SHIELDING REDUNDANT ESSENTIAL ELECTRICAL EQUIPMENT FROM THE EFFECTS OF FIRE SUPPRESSION WATER

R. Barnes - Gage Babcock & Associates, Inc.

E. MacDougall - Brookhaven National Laboratory

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Shielding Redundant Essential Electrical Equipment
From the Effects of Fire Suppression Water Application

1. General

As an adjunct to the program of protecting redundant safe shutdown systems in nuclear power generating stations from the effects of fires, a concern about the effects of fire suppression water spray on these same systems has developed. The problem centers around the possibility that fire suppression water application may damage redundant safe shutdown equipment or instrumentation when that redundant equipment is located in the same room or area. If the application of water, either from a fixed extinguishing system or from manual hose line application, can cause the loss of redundant safe shutdown systems, then the method of suppressing fires has in itself become a causative factor of failure, or a threat to the safe operation and shutdown of the reactor.

The initial review of the effects of fires on redundant safe shutdown equipment resulted in the identification of four ways to assure that a single fire incident would not affect redundant safe shutdown systems located in the same fire area:

1. Construct fire rated barriers to separate the redundant systems.

2. Relocate one of the redundant systems to a separate fire area.

3. Provide automatic water suppression, in conjunction with appropriate barriers where necessary to assure the integrity of at least one of the redundant systems prior to initiation of fire suppression efforts, either automatic or manual, to extinguish fires in permanent or transient combustibles.

4. Provide an alternate shutdown capability which is independent of the area in question and which will perform the same shutdown functions.

Methods 1, 2, and 4 essentially place redundant safe shutdown systems in separate fire areas of the plant, with fire-rated barriers providing separation and water spray giving further protection to assure that both redundant systems will not be rendered inoperable.

Method 3, however, leaves redundant equipment in the same area. Depending on equipment separation, there may or may not be a barrier, or heat shield, placed between the redundant equipment. In either case, the equipment may be easily susceptible to damage, either from overhead sprinkler systems or from hand-held hose line water streams.

Damage to electrical equipment from fire water may be caused by three basic processes: direct water impingement on the electrical equipment; water seepage or runoff along floors, cable, cable trays, or equipment back to the electrical equipment; and elevation of the humidity level above that for which the equipment was designed. Any measures to protect electrical equipment from the damaging effects of water must consider all three processes.

As a basic starting point for discussing the problems and solutions to the water spray problem, it will be assumed that adequate protection and/or separation are provided to prevent disruption of both redundant trains of safe shutdown equipment from a single fire source. As with the general fire protection criteria, there may be areas in a nuclear power plant where the proposed solutions meaning barrier, cooling suppression, etc. are not practical because of space limitations, equipment type, or other considerations. In such cases, equipment should be moved or alternate shutdown capability should be provided.

Regardless of the shielding or other methods provided to protect equipment from the damaging effects of water spray, one may not be able to assure that both redundant systems will remain operational. As with a fire which occurs at one of the redundant pieces of equipment, the possibility that damage to one system will occur will always exist. The purpose of the protection postulated here is to assure that at least one of the redundant safe shutdown systems will always remain operational.

In order to determine if there were any requirements regarding the ability of Class IE electrical equipment to withstand the effects of water, 36 IEEE and 5 ANSI reports were reviewed, see Appendix A.

Only one of the standards listed, ANSI N42.4-1971, "American National Standard for High Voltage Connectors for Nuclear Instruments," provided specific criteria for resistance to the effects of moisture. ANSI 42.4 applies to coaxial high voltage connectors on nuclear instruments, and in Section 2.13 states:

> "Moisture Resistance. Connectors shall meet the following moisture resistance test: Connectors shall be exposed to 95 percent relative humidity at 40°C for 96 hours. Connectors shall then be removed to an environment of 50 percent relative humidity at 25°C. Within 5 minutes after removal from the 95 percent relative humidity, 40°C environment, the insulation resistance shall be not less than 10^{12} ohms."

For nuclear plants built to this standard, there is some assurance that the high voltage connectors can withstand high humidity. For the purposes of this study, this fact is not applicable since we're concerned with all components in Class IE electrical equipment in both spray and high humidity.

The remainder of the standards listed do not contain any specific water-resistance criteria.

2. Protection from Overhead Fire Suppression Systems

Protecting electrical equipment from the damaging effects of water spray from an overhead water suppression system has been a concern for many years. The concerns generally expressed center around the belief that the water spray from the sprinklers could cause even more damage to equipment than would be experienced if the system were not installed or that inadvertent operation of the system could cause damage without a fire.

