# Multi-compartment Fire Modeling for Switchgear Room using CFAST

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## 1. Introduction

The Core Damage Frequency (CDF) of level 1 fire probabilistic safety assessment (PSA) is expressed as multiplication of fire frequency, severity factor, non-suppression probability and conditional core damage probability (CCDP) [1]. New fire PSA method (NUREG/CR-6850) requires that the severity factor is to be calculated by fire modeling. If fire modeling is not performed, the severity factor should be estimated as one conservatively. Also, the possibility of the damages of components and cables located at adjacent compartments should be considered. Detailed fire modeling of multi-compartment fires refers to the evaluation of fire-generated conditions in one compartment that spread to adjacent ones [1]. In general, the severity factor for multi-compartment fire scenario is smaller than that of single compartment scenario. Preliminary quantification of Hanul Unit 3 fire PSA was performed without fire modeling. As a result of quantification, multi-compartment scenario, fire propagation scenario from switchgear room (SWGR) A to SWGR B, is one of significant contributor to the CDF. In this study, fire modeling of multi-compartment was performed by Consolidated Fire Growth and Smoke Transport (CFAST) to identify the possibility of fire propagation.

## 2. Methods and Results

### *2.1 SWGR Room Features of Hanul Unit 3*

Hanul Unit 3 has SWGR room A and B for redundancy. As shown in Fig.1, SWGR room A has electrical cabinets to supply motive and control powers to safety-related components. If Class 1E 4.16 kV cabinet is damaged due to a fire, loss of 4.16 kV AC event will occurs. Main design features of SWGR room A are as follows:

▪ Geometry
- Size of compartment : 26.6 m x 13.6 m x 7.5 m
- Material of floor, ceiling and wall : concrete
- Thickness of concrete : 0.6 m
- Material of cabinet and cable tray : steel
- Room temperature : 20 ℃

▪ Cables : EPR insulated, CSM(CSP) jacketed cables

▪ Mechanical ventilation : five supply and three return vents

▪ Airflow rate : 0.2218 $m^3/s$ (each supply vent) and 0.2596 $m^3/s$ (each return vent)

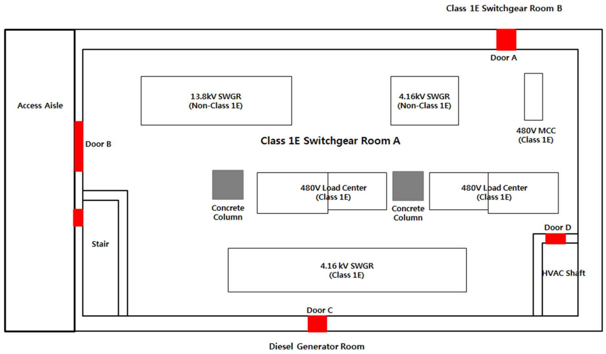


Fig.1 Overview of SWGR A

### *2.2 Fire Scenarios and Assumptions*

The ignition sources of SWGR room A are electrical cabinets and secondary combustibles are the other cabinets and cable trays. As a result of preliminary fire modeling, it was identified that any cabinet fire did not induce the secondary fires of the other cabinets and of horizontal cable trays above the cabinets. However, vertical cables connected to the cabinets were identified as the secondary combustibles for the cabinet fires.
Assumed severe fire scenarios were (1) simultaneous fire of non-class 1E 4.16kV SWGR and class 1E 4.16kV cabinets due to a high energy aching fault (HEAF) event and (2) 480V MCC cabinet fire.
Since non-segregated phase bus (NSPB) which can generates HEAF event is connected to the non-class 1E 4.16kV SWGR and class 1E 4.16kV cabinets, it was assumed that simultaneous fires of them occur. 480V MCC and 480V AC load center cabinets have the vertical cables above them. The vertical cables are ignited when any 480V cabinet fire occurs. Since the vertical cables are connected to the horizontal cables, the horizontal cables will be also ignited when flame reaches to the height of cables. The location of 480V MCC is closer to SWGR room B than that of 480V AC load center. Therefore, 480V MCC cabinet fire was selected as the postulated fire scenario. The fire simulations for each fire scenario were performed using CFAST. The assumptions used for fire simulations were as follows.

▪ Cabinet fire
- Heat release rate (HRR) grows following a “t-squared” in 12 min and remains steady for 8 additional min. After 20 min, it decays linearly to zero in 19 min [1].
- Peak HRR of SWGR is 170 kW and that of MCC is 130 kW [3].
- Cabinets of Fig.1 consist of several sections.

