revised design shows similar responses for the two channels each of which has a response similar to that of the most responsive channel in the current design.

A block diagram of the revised RBM system is presented and a discussion of the electronics change given in the licensee's application. We conclude that sufficient information is given in the report to permit the conclusion that the proposed revisions to the RBM system design are acceptable. The electronics changes are discussed in the next section.

The revisions of the RBM system necessitate the reevaluation of the Rod Withdrawal Error Event. The present deterministic, bounding, cycle specific analysis is replaced with a statistical analysis valid for application to all DAEC cores using GE fuel up to type P8x8R inclusive. A data base calculated from actual plant operation states was created which covers the spectrum of plant sizes and power densities. The data base construction began with the selection of operating states at near full power which had low MCPRs and/or high MAPLHGRs in bundles near deeply inserted control rods. The rod configurations were then adjusted to bring the MCPR values to approximately 1.20. Thirty-nine such configurations were chosen. In order to investigate power and flow dependence, the rod configuration in 26 of the above cases was held constant, the flow was reduced to 40 percent of rated and xenon allowed to equilibrate. Finally, for the 26 cases, the flow was held constant at 40 percent and the rod pattern altered to yield 40 percent power with no xenon. For each of the 91 cases described above 100 rod withdrawal error (RWE) analyses were performed assuming a random distribution of starting points for the error rod (and thus initial MCPR values, $MCPR_I$) and random failures of the LPRMs which provide inputs to the Rod Block Monitor. All cases which did not result in a rod block were rejected from the data base unless the rod started from the fully inserted position. A 15 percent random failure rate was assigned to each LPRM. Experience has shown this value to be high.

The Rod Block Monitor response was generated as a function of error rod position for each RWE. The currently used and approved methods were employed in the analyses. The results were tabulated as error rod position vs assumed Rod Block Monitor setting. These results were then transformed into values of normalized MCPR change ($\Delta MCPR/MCPR_I$) and the mean and standard deviation of the distribution for each set of 100 RWE analyses were determined for each RBM setting. These data were then combined to obtain a mean and standard deviation for the entire data base at each power/flow state for each RBM channel at each assumed RBM setting.

A plot of the required initial MCPR value ($MCPR_I$) as a function of Rod Block Monitor trip setting was constructed. The required value of $MCPR_I$ is that which assures that 95 percent of the rod withdrawal errors which are initiated from it do not violate the MCPR safety limit (1.07) with a 95 percent confidence level.

The final step is the selection of suitable setpoints for the Rod Block Monitor. These are chosen so that the rod withdrawal event is not limiting. At any power level the required operating limit MCPR for this event is not greater than that required for other transients as described in Section 3.2 above. A value of 1.20 at full power/full flow is assumed. In keeping with the three trip settings of the present system, the power range from 30 percent to full power is divided into three intervals with a constant setpoint in each interval. For DAEC the intervals are 30-65, 65-85, and 85-100 percent of full power. The analytic setpoint for the intervals are respectively, 118, 112, and 108 percent of the reference signal.

The effect of the absence of LPRM strings for certain rods near the periphery of the core has been analyzed and it was shown that the setpoints described above are adequate to mitigate the consequences of the Rod Withdrawal Error in the periphery of the core.

A downscale trip at about 94 percent of the reference signal also inhibits rod withdrawal.

The analyses described above assumed unfiltered LPRM signal inputs to the RBM. However, provision is made in the instrument for a filter having a time constant of up to 0.55 seconds. Use of such a filter would necessitate the reduction of the setpoints given above by an amount which depends on the time constant chosen. Analyses were performed to determine the required adjustments and values are given in NEDC-30813-P. If anything other than no filtering is chosen, the maximum time constant is recommended. In addition, a delay occurs between the time when the input signal reaches the setpoint and the imposition of the rod block. A value of 2.0 seconds was assumed for this delay and no greater value may be permitted. This value is incorporated into the Technical Specifications.

In order to confirm the use of a 15 percent failure probability in the statistical analysis a sensitivity study was performed in which failure rates up to 30 percent was assumed. Increasing the failure rate to the higher value had a negligible effect on the results.

