Derivation of Essential Electrical Elements for Ensuring the Reliability of Fire Hazard Analysis in Nuclear Power Plant

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1. Introduction

In a fire hazard analysis (FHA) for nuclear power plant, various electrical circuit analyses are performed in the parts of fire loading calculation, fire modeling, separation analysis, and associated circuit analysis. Thus electrical circuit analyses are very important areas so that reliability of the analysis results should be assured. In this study, essential electrical elements for each analysis were established for verification of the reliability of the electrical circuit analyses in the FHA for nuclear power plants.

2. Elements of electrical circuit analysis

In this section, methodologies of each analysis in FHA are summarized and essential electrical elements required for each analysis are discussed.

2.1 Fire loading calculation

Fire loading calculation is the basic analysis for providing potential fire hazard level for each fire areas. Generally, electrical cable fire loading is the biggest amount among the various combustibles in nuclear power plant, thus calculation of the cable fire loading is utmost important. In order to assure the reliability of the result of the cable fire loading calculation, it is essential to acquire the cable information required for the calculation based on a computerized cable management system. Essential electrical elements for the fire loading calculation area are as followings:

(1) Computerized cable management system including following information
- ◦ Cable location information
  - Cable number
  - Raceway number
  - Cable location (room number, fire area number)
  - Cable length
- ◦ Cable heat of combustion information
  - Cable application (power, control, instrument)
  - Cable insulation (filler, shield, jacket) material or Cable type (EPR, XLPE, etc.)
  - Heat of combustion of cable insulation (Btu/ft or Btu/lb)

(2) Operation of computerized cable management system
- ◦ Revision interval
- ◦ Revision number and date

2.2 Fire modeling analysis

In fire modeling analysis, it is required to identify the information for ignition source, combustibles, and targets. Generally, electrical cables are treated as both combustibles and targets in nuclear power plant, thus cable information are very important in the analysis. In order to assure the reliability of the result of the fire modeling analysis, it is essential to acquire the cable information required for the analysis based on a computerized cable management system. In addition, accurate location information of the cable and other electrical equipments should be acquired through the drawing review and plant walkdown. Essential electrical elements for the fire modeling analysis area are as followings:

(1) Computerized cable management system including following information
- ◦ Location information for ignition sources
  - Electrical cabinet
  - Electrical motor
  - Junction box
  - Transformer
  - Dryer
  - Bus duct
  - Battery charger
- ◦ Information for combustibles and targets
  - Cable number
  - Raceway number
  - Cable location (room number, fire area number)
  - Cable routing
  - Cable application (power, control, instrument)
  - Cable insulation (filler, shield, jacket) material or Cable type (EPR, XLPE, etc.)
  - Heat of combustion of cable insulation (Btu/ft or Btu/lb)

(2) Operation of computerized cable management system
- ◦ Revision interval
- ◦ Revision number and date

2.3 Separation analysis

Separation analysis is performed in consecutive order from the selection of safe shutdown cables, the

examination of safe shutdown equipment and cable location, and the assessment of separation between redundant equipment.

Selection of safe shutdown cables is to identify the required cables for the operation of the safe shutdown equipments through extensive review of the relevant electrical and instrument drawings. Examination of safe shutdown equipment and cable location is to allocate the safe shutdown equipment and cables into fire areas through extensive review of cable location drawings. Two kinds of outputs are generated by examination of safe shutdown cable location: ① cable routing database, ② cable routing mark drawings. Assessment of separation between redundant equipments is to verify redundant safe shutdown equipments and cables meet the separation criteria required for assuring post fire safe shutdown based on cable routing database and mark drawings above.

According to section III.G.2 of 10CFR50 Appendix R, one of the following means of ensuring that one of the redundant trains is free of fire damage shall be provided within the same fire area outside of primary containment (Fig. 1).

a. Separation of cables and equipment and associated non-safety circuits of redundant trains by a fire barrier having a 3-hour rating. Structural steel forming a part of or supporting such fire barriers shall be protected to provide fire resistance equivalent to that required of the barrier;
b. Separation of cables and equipment and associated non-safety circuits of redundant trains by a horizontal distance of more than 20 feet with no intervening combustible or fire hazards. In addition, fire detectors and an automatic fire suppression system shall be installed in the fire area; or
c. Enclosure of cable and equipment and associated non-safety circuits of one redundant train in a fire barrier having a 1-hour rating, In addition, fire detectors and an automatic fire suppression system shall be installed in the fire area;