- Any section fire of cabinet is propagated to both side sections at 15 min after fire ignition [1].

▪ Cable fire

- Fire ignition time of vertical cables is same as that of cabinet.
- Horizontal cables start burning when flame reaches to cable height [2].
- There is no data for EPR/CSM (CSP) cables for fire modeling. Therefore, XLPE/neoprene cable data is used for it.
- HRR of cable is calculated using FLASH-CAT Model [4,5].

▪ Door connected to SWGR B is opened.

▪ Assumed target is any cables in SWGR room B.

▪ The damage criteria of thermoset cable are 11 $kW/m^2$ for heat flux and 330 ℃ for temperature[1].

### *2.3 Simulation Results*

Fig.2 and Fig.3 illustrate the scenarios as modeled by CFAST. The red cone means the flame and the small grey circle in the other room is target. Since the door which connects SWGR room A and B locates downwards of the room, it can underestimate the hot gas layer (HGL) temperature of SWGR room B. In this reason, the sensitivity analysis which changes the door position to upward of room is conducted. The summary of simulation results is shown in Table 1.

Table 1. Results of fire simulation

| Fire Scenario # | # 1 | # 2 | # 3 | # 4 |
|---|---|---|---|---|
| SWGR A peak HGL temp [℃] | 77.9 | 73.1 | 79 | 77.2 |
| SWGR B peak HGL temp [℃] | 21.3 | 28.3 | 21 | 29.4 |
| Target peak temp [℃] | 20.7 | 21.6 | 20.4 | 21.5 |
| Target peak heat flux [$kW/m^2$] | 0.0076 | 0.0165 | 0.0046 | 0.0145 |

#1 : simultaneous cabinets fire due to HEAF (base case)
#2 : simultaneous cabinets fire due to HEAF (door position changed)
#3 : fire propagation from 480V MCC cabinet fire to cables (base case)
#4 : fire propagation from 480V MCC cabinet fire to cables (door position changed)

Peak HGL temperature of SWGR room A is between 73.1℃ and 79℃ and that of SWGR room B is between 21℃ and 29.4℃. In case of changing position of door, it shows the higher HGL temperature of SWGR room B. The temperature and heat flux of target does not reach to the damage criteria since HGL temperature of SWGR room B increased by fire propagation is very low. The causes of this results that the HGL temperature of SWGR room B is low are as follows. First, revised HRR of cabinet is smaller than that of NUREG/CR-6850. Second, the size of compartment is too large.

## 3. Conclusions

In this study, multi-compartment fire modeling for fire propagation scenario from SWGR A to SWGR B is performed using CFAST. As a result of fire simulation, it is identified that fire propagation has little influences. It means that most of multi-compartment fire scenario can be neglected. Through fire modeling of multi-compartment, CDF of fire PSA will be reduced.

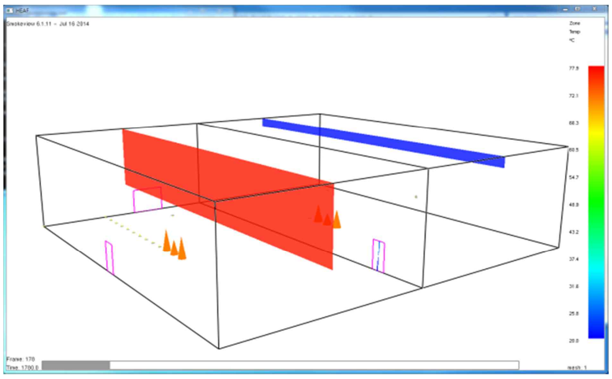

Fig.2 CFAST/Smokeview rendering of fire scenario #1

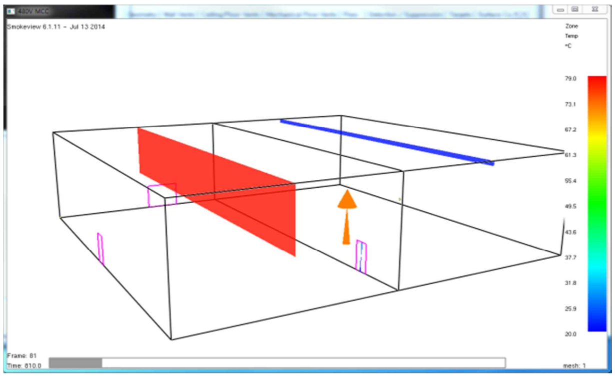

Fig.3 CFAST/Smokeview rendering of fire scenario #3

## Acknowledgements

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