The Rod Block Monitor is currently required to be operable when core power is greater than some low power setpoint (30 percent of full power). Additional surveillance is required if the core has a "limiting control rod pattern" - defined to be a pattern which causes the core to be at the operating limit on MCPR, APLHGR or LHGR. Strictly speaking, however, the RBM is only required if the complete withdrawal of any single rod in the core would violate safety limits. Analyses have been performed - using the data base described above - to obtain operating limit MCPR values above which no rod withdrawal error could lead to violation of the limits. Two values are defined - one for power levels greater than 90 percent full power and one for levels from 25 to 90 percent full power. If the plant is operating at or below these limits it is on a "limiting control rod pattern" and the RBM is required to be operable. It may be bypassed when operating above these limits.

Electrical Instrumentation and Controls

The RBM system is designed to automatically detect and block control rod withdrawal that could violate Technical Specification safety limits during a single control rod withdrawal error (RWE) transient. It is assumed that the core is operated in compliance with plant Technical Specifications before the RWE event. There are two RBM channels, either of which can initiate a rod block (i.e., prevent control rod withdrawal). The RBM channels are powered from the Reactor Protection System (RPS) buses (RBM channel A is powered from RPS bus A, and RBM channel B is powered from RPS bus B). Although the RBM system is not safety related, separation is provided between the RBM channels to allow for single failures and to allow one channel to be bypassed if necessary. RBM channel bypass is accomplished via a single three position bypass switch such that only one RBM channel can be bypassed at a time. Both RBM channels are operable when the switch is placed in the center (normal) position. Both local and remote indication of a RBM channel bypass are provided via indicator lights. The licensee has stated that to the maximum extent possible, the new RBM system design meets the same separation and isolation requirements as the previous RBM system. The only exceptions are the sharing of LPRM signals from the 'C' level detectors by both RBM channels. Since the new RBM system is fail safe for failed LPRM input signals and the RBM channel is declared inoperable if too few detectors are available, we find that it would not pose a safety problem and is, therefore, acceptable. The RBM output functions (i.e., recorders located on the reactor operator's console, local meters, trip units, and the on-line computer) will remain unchanged, although in some cases the signals used for these functions have been modified. Upon selecting a control rod for movement, each RBM channel automatically computes the average of all assigned (and unbypassed) local power range monitor channels. The average signal is then filtered to reduce signal noise, delayed to allow the signal to reach its asymptotic value and then automatically amplified to read the same as a fixed reference signal. This process (referred to as the RBM null sequence) is reinitiated each time a new rod is selected for movement. Control rod motion is blocked during the null sequence. Each RBM channel then compares the calibrated (nulled) signal to an automatically selected preset rod block alarm/trip level (one of three power biased upscale trip levels is selected dependent upon the current reactor power level). The trip level is selected based on the magnitude of a reference APRM. If the local neutron flux level increases to the upscale trip setpoint, further control rod withdrawal is blocked, thus limiting the change (increase) in local power. Thus, the ARTS modification to the RBM trip logic replaces the standard RBM flow biased (recirculation flow) trip feature with power (neutron flux level) biased trips. This modification will be implemented by changes to the PC card electronics (averaging cards, null sequence cards, RBM setpoint cards, and quad trip cards).

It should be noted that an adjustable time delay (t_{d2}, 1 to 50 seconds ± 0.5 seconds) has been added to delay the calibrated (nulled) average local neutron flux signal to the RBM trip logic. The purpose of this delay is to allow minimum rod movements despite abnormally high signal noise not removed by filtering. This delay is typically set at a value of 1 to 2 seconds. The design of the control rod drive system is for a normal speed of 3 inches per second ± 0.6 inches per second. The licensee has provided analyses that show the delay is short enough to limit rod movement well below that which could cause a thermal limits violation. However, if this time delay is set above the minimum value, it is considered a bypass of the associated RBM channel since the analyses did not consider time delays in excess of the minimum value. General Electric Co. report submitted by the licensee in support of the ARTS modification, states that time delay t_{d2} shall only be set above the minimum value as a means of bypassing the RBM. The staff's position is that manual adjustment of the t_{d2} setpoint as a means of bypassing a RBM channel in lieu of using the existing RBM channel bypass switch (which provides automatic indication of the bypass condition) is not acceptable and should not be permitted. The licensee has stated that only the RBM bypass switch will be used to effect a RBM channel bypass.

