SEP TECHNICAL EVALUATION

TOPIC VIII-4
ELECTRICAL PENETRATIONS OF REACTOR CONTAINMENT

LACROSSE BOILING WATER REACTOR

Dairyland Power Cooperative

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1.0 INTRODUCTION

This review is part of the Systematic Evaluation Program (SEP), Topic VIII-4. Dairyland Power Cooperative (DPC) has provided information[1] describing typical penetrations, typical in-containment loads, and fault currents. Reference 1 did not provide an analysis of the suitability of the penetrations and circuit protection devices. Reference 2 is a previous NRC analysis of the suitability of the penetrations and their circuit protective devices. The objective of this review is to determine the capability of the overcurrent devices to prevent exceeding the design rating of the electrical penetrations through the reactor containment upon short circuit conditions at LOCA temperatures.

General Design Criterion 50, "Containment Design Basis" of Appendix A, "General Design Criteria for Nuclear Power Plants" to 10 CFR Part 50 requires that penetrations be designed so that the containment structure can, without exceeding the design leakage rate, accommodate the calculated pressure, temperature, and other environmental conditions resulting from any loss-of-coolant accident (LOCA).

IEEE Standard 317, "Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations", as augmented by Regulatory Guide 1.63, provides a basis of electrical penetrations acceptable to the staff.

Specifically, this review will examine the protection of typical electrical penetrations in the containment structure to determine the ability of the protective devices to clear the circuit during a short circuit condition prior to exceeding the containment electrical penetration test or design ratings at an initial LOCA temperature.

2.0 CRITERIA

IEEE Standard 317, "Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations" as supplemented by Nuclear Regulatory Commission Regulatory Guide 1.63, "Electric Penetration Assemblies in Containment Structures for Light-Water-Cooled Nuclear Power Plants" provides the basis acceptable to the NRC staff. The following criteria are used in this report to determine compliance with current licensing requirements:

(1) IEEE Standard 317, Paragraph 4.2.4 -- "The rated short circuit current and duration shall be the maximum short circuit current in amperes that the conductors of a circuit can carry for a specified duration (based on the operating time of the primary overcurrent protective device or apparatus of the circuit) following continuous operation at rated continuous current without the temperature of the conductors exceeding their short-circuit design limit with all other conductors in the assembly carrying their rated continuous current under the specified normal environmental conditions."

This paragraph is augmented by Regulatory Guide 1.63, Paragraph C-1 -- "The electric penetration assembly should be designed to withstand, without loss of mechanical integrity, the maximum possible fault current versus time conditions that could occur given single random failures of circuit overload protection devices."

(2) IEEE Standard 317, Paragraph 4.2.5 -- "The rated maximum duration of rated short circuit current shall be the maximum time that the conductors of a circuit can carry rated short circuit current based on the operating time of the backup protective device or apparatus, during which the electrical integrity may be lost, but for which the penetration assembly shall maintain containment integrity."

3.0 DISCUSSION AND EVALUATION

In this evaluation, the results of typical containment penetrations being at LOCA temperatures concurrent with a random failure of the circuit protective devices will be analyzed.

DPC has provided information (Reference 1) and the NRC has prior information (Reference 2) on typical penetrations. All were manufactured by General Cable Company. No short circuit test data was made available by DPC for these penetrations. Under accident conditions, a peak containment temperature of 280°F (138°C) is expected.

In supplying the value of the maximum short circuit current available (I_{sc}), DPC supplied values for a three-phase (on a three-phase system) bolted fault; this type being able to supply the most heat into the penetration. DPC did not specify if the I_{sc} value includes, in the symmetrical AC component, contributions by other connected induction motors.

The following formula (Reference 7) was used to determine the time allowed for a short circuit before the penetration temperature would exceed its limiting value.

$$\left[\frac{I}{A}\right]^2 t = 0.0297 \log \left[\frac{T_2 + 234}{T_1 + 234}\right]$$

$$t = \frac{0.0297\ A^2}{I_{sc}^2} \log \left[\frac{T_2 + 234}{T_1 + 234}\right] \qquad \text{(Formula 1)}$$

where

t = Time allowed for the short circuit – seconds

I_{sc} = Short circuit current – amperes

A = Conductor area – circular mils

T_1 = Maximum operating temperature (138°C, LOCA condition, to account for current in other penetration conductors)

T_2 = Maximum short circuit temperature (limiting factor for a given penetration).

This is based upon the heating effect of the short circuit current on the conductors. Credit for any time lag for the seal materials in reaching elevated temperatures is not given in this review.

It should be noted that the short circuit temperature-time limits of the conductors in this report vary from the values calculated by DPC (Reference 1). This report uses the DPC supplied fault current magnitude and a assumed smaller temperature rise to calculate the maximum time allowed to clear a fault condition. Also in this report, a pre-fault penetration conductor temperature equal to the peak LOCA containment atmosphere temperature is assigned, thus simplifying, while accounting for, an elevated conductor temperature caused by a pre-existing current flow and an above normal ambient temperature.

3.1 <u>Typical Low Voltage (0-1000 VAC) Penetration</u>. DPC has provided information on a penetration for the Seal Injection Pump 1A as typical of a 480-V AC circuit. This penetration has a multi-conductor #4 mineral insulated copper sheathed cable. Reference 2 has identified epoxy seals on each end of the penetration which results in a limiting temperature of 320°F (160°C) for the penetration. The maximum I_{sc} available at this penetration is approximately 17,000 rms amperes symetrical.