Experience has shown that in case of a fire there should be little concern that the water from a suppression system will cause excessive damage to equipment. If a fire develops sufficiently enough to operate the sprinklers, the sprinklers, if properly installed and maintained, will provide for effective fire control and extinguishment with no measurable increase in damage to electrical equipment over that which could reasonably be expected from heat, smoke, and flame if the sprinklers were not installed. If the electrical equipment is installed so that redundant systems could be damaged by the discharge from an overhead water suppression system operating in response to a fire, then that same equipment is most likely susceptible to direct fire damage and is not adequately protected.

The fact that nuclear power plants should protect themselves from damage to their power system due to the operation of an overhead sprinkler system is spelled out in IEEE 308 - see Appendix B-1. This includes both the design operation of the overhead sprinkler in case of a fire and the inadvertant operation of the system.

However, for motors the case is not as clear. IEEE standard 334, see Appendix B-2, leaves the decision as to weatherproof or waterproof integrity is required to the owner-operator.

A few instances may exist where a partial fire-rated partition has been erected between redundant equipment. In such cases, it is possible that a fire on one side of the partition could set off a sprinkler head which would wet down areas on both sides of the partition. In such cases, or where it is desirable to protect an individual piece of equipment from the effects of overhead water spray, enclosures for the equipment should meet the NEMA requirements for enclosures for outside protection, particularly for protection against rain, snow and sleet. The various types of NEMA enclosures are listed in NEMA publication Part 105.1-110 "Enclosures" - February 1973 pages 1-17. The NEMA requirement for rainproof and raintight enclosures requires a rain test which is to produce a continuous water spray at a rate of 18 inches per hour at an operating pressure of 5 psi for one hour. This flow rate would be the equivalent of approximately 0.19 gpm/sq. ft. of sprinkler discharge. Typical automatic sprinkler densities for automatic sprinkler systems commonly utilized in nuclear power plants range from 0.10 to 0.30 gpm/sq. ft. Such enclosures will adequately protect the equipment from falling water spray. To protect the equipment from water collection or run-off on the floor, the equipment should be mounted on pedestals or other means should be provided to prevent water accumulation from damaging the equipment.

In order to protect from overhead water spray, NEMA weathertight enclosures should be used if possible. Although these enclosures will not necessarily protect the electrical equipment from impinging horizontal hose sprays, they do offer protection from vertically falling water, and may provide somewhat better protection from the horizontal spray than non-weathertight enclosures.

Another method of providing protection from overhead water spray is to install noncombustible shields over the equipment to be protected. Such shields should extend far enough beyond the sides of the equipment to prevent direct water impingement on the sides of the equipment from sprinklers in the area.

Means should also be provided to prevent water from running back to the equipment along cable, conduit, or other possible means of conveyance from the area outside of the shields.

Although shielding can be an effective way to protect equipment from sprinkler water, they have an important drawback. A fire in the equipment or area under a shielding may not be extinguished by the sprinkler system, thus allowing additional products of combustion to be developed which may directly affect redundant equipment. In addition, an unnecessarily large number of sprinklers may open which could create additional water problems, or the use of hose lines may become necessary to extinguish the fire, thus resulting in even more water damage.

The problem of inadvertent operation of the sprinkler system should be of little concern as far as safe plant shutdown is concerned if the equipment is adequately protected and separated from a fire protection viewpoint and from possible overhead water impingement as indicated above. To reduce the already minimal incidences of inadvertent sprinkler operation, pre-action sprinkler systems may be used. Such systems require two actions (detection system and fusible link actuation) before water is discharged on a fire. They also would require two essentially simultaneous failures to produce a water spray inadvertently.

3. Protection from Hand Held Fire Hose Lines

Protection of electrical equipment from the damaging effects of water spray from hand-held fire hose lines is a very real concern and must be addressed for those areas where redundant safe shutdown equipment is located in the same room or area. Whereas spatial separation in conjunction with automatic suppression may be adequate to assure that sprinklers will not operate in the vicinity of both redundant pieces of equipment, the same cannot be said for hand-held hose lines which are not limited in application to those areas where sufficient heat is generated to operate overhead sprinklers.

Since ventilation systems in existing nuclear power generating plants are generally not designed to act as smoke control or smoke removal systems, even relatively small fires may produce sufficient quantities of smoke to restrict visibility in the fire area. With poor visibility hindering the discovery of the exact location of the fire in a room or area, discreet application of fire hose water to limit damage becomes very unlikely.

We recommend the use of portable fans and ducting to remove smoke and improve visibility for the fire fighter. It is assumed that only fog nozzles will be used around electrical equipment. However, the use of fog type nozzles does not completely eliminate the concern for water damage to any equipment in an area. Although the distance that a fog type water spray pattern can reach is considerably less than a solid stream, the water discharge can thoroughly wet down all equipment in a given area. With poor visibility, the fog spray could easily be applied to redundant equipment, thus causing the loss of safe shutdown capability.

To protect electrical equipment from the effects of hose water application, enclosures for the equipment could be required to be NEMA watertight enclosures. However, NEMA watertight enclosures are nonventilated enclosures which is a major problem for Class 1E equipment in nuclear plants since most of the Class 1E equipment requires ventilation to prevent overheating.

As noted in part 2, weathertight enclosures may provide somewhat better protection against a horizontal hose spray.

To provide adequate protection of redundant equipment from hose sprays, a barrier wall should be provided, if possible, to separate the redundant equipment into distinct and separate areas. The barrier should be designed such that there would be little probability that hose streams would be required to be used in both areas. Consideration must also be given to the probability of smoke infiltrating both areas, thus making the use of hose in both areas more likely prior to discovery of the source of fire.

Another method of protecting the equipment would be to provide baffles or shield walls erected in such a manner around each piece of equipment to physically preclude a hose stream from impinging on the equipment unless the hose line is brought into the enclosed shield areas. This could be accomplished using offset or labrynth type openings to gain access to the equipment. Consideration would also need to be given to the possibility of the hose stream, being directed over the top of the shield walls or baffles, although NEMA weathertight enclosures would considerably lessen the effect of such water impingement.

The design of such shielding walls or partitions must take into consideration, among other things, the nature of the equipment, the location of the equipment with respect to its redundant counterpart, the congestion in the area both for combustible loading and fire brigade access, and the need for access to the equipment both for normal maintenance and operation and for possible suppression of fires within the equipment.

4. Conclusions

This study has been made for the purpose of recommending to the staff the best means of providing protection against the loss of safe shutdown equipment due to fire suppression water. The aim is to assure that at least one of the redundant safe shutdown systems will remain operational after the application of fire water suppression.

The greatest concern here is in the application of manual hose streams in a smoke filled room. To limit the risk of the fire brigade disabling redundant safety related equipment, we recommend specific training of the brigade on this problem.

To limit the risk of water suppression systems damaging safety related equipment we have recommended the use of the following as outlined in this report:

- fog type nozzles for electrical equipment fires
- NEMA rated weathertight or raintight enclosures - as noted in the report
- pedestal mounting of equipment
- shielding (only with precautions)
- pre-action sprinklers - as noted
- ventilation by portable fans
- barrier walls - where possible.

APPENDIX A

IEEE Std. 279-1971. IEEE Standard Criteria for Protection Systems for Nuclear Power Generating Stations

IEEE Std. 300-1969. IEEE Test Procedure for Semiconductor Radiation Detectors (For Ionization Radiation)

IEEE Std. 301-1968. IEEE Standard Test Procedure for Amplifiers and Preamplifiers for Semiconductor Radiation Detectors for Ionizing Radiation

IEEE Std. 308-1978. IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations

IEEE Std. 309-1970. IEEE Standard Test Procedure for Geiger-Muller Counters

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

IEEE Std. 323-1974. IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations

IEEE Std. 325-1971. IEEE Standard Test Procedures for Germanium Gamma-Ray Detectors

IEEE Std. 334-1974. IEEE Standard for Type Tests of Continuous Duty Class 1E Motors for Nuclear Power Generating Stations

IEEE Std. 336-1977. IEEE Standard Installation, Inspection, and Testing Requirements for Instrumentation and Electric Equipment During the Construction of Nuclear Power Generating Stations

IEEE Std. 338-1977. IEEE Standard Criteria for the Periodic Testing of Nuclear Power Generating Station Safety Systems

IEEE Std. 344-1975. IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

IEEE Std. 352-1975. IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Protection Systems

IEEE Std. 379-1977. IEEE Standard Application of the Single Failure Criterion to Nuclear Power Generating Station Class 1E Systems

IEEE Std. 380-1975. Definitions of Terms Used in IEEE Standards on Nuclear Power Generating Stations

IEEE Std. 381-1977. IEEE Standard Criteria for Type Tests of Class 1E Modules Used in Nculear Power Generating Stations

IEEE Std. 382-1972. IEEE Trial Use Guide for Type Test of Class 1 Electric Valve Operators for Nuclear Power Generating Stations