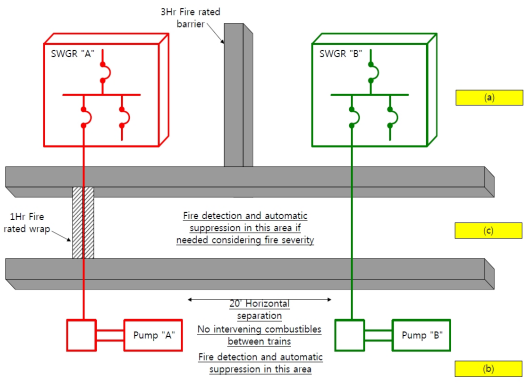

Fig. 1 Separation Criteria between redundant cables

In order to assure the reliability of the result of the separation analysis, it is essential to acquire the cable information required for the analysis based on a computerized cable management system. In addition, accurate location information of the cable and other electrical equipments should be acquired through the drawing review and plant walkdown. Essential electrical elements for the separation analysis are as followings:

(1) Computerized cable management system including following information
  ◦ Safe shutdown cable list
    - Cable number
    - Raceway number
    - Cable application (power, control, instrument)
  ◦ Safe shutdown cable location information
    - Cable location (room number, fire area number)
    - Cable routing
(2) Operation of computerized cable management system
  ◦ Revision interval
  ◦ Revision number and date
(3) Identification of areas containing both redundant cables
(4) Cable routing mark drawing

2.4 Associated circuit analysis

FHA should evaluate those circuits, which are non-safety or safety circuits that could adversely affect the identified shutdown equipment by feeding back potentially disabling conditions (e.g., hot shorts or shorts to ground) to power supplies or control circuits of that equipment. Such disabling conditions should be prevented to ensure that the identified safe-shutdown equipment will function as designed. Associated circuits of concern are defined as those cables that have a physical separation less than that specified in separation criteria and that meet one of the following criteria:

a. A common power source with the shutdown equipment is not electrically protected from the circuit of concern by coordinated breakers, fuses, or similar devices.
b. A connection to circuits of equipment would adversely affect the shutdown capability if spuriously operated.
c. A common enclosure (e.g., raceway, panel, and junction box) with shutdown cables (1) is not electrically protected by circuit breakers, fuses, or similar devices or (2) will allow propagation of the fire into the common enclosure.

In order to assure the reliability of the result of the associated circuit analysis, it is essential to maintain documents for electrical system design, procurement, and operations. Essential electrical elements for the separation analysis are as followings:

(1) Common power supply

◦ Review of possibility of the common power supply problem
◦ Documents for electrical coordination data
(2) Common enclosure
◦ Performance characteristics of circuit breakers
◦ Cable flame test reports
◦ Current transformer list
◦ Review of current transformer problem
(3) (Multiple) spurious operation
◦ Spurious operation scenario list
◦ Fire areas implying spurious operation

3. Conclusions

Essential electrical elements required for fire loading calculation, fire modeling analysis, separation analysis, and associated circuit analysis in FHA were derived in this study. Electrical elements derived are as Table 1.

The most important element is to possess and operate the computerized cable management system reflecting up to date information. And some other electrical elements should be additionally secured such as cable routing mark drawing, electrical system design and test documents, spurious operation information.

Table 1 Electrical elements required for each analysis in Fire Hazard Analysis

Area	Electrical elements	
Fire loading calculation	Computerized cable management system	
	- Cable location	
	- Cable heat of combustion	
	Operation of computerized cable management system	
Fire modeling analysis	Computerized cable management system	
	- Ignition source location	
	- Combustible and target location	
	Operation of computerized cable management system	
Separation analysis	Computerized cable management system	
	- Safe shutdown cable list	
	Separation information of safe shutdown cables (Cable location and routing information)	
	Operation of computerized cable management system	
	Identification of areas containing both redundant cables	
	Cable routing mark drawing	
Associated circuit analysis	Common power supply	Review of possibility of the common power supply problem
		Documents for electrical coordination data
	Common enclosure	Performance characteristics of circuit breakers
		Cable flame test reports
		Current transformer list
		Review of current transformer problem
	(Multiple) Spurious operation	Spurious operation scenario list
		Fire areas implying spurious operation issue

ACKNOWLEDGEMENTS

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