It is calculated that, with the 160° temperature limit of the seal material, this short circuit current can be carried by the penetration for 0.005 second before the penetration conductors exceed 160°C, with an initial temperature of 138°C (peak LOCA in-containment temperature).

Both the primary circuit breaker and the backup fuse will clear this fault in less time than this (essentially instantaneous at this level). At all levels of current less than maximum I_{sc}, the primary circuit breaker cleared the fault, while the backup fuse failed to clear the fault before the conductor temperature exceeded 160°C.

3.1.1 Low Voltage Penetration Evaluation. With an initial penetration temperature of 138°C (the LOCA containment temperature), the containment electrical penetration design for this low voltage penetration is not in conformance with the criteria described in Section 2.0 of this report for all levels of overcurrent. The DPC also supplied curves showing that, above the rated current of the penetration (90 ameres), no protection is afforded until 120 amperes (primary) and 350 amperes (backup). It is recommended that DPC investigate other possibilities of protecting this penetration and circuit.

3.2 Typical Medium Voltage (>1000 VAC) Penetration. DPC has provided information on a penetration used to power the forced circulation pump 1A as typical of medium voltage penetrations. Each penetration consists of multi-conductor #4/0 mineral insulated, copper sheathed cable. Again, the temperature limiting element of the hermetic seal of the penetration is the epoxy seal which softens at 160°C.[2] The maximum I_{sc} available at the penetration is approximately 22,000 rms symetrical amperes. DPC did not supply the asymetrical fault current.

It is calculated that 0.07 second elapse after a fault occurs at a penetration temperature of 138°C (LOCA containment temperature) before the conductors exceed the temperature limit of 160°C.

The fault clearing time of the primary and the identical secondary circuit breakers are approximately 0.5 second per Reference 1. Only at levels of current between 2800 and 6400 amperes, do both circuit breakers clear the fault before the conductor temperature exceeds 160°C.

3.2.1 Medium Voltage Penetration Evaluation. With an initial penetration temperature of 138°C (the LOCA containment temperature), the containment penetration design for this medium voltage penetration is not in conformance with the criteria described in Section 2.0 of this report for all levels of overcurrent. Moreover, as the DPC supplied information shows, neither circuit breaker provides the penetration with protection between the rated continuous current (235 amperes) and approximately 2500 amperes. It is recommended that DPC investigate other means of protecting this penetration.

3.3 Typical Direct Current Penetration. DPC has provided information for a typical 125-V DC penetration used with DC magnetic clutches. The penetration construction is identical to that discussed in Section 3.1 except that a multiconductor #6 mineral insulated cable is used. The temperature limit is also 160°C.[2] The maximum I_{sc} available at this penetration is approximately 5000 amperes.

It is calculated that the maximum I_{sc} can be carried by this penetration for 0.02 second before the conductor temperature reaches 160°C.

The primary circuit breaker and the secondary fuse curves supplied by DPC show that both the primary circuit breaker and the secondary fuse will clear this fault in less than .01 second. At all current levels above the 70-ampere rating of the penetration, the clearing time is adequate to prevent damage to the penetration seal.

3.3.1 Direct Current Penetration Evaluation. With an initial penetration temperature of 138°C (the LOCA containment temperature), t containment electrical penetration design for this DC penetration is in conformmance with Section 2.0 of this report.

4.0 SUMMARY

This evaluation looks at the capability of the circuit protective devices to prevent exceeding the design test ratings of the selected penetrations to maintain containment atmosphere isolation in the event of (a) a LOCA event, (b) a fault current through the penetration and simultaneously, (c) a random failure of the circuit protective devices to clear the fault. The environmental qualification tests of the penetrations is the subject of SEP Topic III-12.

This assessment neglects any heat transfer from the penetration to the containment liner. To account for rated current in the penetration conductors, an initial penetration temperature equal to the peak LOCA in-containment temperature was assigned.

With a LOCA environment inside containment, the protection of the DC penetration conforms to the specified criteria, which assumes a short circuit fault and a single random failure of the circuit protective devices. Under the same circumstances, it is expected that the temperature of both AC penetrations analyzed will exceed the temperature limit of the hermetic seals. The medium voltage penetrations analyzed will exceed the temperature limit of the penetration in a LOCA environment without failure of circuit protective devices, at currents greater than 6400 amperes, or between the rated continuous current and 2800 amperes.

The review of Topic III-12, "Environmental Qualification," may result in changes to the electrical penetration design and therefore, the resolution of the subject SEP topic will be deferred to the integrated assessment, at which time, any requirements imposed as a result of this review will take into consideration design changes resulting from other topics.

5.0 REFERENCES

1. F. Linder, DPC, LAC-6210, to D. L. Ziemann, NRC, "Systematic Evaluation Program (SEP), Topic VIII-4", Docket No. 50-409, April 17, 1979, DPC letter.

2. R. W. Reid, NRC, to Dairyland Power Cooperative, Docket No. 50-409-411, August 12, 1976, NRC letter.

3. General Design Criterion 16, "Containment Design" of Appendix A, "General Design Criteria of Nuclear Power Plants," 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."

4. Nuclear Regulatory Commission Standard Review Plan, Section 8.3.1, "AC Power Systems (Onsite)."

5. Regulatory Guide 1.63, Revision 2, "Electrical Penetration Assemblies in Containment Structures for Light-Water-Cooled Nuclear Power Plants."

6. IEEE Standard 317-1976, "IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations."

7. IPCEA Publication P-32-382, "Short Circuit Characteristics of Insulated Cable."

8. IEEE Standard 242-1975, "IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems."