UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, DC 20555-0001

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NRC INFORMATION NOTICE 2002-27: RECENT FIRES AT COMMERCIAL NUCLEAR POWER PLANTS IN THE UNITED STATES

Addressees

All holders of operating licenses for nuclear power reactors, except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to inform addressees of recent fire incidents at commercial nuclear power plants (NPPs) in the United States. The NRC anticipates that recipients will review the information for applicability to their facilities and consider taking appropriate actions. However, suggestions contained in this IN do not constitute NRC requirements and, therefore, no specific action or written response is required.

San Onofre Nuclear Generating Station (SONGS)

Description of Circumstances

On February 3, 2001, SONGS Unit 3, was operating at 39-percent power following a refueling outage. While switching offsite power sources for Unit 3, a 4.16-kV breaker (3A0712) faulted and initiated a fire. This resulted in a loss of power to Unit 3 nonsafety-related systems, a reactor trip, a turbine/generator trip, and an automatic start of both Unit 3 emergency diesel generators (EDGs).

The main control room (MCR) received an annunciator fire alarm, along with a visual report of smoke and flames at the 30-foot elevation switchgear room of the turbine building. The incident was further complicated when the MCR annunciators were lost as a result of a tripped breaker approximately 5 minutes into the event.

The San Onofre onsite fire department was dispatched upon receipt of the fire alarm in the switchgear room and arrived at the scene within 7 minutes. The on-scene fire department captain requested additional support from an offsite fire department. Firefighters observed that the room was completely filled with heavy smoke, with essentially zero visibility. The source of the heavy smoke and heat was determined to be within the closed cubicle 4.16-kV switchgear cabinetry. The firefighters also noted flames from burning instrument gauges on the front of cubicle 3B14, which is located directly across from the 4.16-kV breaker cubicle. The onsite fire department captain established a command post, initiated fire suppression using portable fire extinguishers, and began ventilating the area. Communication between the onsite fire department captain and the plant shift manager was through the technical advisor at the scene. The firefighters discharged portable Halon and dry chemical fire extinguishers through the cabinet vents in an attempt to extinguish any active fire within the cabinet. The extinguishing agents had no noticeable effect on the production of smoke. The technical advisor transmitted to the operations shift manager a report that the fire was out, although the fire department captain only advised the operations technical advisor that flames were no longer visible.

With the exception of some low-voltage circuits, all power was isolated to the 4.16-kV switchgear. The firefighters then determined that the cubicle door could be opened safely. Upon opening the cubicle door, the firefighters observed flames within the cubicle, and discharged additional dry chemical in another attempt to extinguish the flames. The firefighters then closed the cubicle door as a containment measure. The cubicle door was subsequently opened several times, and each time the door was opened, in-rushing air caused the fire to reflash. Firefighters then used dry chemical each time the fire reflashed.

The fire department captain advised the operations technical advisor that the fire could not be completely extinguished unless the firefighters applied water to the fire. It appeared that the dry chemical temporarily removed air from the fire, but did not reduce the heat, and the fire would reflash once air was reintroduced. The operations technical advisor relayed this request to the shift manager for permission to use water on the smoldering area inside the cubicle to prevent reflash. Because he was concerned that the buses were still energized with 125-v dc and low-voltage ac power, the shift manager initially denied the fire department captain's request to use water. However, after the fire department captain spoke directly with the shift manager to advise him that the deep-seated fire could not be extinguished unless water was applied, the shift manager granted permission to use water to extinguish the fire. The fire was ultimately extinguished after firefighters applied water. The deep-seated fire burned for approximately 3 hours before finally being extinguished. The licensee later determined that communication weaknesses in identifying the actual fire status during the event contributed to the delay in extinguishment.

Discussion

The extensive damage made it difficult to determine the exact cause of the fault. The licensee found that the 4.16-kV switchgear phase C arcing contact had completely melted, and concluded that the phase C circuit breaker failed to close completely during the bus transfer. The breaker was approximately 25 years old and had its last preventive maintenance performed in 1997. The licensee also believed that arcing, fire, smoke, and ionized gases in the 4.16-kV circuit breaker caused multiple faults on a 3A07 bus and the offsite power circuit terminal connection at circuit breaker 3A0714.

