# Modeling of Cabinet Fire in Switchgear Room Using Fire Dynamic Simulator

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## 1. Introduction

NFPA 805[1], which provides a comprehensive, risk-informed, performance-based standard for fire protection, and ASME PRA standard [2], which describes the technical element of PRA, require performing uncertainty analysis in detailed fire modeling. NFPA 805 specifies the set of fire scenarios for each plant area; maximum expected fire scenarios (MEFS) and limiting fire scenarios (LFS). The MEFS are scenarios that represent the most challenging fire that could be reasonably anticipated for the occupancy type and conditions in the space. The LFS is scenario(s) that result in unfavorable consequences with respect to the performance criteria being considered. The actual evaluation of the margin between the MFES and the LFS provides a means of identifying weakness in the analysis where a small change in a model input could indicate an unacceptable change in the consequence. In this paper, cabinet fire in switchgear room of nuclear power plants presented in NUREG-1934 [3] was simulated to identify the cable damage time and to evaluate cable temperature using Fire Dynamics Simulator (FDS) 5.5 [4]. Uncertainty analysis of input parameters for fire simulation was also performed to predict the uncertainty ranges of cable damage time and maximum cable temperature. In this study, the MFES was assumed to be fire scenario presented in NUREG-1934. The LFS could be evaluated through uncertainty analyses.

## 2. Switchgear room fire

4.16KV switchgear room to be analyzed has three electrical cabinets and there are three cable trays above each electrical cabinet. Main design features of switchgear room are as follows:

- Geometry
  - Size of compartment: 27.5mX19.5mX6.6m
  - Concrete thickness of floor, ceiling, and wall: 0.5m
  - Steel thickness of cabinet and cable tray: 1.5mm
  - Room temperature: 20℃
- Cables: PE insulated, PVC jacketed control cables
- Fire detectors: two smoke detectors
- Forced ventilation: three supply and three return vents

NUREG-1934 assumed that a fire start in one electrical cabinet in the middle bank of cabinets. There is an air vent on the top of the cabinet. The target to be analyzed is the cable just above fire initiation place in the central cabinet. The heat release rate (HRR) is assumed to grow following a “t-squared” curve to a maximum value of 176.28 $kW/m^2$ in 12 minutes and remain steady for 8 additional minutes. After 20 minutes, the HRR is assumed to decay linearly to zero in 12 minutes. Other nominal values of input parameters for fire modeling described in NUREG-1934 are presented in Table 1.

## 3. Fire simulation results

### 3.1 Basic evaluation results

FDS 5.5, field model fire simulation code, was used to simulate fire scenario presented in NUREG-1934 with the grid size of 0.2m. Cable temperature was predicted with THIEF (Thermally Induced-Failure) Model in FDS 5.5. As THIEF model was made based on the fire experimental results, it can realistically predict cable temperature. Cable damage criterion was assumed to be 200℃ according to NUREG-1934. 32 points just above fire starting place in the central cabinet were selected to determine maximum cable temperature. Basic simulation results showed that the time of cable damage was 754 second and the maximum cable temperature was 330℃, respectively

### 3.2 Uncertainty analysis results

MOSAIQUE [5] was used to perform uncertainty analysis with Latin Hyper Cube Sampling and network based computer running. Wilks tolerance limit [6] was used to reduce sample size from few thousands to 93. As there was no detailed information on materials for fire simulation, uncertainty distributions of input parameters, as shown in Table 1, were determined based on relating references. Uncertainty analysis results were as follows:

- range of cable damage time: 466~1267second
- average cable damage time: 771.6second
- range of maximum cable temperature: 45.3~752℃
- average cable temperature: 310.7℃

### 3.3 Discussions

Comparing to basic simulation results, uncertainty analysis results showed that average cable damage time is long and average maximum cable temperature was low. Consequently, input parameters for basic simulation were determined in a little conservative way comparing to average input parameters used for uncertainty analysis. If the minimum cable damage time and the maximum cable temperature in uncertainty analysis were determined as evaluation results of the LFS, basic simulation results using only nominal values could predict cable damage time 1.6 times longer than uncertainty analysis results and estimated the maximum cable temperature 0.45 times lower than them.

**4. Concluding Remarks**

In this paper, modeling of cabinet fire in switchgear room of nuclear power plants and their uncertainty analyses were performed to predict cable damage time and to evaluate maximum cable temperature. Simulation results showed that basic evaluation results could predict cable damage time 1.6 times longer than the evaluation results of the LFS and estimate 0.45 times lower than them. More efforts are needed to focus on the study of uncertainties between fire experiment results and computer code simulation results.

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Table 1. Uncertainty distribution of input parameters

| Parameter description | Nominal Value | Parameter uncertainty | Uncertainty distribution |
|---|---|---|---|
| Concrete Wall | | | |
| Specific Heat | 0.75 kJ/kg/K | σ= 0.15, σ/ μ= 20% | Normal |
| Conductivity | 1.6 W/m/K | σ= 0.32, σ/ μ= 20% | Normal |
| Density | 2,400 Kg/m$^3$ | σ= 480, σ/ μ= 20% | Normal |
| Cabinet-Steel | | | |
| Specific Heat | 0.465 kJ/kg/K | σ= 0.2325, σ/ μ= 50%, min-0.372, max-1.2 | Normal |
| Conductivity | 54 W/m/K | σ= 27, σ/ μ= 50%, min-30, max-64.8 | Normal |
| Density | 7,850 Kg/m$^3$ | σ= 1570, σ/μ= 20% | Normal |
| Cable-PE/PVC composition | | | |
| Specific Heat | 1.289kJ/kg/K | σ= 0.5158, min-0.81, max-2.5 | Normal |
| Conductivity | 0.192 W/m/K | σ= 0.0384, σ/ μ= 20% | Normal |
| Density | 1,380 Kg/m$^3$ | σ= 276, σ/ μ= 20% | Normal |
| Ventilation | | | |
| Supply Fan | (-0.472 m$^3$/s) | 0, -.0472 | Discrete |
| Return Fan | 0.472 m$^3$/s | 0, 0.472 | Discrete |
| Fuel | | | |
| HRR | 176.28kW | α = 2.6, β=67.8 | Gamma |
| Combustion | 24,000 kJ/kg | α = 25.34, β=947.07 | Gamma |
| CO Yield | 0.038 | σ=0.01887 | Normal |
| SOOT Yield | 0.1 | σ=0.05102, | Normal |