The trips include too few LPRM inputs, downscale rod withdrawal block (RBM signal abnormally low), upscale rod withdrawal block, instrument inoperative, mode switch in other than operate, a module removed, number of unbypassed inputs too few and failure to null to the reference source signal. The licensee states that the response time of the trip logic and drift of the setpoints equals or is less than that of the logic being replaced. The staff finds it acceptable.

All rod blocks are alarmed. The upscale rod block alarm can only be reset by activating a reset switch or selecting another rod for movement. Locally mounted color coded lights are provided to indicate the type of rod block (upscale - amber, instrument inoperative - white and downscale - white).

The RBM system is required to be operable whenever a limiting rod pattern exists. A limiting rod pattern exists when any control rod in the core would result in violation of the safety limit MCPR if it were fully withdrawn. During operation with a limiting rod pattern, both RBM channels should be operable. If only one RBM channel is operable, an instrument functional test of the operable (bypassed) channel must be performed prior to withdrawal of any control rods. If the inoperable channel is not restored within 24 hours, then all control rod withdrawal shall be blocked. If both RBM channels are inoperable, then all control rod withdrawal shall be blocked until operability of at least one channel is restored. It should be noted that the operators are responsible for determining whether a limiting rod pattern exists (and therefore, for determining RBM system operability requirements) prior to control rod withdrawal in accordance with plant operating procedures. The staff has found this to be acceptable. The APRM and RBM instrument surveillance requirements (i.e., instrument functional tests and calibrations) have not changed as a result of implementation of the ARTS improvement program. The staff finds the proposed Technical Specification requirements for RBM system operability and the associated limiting conditions for operation to be acceptable.

Based on our review of the electrical, instrumentation, and control aspects of the Duane Arnold Energy Center ARTS improvement program, we conclude that implementation of this design complies with the requirements of Section 7.7 (Control Systems) of the Standard Review Plan (NUREG-0800), and therefore, is acceptable. The separation provided between redundant RBM channels and the isolation provided between the RBM system and safety related circuits have not been compromised as a result of the ARTS modification.

Technical Specification Changes

Implementation of the hardware changes and revised analyses described above requires changes in the DAEC Technical Specifications. These changes are discussed below:

APRM Technical Specification Changes

The requirement for the setdown of the trip setpoint is deleted from the specification and the setdown factor (Fraction of Rated Power divided by Core Maximum Fraction of Limiting Power Density) is removed from the equation for the trip setpoint. The slope and intercept of the APRM flow biased rod block line and of the APRM/STPM flow biased scram are altered to permit operation within the domain defined by the extended load line limit analysis.

Rod Block Monitor Technical Specifications

The RBM biased trip equation is replaced by power dependent setpoint definitions and incorporate RBM filter and time delay setpoints. Current operability requirements are replaced by the new ones including the revised definition of the limiting control rod pattern.

Thermal-Hydraulic Operating Limit Specifications

The following changes are required in the Power Distribution Limit Specification:

1. A curve of MCPR multiplier, K_p, as a function of power must be added.

2. The K_f family of curves must be replaced with curves of $MCPR_f$ as a function of flow.

3. The MCPR Technical Specification must be altered to define the manner in which the two curves are combined with the full power, full flow value of the operating limit MCPR to obtain the power/flow dependent limit.

4. Power and flow dependent multiplier factors ($MAPFAC_p$ and $MAPFAC_f$) must be added and the MAPLHGR Technical Specification must be altered to define the manner in which the two curves are combined with the full power/full flow MAPLHGR curves to obtain the power and flow dependent MAPLHGR limits.

5. The bases for the various Technical Specifications must be modified to account for the altered Technical Specifications.

We have confirmed that the proposed DAEC Technical Specifications meet the requirements given above and are acceptable.

Impact of Other Licensing Action on Technical Specifications

In addition to the introduction of the ARTS program for Cycle 8 certain other Licensing Actions are also proposed. Two of these - use of Single

Loop Operation and the introduction of Lead Test Assemblies (LTAs) in the core have an impact on the ARTS Technical Specifications.

Effect of Presence of LTAs

As indicated above, the MAPLHGR reduction factor as a function of flow required by the LOCA analysis is bounded by that required by other transients. This conclusion was based on the presence of "standard" 8x8R or P8x8R fuel in the core. However, the LOCA analysis for the LTA-311 fuel results in a MAPLHGR reduction factor that is not bounded by the other transients. Accordingly, a separate curve of MAPLHGR Flow Factor as a function of core flow has been added to Technical Specification 3.12.A for the LTA-311 assembly. This curve (for a maximum flow of 102.5 percent of rated) has a stepwise reduction in the factor to 0.95 at 70 percent flow. This is acceptable.

In addition the LTA-311 bundles have different single loop multiplication factors for MAPLHGR as described below.

Single Loop Operation

Inclusion of single loop operation (SLO) in the operational envelope of DAEC makes several revisions to the Technical Specifications necessary. These include:

1. Expanding the definition of REACTOR POWER OPERATION to include SINGLE LOOP OPERATION (SLO).

2. Increasing the safety limit value for MCPR from 1.07 to 1.10 in order to account for increased uncertainties in the measurement of core parameters.

3. Increasing the allowable operating (LCO) MCPR limit by 0.03 when in SLO in order to maintain operating margins.

4. Reducing the MAPLHGR limits to accommodate the reduced flow of SLO.

The particular changes in the Technical Specifications are described below.

• Defintion 8 "REACTOR POWER OPERATION"

This definition has been expanded to include a definition of SINGLE LOOP OPERATION (SLO). Such a definition permits a convenient reference to single loop operation in the Technical Specifications and is acceptable.

° Specification 1.1.A

This specification has been amended to include a value of 1.10 as the safety limit MCPR. This is conservative with respect to the approved value (see Amendment No. 119 for evaluation of core stability and single loop operation) and is acceptable.

° Specification 2.1.A Neutron Flux Trips and Table 3.1-1 and 3.2.C

The APRM High Flux Scram Trip has been reduced by 3.5 percent full power in order to protect the core from violation of the 1.10 MCPR value. This reduction is consistent with the increase in safety limit and is acceptable.

° Specification 3.12.A MAPLHGR

This specification has been changed to include a separate MAPLGHR Flow Factor Curve for SLO. This change has been made in order to mitigate against possible confusion to operators caused by having too much information on a single figure. This is acceptable.

The SLO reduction factor for 8x8 fuel has been increased from the current value of 0.7 to 0.87. The reduction factor for LTA-311 fuel is 0.74 (see separate evaluation of stability and single loop operation).

° Specification 3.12.C MCPR

This specification has been altered to require the addition of 0.03 to the MCPR value obtained for the power and flow conditions in the core. This is consistent with the change in the safety limit MCPR and is acceptable.

Based on the above review, we conclude that the proposed Extended Load Line Limits and ARTS Improvement Program are acceptable for use in the Duane Arnold Energy Center. This conclusion is based on the following:

1. The analysis methods used for the safety analyses presented in the report are those which have been previously used and approved for reload safety analyses.

2. The revised operating limits and procedures do not result in reductions to safety margins relative to current values. In general, margins are increased.

3. The revised operating procedures are simpler to follow which tends to increase operating safety.

3.0 ENVIRONMENTAL CONSIDERATIONS

This amendment involves a change in the installation or use of a facility component located within the restricted area as defined in 10 CFR Part 20. The staff has determined that the amendment involves no significant increase in the amounts, and no significant change in the types, of any effluents that may be released offsite, and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that this amendment involves no significant hazards consideration and there has been no public comment on such finding. Accordingly, this amendment meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b) no environmental impact statement or environmental assessment need be prepared in connection with the issuance of this amendment.

4.0 CONCLUSION

We have concluded, based on the considerations discussed above, that (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, and (2) such activities will be conducted in compliance with the Commission's regulations, and the issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public.

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