The licensee also determined that the fire event generated a much higher heat release rate (HRR) than would normally be assumed in typical fire risk modeling to perform probabilistic risk assessment (PRA). In "A Supplement to EPRI Fire PRA Implementation Guide (TR-105928)," report SU-105928, the Electric Power Research Institute (EPRI) provides data for electrical cabinet fires, indicating an HRR of either 68.60-kW or 200.50-kW (65- or 190-Btu/sec), depending on the type of cable installed. The EPRI data focus on the HRR contributions of combustibles in the electrical cabinet (only cable insulation) and neglect the large amounts of electrical energy that may be released from electrical faults. According to a report by the NRC's Office of Nuclear Regulatory Research, entitled "Operating Experience Assessment

Energetic Faults in 4.16-kV to 13.8-kV Switchgear and Bus Ducts That Caused Fires in Nuclear Power Plants in 1986–2001" (ADAMS Accession #ML021290358, February 2002) for medium- and high-voltage applications, the research indicates that these HRR values [68.60-kW and 200.50-kW (65- and 190-Btu/sec)] may be underpredicted by a factor of 1,000.

This operating experience indicates that equipment rated at 4.16-kV and higher is vulnerable to particularly energetic electrical faults. This event demonstrates that energetic electrical faults instantaneously release large amounts of electrical energy and may bypass the normal fire initiation and growth stages. In the SONGS fire event, the equipment that caught fire was directly connected to the auxiliary transformer (AT), which is powered from the grid or main generator. If a circuit breaker is stuck or slow in responding, there is sufficient energy to cause an explosion and vaporize metal in a few cycles.

Conclusion

This event demonstrates the importance of using water to extinguish deep-seated electrical cable fires. It is similar to previous fire events (Browns Ferry 1975, Waterford 1995) in which delayed application of water on electrical fires extended the duration of the fires and delayed recovery from the events. It is essential that fire brigade and operator training address the appropriate use of water in firefighting operations in energized electrical equipment. This event also highlights that the HRR from fires in electrical cabinets may be much greater than assumed in NPP fire hazard analysis (FHA).

Point Beach Nuclear Plant

Description of Circumstances

On April 24, 2001, while Point Beach Unit 1 was shut down and defueled for refueling outage U1R26, a fire occurred in the "A" steam generator (S/G) vault on the access platform to the primary side manway covers. The fire was believed to originate as the result of a short in a 12-Vdc communication box. The fire consumed a bag of rags and testing equipment debris, and lasted for approximately 23 minutes. After multiple failed attempts in which the fire brigade discharged approximately 70 pounds of dry chemical (3 portable fire extinguishers), the fire was finally extinguished using 15–20 gallons of water. The licensee reported that approximately 50 percent of the containment basement floor (8 feet elevation), 50 percent of the "A" S/G vault, and 30 percent of the "A" reactor coolant pump (RCP) vault were covered in white dust (dry chemical fire extinguishing agent). Also, a white dust layer was visible on components on the main refueling floor (66 feet evaluation). Smoke and soot resulting from the fire left a mark about 4 feet wide by 25 feet high against the vault wall.

Discussion

The dry chemical extinguishing agent is discharged by an inert gas when a fire extinguisher is used. All forms of dry chemical act as extinguishing agents to suppress the flame of a fire (Friedman, 1998), but may require extensive cleanup after use, as illustrated by this event.

Most chemical extinguishing agents can produce some degree of corrosion or other damage, but of the seven types of dry chemicals, monoammonium phosphate is especially acidic and tends to corrode more readily than other dry chemicals, which tend to be more neutral or mildly alkaline. Furthermore, corrosion resulting from the other dry chemicals is stopped in a moderately dry atmosphere, while phosphoric acid generated by using monoammonium phosphate has such a strong affinity for water that an exceedingly dry atmosphere would be needed to stop the corrosion.

Application of dry chemical agents on electrical fires is considered a safe practice from the viewpoint of electric shock. However, these agents, especially monoammonium phosphate, can damage delicate electrical equipment.

One potential issue with using dry chemical extinguishers results from the sudden release of the agent and the large area of discharge. Dry chemicals become sticky when heated and, therefore, are not recommended for locations where it may be difficult to remove residue from equipment. It is important to note that when water is applied to the affected areas, corrosion will occur because moisture initiates a chemical reaction that accelerates corrosion of equipment exposed to the dry chemical.

Dry chemicals are generally nontoxic, but can pose a health hazard when used in closed areas. Persons who breathe concentrations of the dry chemical powder may experience respiratory irritation and coughing. When dry chemicals are discharged into an enclosed area, impaired breathing and reduced visibility should be considered.

