SEP TECHNICAL EVALUATION

TOPIC VIII-4
ELECTRICAL PENETRATIONS OF REACTOR CONTAINMENT

MILLSTONE NUCLEAR STATION, UNIT NO. 1

Northeast Utilities

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1.0 INTRODUCTION

This review is part of the Systematic Evaluation Program (SEP), Topic VIII-4. The objective of this review is to determine the capability of the electrical penetrations of the reactor containment to withstand short circuit conditions of the worst expected transient fault current resulting from single random failures of circuit overload protection devices.

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 faults prior to exceeding the penetration design ratings under LOCA temperatures.

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 temperature initially concurrent with a random failure of the circuit protective devices will be analyzed.

Northeast Utilities (NU) provided information (References 1 and 2) on typical penetrations. No evaluation of the data was provided. A temperature limit of 352°F (177°C) before seal failure for the three penetrations has been established based on testing done by Oyster Creek Nuclear Station for identical type connectors (Reference 2).

Maximum short circuit current available (I_{sc}) was provided by Northeast Utilities for a three-phase bolted fault. Rated current (I_r) for each penetration was also provided.

The following formula (Reference 3) was used to determine the time allowed before a short circuit would cause the penetration to heat up to the temperature limit.

$$t = \frac{A^2}{I^2} \quad .0297 \log \frac{T_2+234}{T_1+234} \qquad \text{(Formula 1)}$$

where

t = time in seconds

I = current in amperes

A = conductor area in circular mils

T_1 = initial temperature (138°C, LOCA condition)

T_2 = maximum penetration temperature before failure.

This is based on the heating effect of the short circuit current on the conductor and does not take into account heat losses of the conductor. For times less than several seconds, this heat loss is negligible.

In evaluating the capability of the penetration to withstand a LOCA temperature with a short circuit current, Formula 1 was used to calculate the time required to heat the conductor from the LOCA temperature to penetration failure temperature for currents from rated current to maximum short circuit current in 20% increments. Times for the primary and secondary overcurrent devices to interrupt these fault currents were calculated. Where breaker ratings provided by the licensee indicated minimum and maximum fault clearing times, the maximum time was used for conservatism.

3.1 Typical Low Voltage (0-1000V) Penetrations. Northeast Utilities has identified penetration X-105D (GE type NS04) as being typical of low voltage penetrations. This penetration provides 480 V ac power to motor-operated valve 1-IC-1.

This penetration uses #8 AWG cable and has a continuous current rating of 20 amps. The maximum available short circuit current has been determined by NU to be 1600 amps. A temperature limit of 352°F (177°C) before seal failure has been determined based on testing. At the maximum short circuit current (1600 amps), overtemperature will be reached in 0.14 second from LOCA temperature initially.

From LOCA temperature initially, neither the primary nor secondary breaker will operate to clear any fault currents before penetration seal limiting temperature is attained.

3.1.1 Low Voltage Penetration Evaluation. With an initial penetration temperature of 138°C (LOCA), penetration X-105D does not meet current requirements of RG 1.63 and IEEE Std. 317 for any short circuit fault with a failure of the primary breaker. Furthermore, it does not meet current requirements for short circuit faults even if the primary breaker operates as designed.

3.2 Typical Medium Voltage (>1000 V) Penetration. Northeast Utilities has identified penetration X-101A (GE type NS03) as being typical of medium voltage penetrations. This penetration provides 4160 V ac power to Reactor Recirculation Pump 1.

This penetration uses 500 MCM cable and has a continuous current rating of 550 amps. The maximum available short circuit current has been determined by NU to be 1700 amps. A temperature limit of 352°F (177°C) has been established based on testing. At the maximum short circuit current (1700 amps), overtemperature will be reached in 110 seconds from LOCA temperature initially.

There are no circuit protective devices located between the motor generator and the reactor recirculation pump. Overcurrent protection is provided by a differential current sensing relay and a line overcurrent sensing relay, each of which will operate to trip the motor generator by securing power to the motor generator motor and opening the generator field windings. At ≥156 amps of current difference between phases, the differential relay will cause a trip of the motor generator in 0.133 second or less. At line current in excess of 780 amps, the overcurrent relay will cause a trip of the motor generator in 0.18 second or less.

For a three-phase short circuit condition, it cannot be assumed that sufficient current differences will exist to cause the differential relay to operate and trip the motor generator. Therefore, operation of this relay cannot be expected to clear fault currents prior to exceeding the penetration seal temperature limit of 177°C. For fault currents producing current differences between phases in excess of 156 amps, this relay will operate to trip the motor generator prior to reaching the penetration seal temperature limit.

The line overcurrent relay will operate to clear all fault currents in excess of 780 amps prior to reaching the penetration seal temperature limit from LOCA temperature initially. For fault currents less than 780 amps, this relay will not operate to trip the motor generator.

3.2.1 Medium Voltage Penetration Evaluation. At LOCA temperature, penetration X-101A does not meet current requirements of RG 1.63 and IEEE Std. 317 for short circuit faults with a failure of the line overcurrent relay since the differential relay cannot be assumed to operate for a three-phase short circuit. With a failure of the differential current relay at LOCA temperature, the penetration does not meet current requirements for fault currents less than 780 amps.

3.3 Typical Direct Current Penetration. Northeast Utilities has identified penetration X-100A (GE type NS04) as being typical of DC penetrations. This penetration provides 125 V dc power to the solenoid valve on main steam isolation valve 203-1A.

This penetration uses #14 AWG cable and has a continuous current rating of 10 amps. The maximum available short circuit current has been determined by NU to be 95 amps. A temperature limit of 352°F (177°C) before seal failure has been determined based on testing. At the maximum short circuit current (95 amps), overtemperature will be reached in 2.38 seconds from LOCA temperature initially.

At LOCA temperature, both the primary and secondary fuses will operate to clear all fault currents before the penetration seal temperature limit is reached.

3.3.1 DC Penetration Evaluation. At LOCA temperature, penetration X-100A meets current requirements of RG 1.63 and IEEE Std. 317 for all fault currents with a failure of the primary protective device.

4.0 SUMMARY

At LOCA temperature, penetrations X-105D and X-101A do not meet current requirements of RG 1.63 and IEEE Std. 317 for any fault current with a failure of the primary protective device. Furthermore, penetration X-105D does not meet current requirements even if the primary breaker operates as designed. Penetration X-101A does not meet current requirements with a failure of the line overcurrent relay at LOCA temperature with a short circuit. If the line overcurrent relay operates as designed under these conditions, the penetration still does not meet current requirements for fault currents less than 780 amps.

At LOCA temperature, penetration X-100A meets current requirements of RG 1.63 and IEEE Std. 317 for all fault currents with a failure of the primary protective device.

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. Northeast Utilities letter (Counsil) to NRC (Ziemann) dated March 14, 1979.

2. Final Description and Safety Analysis Report, Oyster Creek Nuclear Station, Ammendment 62 (Docket No. 50-219-102).

3. IPC&A Publication P-32-382, "Short Circuit Characteristics of Insulated Cable."