IEEE Std. 383-1974. IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations

IEEE Std. 384-1977. IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits

IEEE Std. 387-1977. IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations

IEEE Std. 398-1972. IEEE Standard Test Procedure for Photomultipliers for Scintillation Counting and Glossary for Scintillation Counting Field

IEEE Std. 415-1976. IEEE Guide for Planning of Pre-Operational Testing Programs for Class 1E Power Systems for Nuclear Power Generating Stations

IEEE Std. 420-1973. IEEE Trial-Use Guide for Class 1E Control Switchboards for Nuclear Power Generating Stations

IEEE Std. 450-1975. IEEE Recommended Practice for Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Generating Stations and Substations

IEEE Std. 484-1975. IEEE Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations

IEEE Std. 485-1978. IEEE Recommended Practice for Sizing Large Lead Storage Batteries for Generating Stations and Substations

IEEE Std. 494-1975. IEEE Standard Method for Identification of Documents Related to Class 1E Equipment and Systems for Nuclear Power Generating Stations

IEEE Std. 497-1977. IEEE Trial-Use Standard Criteria for Post Accident Monitoring Instrumentation for Nuclear Power Generating Stations

IEEE Std. 498-1975. IEEE Standard Supplementary Requirements for the Calibration and Control of Measuring and Test EQuipment Used in the Construction and Maintenance of Nuclear Power Generating Stations

IEEE Std. 566-1977. IEEE Recommended Practice for the Design of Display and Control Facilities for Control Rooms of Nuclear Power Generating Stations

IEEE Std. 577-1976. IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Power Generating Stations

IEEE Std. 603-1977. IEEE Trial-Use Standard Criteria for Safety Systems for Nuclear Power Generating Stations

IEEE Std. 634-1978. IEEE Standard CAble Penetration Fire Stop Qualification Test

IEEE Std. 645-1977. IEEE Test Procedures for High-Purity Germanium Detectors for Ionizing Radiation

IEEE Std. 680-1978. IEEE Standard Techniques for Determination of Germanium Semiconductor Gamma-Ray Efficiency Using a Standard Marinelli (Reentrant) Breaker Geometry

IEEE Std. C37.98. IEEE Standard Seismic Testing of Relays

ANSI N13.4-1971. American National Standard for the Specification of Portable X- or Gamma-Radiation Survey Instruments

ANSI N13.10-1974. American National Standard Specification and Performance of On-Site Instrumentation for Continuously Monitoring Radioactivity in Effluents

ANSI N42.4-1971. American National Standard for High Voltage Connectors for Nuclear Instruments

ANSI N42.5-1965. American National Standard Bases for GM Counter Tubes

ANSI N42.6-1965. American National Standard Interrelationship of Quartz-Fiber Electrometer Type Dosimeters and Companion Dosimeter Chargers

APPENDIX B-1

IEEE Standard 308, "IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations," states in Section 5 that a design basis event should not jeopardize safe operation or shutdown of the plant. Section 5.2 states:

> "The Class 1E Power Systems shall be capable of performing their function when subjected to the effects of any design basis event."

And in Section 5.4:

> "Design Basis. A specific design basis shall be provided for the Class 1E power systems of each nuclear power generating station. The design basis shall include as a minimum....
>
> (6) The malfunctions, accidents, environmental events, and operating modes (See Table 2) which could physically damage Class 1E power systems or lead to degradation of system performance and for which provisions must be incorporated."

The referenced Table 2 indicates that the postulated phenomena should include "fire, fire protection system operation, and accident generated flooding, sprays, or jets." The inclusion of the consideration of sprinkler system operation is clearly stated. A fire brigade hose stream should also be included as a fire protection system operation or as an accident generated spray (i.e. the "accident," or fire, requires the use of a hose stream). However, no more specific guidelines as to the qualification of the equipment is given in IEEE Standard 308.

APPENDIX B-2

IEEE Standard 334, "Standard for Type Tests of Continuous Duty Class 1E Motors for Nuclear Power Generating Station," in Section 11, states that the design basis event includes "a spray or jet of water, chemical solution, or other fluids." However, the standard also states that the owner-operator is to define the exact environment to be considered in each case. If the owner-operator does not include criteria for resistance to water in his equipment specifications, there essentially are none.

Several other standards reviewed basically say the same thing: the effects of water spray as a part of a design basis event scenario is a possibility, but the exact details are left to the owner-operator. If the owner-operator does not include criteria for resistance to hose and other water sprays, either by omission or by conclusion that such events won't occur, then there are no requirements for any water resistance of Class 1E equipment.