Conclusion

Although the Point Beach incident lasted approximately 23 minutes, it was not a large fire in terms of HRR. The dry chemical extinguishing agent did suppress the fire, but failed to completely extinguish the fire (the fire reflashed twice). The fire brigade unsuccessfully attempted to extinguish the fire with dry chemical agent three times before easily extinguishing it with a hose line (water). A more thorough selection of extinguishing media should be considered in light of the cleanup effort from the small fire. It is important to recognize that the fire was successfully extinguished with a relatively small quantity of water, which required minimal post-fire cleanup.

Prairie Island Nuclear Generating Plant

Description of Circumstances

On August 3, 2001, at 8:44 p.m., an operator enroute to the Unit 1 bus 11/12 area observed fire and smoke, but could not identify the cubicle from which it was originating. The operator entered the bus 13/14 room and called the main control room (MCR) to report the fire. The MCR immediately initiated the fire alarm and activated the onsite fire brigade. The MCR also notified the offsite Red Wing Fire Department (RWFD).

The fire brigade entered the turbine building to assess the extent and exact location of the fire. They reported flames in the upper and lower compartments of the 12-4 cubicle and along the left side of the breaker. They also found that the door in both the upper and lower compartments of the cubicle were blown open.

At 8:58 p.m., the fire brigade began initial suppression of the fire using three portable carbon dioxide (CO_2) extinguishers and one Halon extinguisher through the open front door of the breaker cubicle. The fire was not extinguished, and the fire brigade observed electrical arcing in cubicle 12-4.

The fire appeared to be localized in one area and not spreading. The initial efforts to deenergize the bus from the MCR failed. The fire brigade chief reported to the MCR that breaker 12-4 was still energized, as evidenced by arcing observed in cubicle 12-4. Because of the uncertainty as to whether bus 12 was deenergized, the Unit 2 shift supervisor decided to deenergize the 1R transformer. The fire department reported to the MCR that there were small flames and heavy smoke in breakers 12-1 and 12-4. At 10:13 p.m., approximately 1.5 hours into the event, the fire brigade extinguished the fire with assistance from the RWFD.

Discussion

The fire was extinguished after 1.5 hours by using more than 20 portable CO_2 fire extinguishers in the evolution (in addition to the 3 CO_2 extinguishers and 1 Halon extinguisher used in the initial attack). One factor that complicated extinguishing the fire was the decision not to use water because of energized electrical equipment. This resulted in continued burning and elevated temperature. Because of the elevated temperature caused by this electrical fire, two fire brigade members were treated for heat exhaustion at the site, and one of them was subsequently transported to the hospital for further treatment. In addition, several inches of the copper feed stabs from the 1M transformer completely vaporized during this fire (providing additional evidence of high temperature).

The licensee determined that the cause of the event was a poor electrical connection between the breaker 12-4 C-phase primary disconnect assembly (PDA) and the 1MY bus stab, which caused the PDA to overheat. The arcing also actuated the protective relaying, which resulted in an automatic turbine/reactor trip. The arcing event at breaker 12-4 released enough energy to cause the cubicle to expand and the door to be blown open. The breaker compartment was heavily oxidized and holes were burned through the cubicle on either side of the breaker. The arcing event destroyed many of the springs and fingers in the PDAs. A few were found at the very bottom of the debris, particularly below C phase.

Conclusion

The root cause evaluation of the nonsafety-related breaker fire concluded that maintenance practices could have contributed to the failure of the PDA by creating a poor connection, which caused localized over heating of parts of the PDA. This overheating caused the PDA to disintegrate. At that point, the loose parts of the PDA created a short-to-ground path. Once the arc was struck, phase-to-phase faulting occurred between the A-B and B-C phases. The initial arcing to ground quickly interrupted the dc circuit below the breaker pan (located directly below the PDA).

In this fire event, the use of portable CO_2 and Halon fire extinguishers may not have been the most effective choice of extinguishing agent to use. Operating experience in energized electrical equipment fires shows that the use of a relatively small quantity of water was effective in successful fire extinguishment.

Fort Calhoun Station

Description of Circumstances

In October 2001, the licensee for Fort Calhoun Station began a surveillance of the Unit 1 containment prestressing system. This surveillance included testing the tension of the containment concrete tensioning cables. It also involved pumping lubricating grease into the containment tendon sheathings to replace the grease that had been lost as a result of leakage. In support of this activity, 55-gallon drums of grease were located in the tension gallery. During this surveillance activity, the plant personnel discovered that the grease was too cold to pump and would need to be heated before use. Drum heaters were, therefore, used on the outside of the drums to heat the grease and facilitate pumping into the containment tension sheathings. Two drum heaters were used, one powered from a receptacle located in the tension gallery and the second powered from a receptacle located in room 22. In order to supply power from the outlet in room 22 to one of the drum heaters, two extension cords were connected in series and routed through the open door separating room 22 from the tension gallery. At the end of the day, the drum heater powered from the receptacle in room 22 was left energized to keep the grease warm overnight so that work could begin the next morning.

Unbeknownst to plant personnel involved in performing the surveillance, the extension cords used to power the drum heater were not rated for this application. The extension cords were rated at 15 amperes, and had male connections that would only allow them to be connected to 15-ampere receptacles. However, the 20-ampere male connection on the drum heater had been inappropriately modified to allow it to be connected to a 15-ampere plug or receptacle. The licensee later determined that the, 2000-watt drum heater drew a current of 17.39 amperes.

As a result of using underrated extension cords, the extension cords continued to heat up during the evening. The extension cords eventually overheated and ignited the plastic on the radiological control point stepoff pad and a rubber air hose.

On December 19, 2001, at 2:48 a.m., the MCR operators received an alarm from an ionization smoke detector located in room 22. A control room operator dispatched the auxiliary building operator and a radiation protection technician to investigate the cause of the fire alarms. The auxiliary building operator arrived at the door to room 22, cracked the door open, and determined that there was too much smoke to enter the room without using protective firefighting bunker gear and a self-contained breathing apparatus (SCBA) and informed the MCR. The fire brigade was activated while operators entered the abnormal operating procedure for fighting fires. During this event, the MCR received another ionization smoke detector alarm in corridor 4.

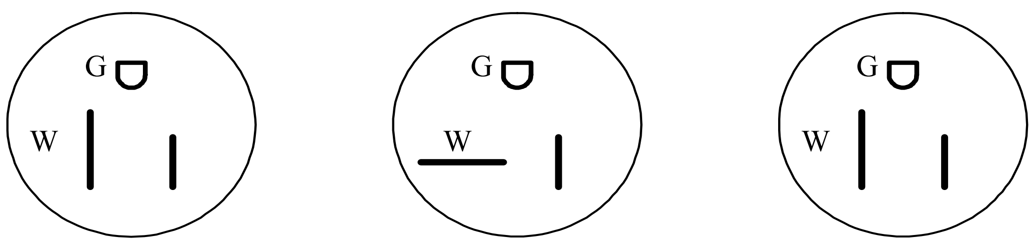
The fire brigade laid out an attack line from the hose cabinet outside room 22 and a backup line from the cabinet outside room 6 before the attack team prepared to enter room 22. The attack team entered room 22 and proceeded down the stairs toward the entrance to the containment tension stressing gallery. The nozzle man described room 22 as being completely filled with smoke with no visibility. The smoke that traveled from room 22 through the open door caused the actuation of the water curtain open head deluge system on the auxiliary building stairwell, which resulted in water being sprayed onto safety-related motor control centers (MCCs), which subsequently caused actuation of the 480-V bus ground alarms in the MCR.

These MCCs are safety-related but are not required to function during a safe shutdown event, as defined by Appendix R to Title 10, Part 50, of the *Code of Federal Regulations* (10 CFR Part 50). Operators also restarted the room 22 ventilation to remove the smoke.

Discussion

Licensee personnel performed unauthorized modifications to the male connections of two drum heaters, allowing them to be inserted into underrated outlets and extension cords, which ultimately caused the fire. The licensee concluded that the root cause of the fire was the modification of the male connection on a 2,000-watt drum heater. The plug on a second 2,000-watt drum heater was also found to be modified. This unauthorized modification defeated a manufactured safety device (electrical connector standards), thereby allowing the heaters to be energized using undersized extension cords and electrical outlets. On one of the plugs, a prong was twisted 90 degrees to make it similar to a 15-ampere plug. On the other heater, the plug was completely removed and replaced with a 15-ampere plug (see illustrations below).

Standard 15 Amp Receptacle | Standard 20 Amp Plug | Altered 20 Amp Plug



Conclusion

The fire was a result of modified plugs on two drum heaters, which defeated the intent of the design of electrical outlets. The licensee failed to with comply the procedural requirements for a temporary modification. The heavy smoke from the fire caused a deluge sprinkler system to actuate in a different fire area which sprayed on safety-related electrical equipment. 10 CFR 50.48(a) requires licensees to have a fire protection plan that meets General Design Criterion (GDC) 3 of Appendix A to 10 CFR Part 50. GDC 3 requires that structures, systems, and components that are important to safety shall be designed and located to minimize, the probability and effect of fires and explosions, consistent with other safety requirements.

Summary of Recent Fire Events

This IN discusses four separate, noteworthy fire events. These events indicate that addressees should give special consideration to the means and associated effects of fire extinguishment.

The use of water on electrical cable fires is discussed in Section 9.5.1 (page 9.5.1-15) of the NRC's Standard Review Plan (SRP), NUREG-0800, dated April 1996, as follows:

"*Experience with major electrical cable fires shows that water will promptly extinguish such fires. Since prompt extinguishing of the fire is vital to reactor safety, fire and water damage to safety systems is reduced by the more efficient application of water from fixed systems spraying directly on the fire, rather than by manual application with fire hoses. Appropriate firefighting procedures and fire training should provide the techniques, equipment, and skills for the use of water in fighting electrical cable fires in nuclear plants, particularly in areas containing a high concentration of electric cables with plastic insulation. This is not to say that fixed water systems should be installed everywhere. Equipment that may be damaged by water should be shielded or relocated away from the fire hazard and the water. Drains should be provided to remove any water used for fire suppression and extinguishment to ensure that water accumulation does not incapacitate safety-related equipment.*"

The affected and nearby equipment may need to be deenergized to eliminate the potential for a personnel shock hazard. Fire brigade training and pre-fire plans should address fighting fires in energized electrical equipment, as well as the responsibility to deenergize and open cabinets for safe access to concealed fires (such as in electrical cabinets). All of these activities contribute to the duration of and recovery from the event.

The NRC expects addressees to evaluate the above information for applicability to licensed activities. However, this IN does not require any specific action or written response. If you have any questions about this notice, please contact one of the technical contacts listed below or the appropriate project manager in the NRC's Office of Nuclear Reactor Regulation (NRR).

/RA/
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Attachments:
1. List of Recently Issued NRC Information Notices
2. References, List of NRC Generic Communications, and
   List of Recently Issued NRC Information Notices Related to Fire Protection

References

Fort Calhoun Station, NRC Special Team Inspection Report, 50-285/02-06, April 5, 2002, (ADAMS Accession #ML020960001).

Friedman, R., Principles of Fire Protection Chemistry and Physics, 3rd Edition, Chapter 14, "Fire-Fighting Procedures," pp. 229-230, National Fire Protection Association, Quincy, Massachusetts, 1998.

Licensee Event Report (LER) 1-01-05, "Fault and Fire in Non-Safeguards Circuit Breaker Results in Reactor Trip and Auxiliary Feedwater System Actuation," Prairie Island Nuclear Generating Plant, Unit 1, October 2, 2001.

NRC Inspection Report No. 50-362/01-05, "San Onofre Nuclear Generating Station NRC Special Team Inspection Report," April 20, 2001 (ADAMS Accession #ML011130225).

NRC Preliminary Notification PN301027, "Electrical Panel Fire During Plant Startup," Prairie Island Nuclear Generating Plant, Unit 1, August 6, 2001.

Point Beach Nuclear Plant, NRC Inspection Report 50-266/01-08, 50-301/01-08, June 6, 2001 (ADAMS Accession #ML011580082).

List of Related NRC Generic Communications

NRC Bulletin 75-04, "Cable Fire at Browns Ferry Nuclear Power Station," March 24, 1975.

NRC Bulletin 75-04A, "Cable Fire at Browns Ferry Nuclear Power Station," April 3, 1975.

NRC Bulletin 75-04B, "Cable Fire at Browns Ferry Nuclear Power Station," November 3, 1975.

NRC Circular 77-03, "Fire Inside a Motor Control Center," February 28, 1977.

NRC Information Notice 89-64, "Electrical Bus Bar Failures," September 7, 1989.

NRC Information Notice 95-33, "Switchgear Fire and Partial Loss of Offsite Power at Waterford Generating Station, Unit 3," August 23, 1995.

NRC Information Notice 97-01, "Improper Electrical Grounding Results in Simultaneous Fires in the Control Room and the Safe-Shutdown Equipment Room," January 8, 1997.

NRC Information Notice 2000-14, "Non-Vital Bus Fault Leads to Fire and Loss of Offsite Power," September 27, 2000.

NRC Information Notice, 2002-01, "Metalclad Switchgear Failures and Consequent Losses of Offsite Power," January 8, 2002.

List of Recently Issued NRC Information Notices Related to Fire Protection

NRC Information Notice 2002-15, "Hydrogen Combustion Events in Foreign BWR Piping," April 12, 2002.

NRC Information Notice 2002-24, "Potential Problems With Heat Collectors on Fire Protection Sprinklers," July 19, 2002.