Estimation of Fire Ignition Frequency for Domestic NPP Using the Updated Fire Event Database

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1. Introduction

Fire ignition frequencies were previously developed in the NUREG/CR-6850[1] and revised in Supplement 1[2] to NUREG/CR-6850. The fire ignition frequencies published in NUREG/CR-6850 and Supplement 1 incorporate fire event experience through the year 2000. In January, 2015, EPRI published the updated fire events database (FEDB): NUREG-2169[3]. As there is no FEDB for domestic nuclear power plants (NPPs), FEDB of USA has been used for the estimation of fire frequencies for them. Up to now, EPRI report[4], NUREG/CR-6850, or Supplement 1 to NUREG/CR-6850 was used for the estimation of fire frequencies for the fire probabilistic safety assessment (PSA) works of domestic NPPs. This paper presents the calculation results of fire ignition frequencies for Hanul(formerly Ulchin) 3&4 using the updated FEDB data, NUREG-2169.

2. Overview of Updated FEDB

The fire ignition sources used in fire PSAs are divided into groups called bins that represent location, causal, and mechanistic factors deemed important to depict frequencies of initiating fire scenarios at different plants. The generic bin definitions, plant operating mode applicability, and associated frequencies used in fire PSAs were originally developed and provided in NUREG/CR-6850. The results of the FPIE(Full-power initiating event) fire bin frequency estimates in comparison to the NUREG/CR-6850 Supplement 1 recommended fire ignition frequencies (FIFs) are shown in Figure 1. In aggregate, the updated fire frequency results are higher than the NUREG/CR-6850 Supplement 1 results by 36%.

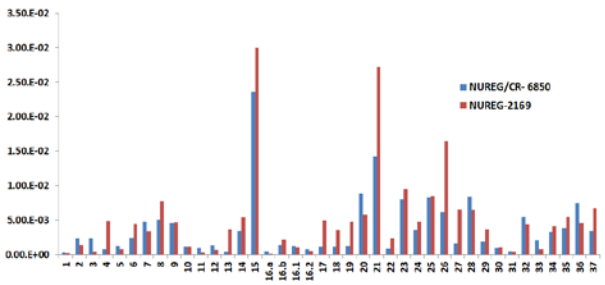

Figure 1 Comparison of bin fire ignition frequencies using recent FEDB updated data to values provided in NUREG/CR-6850, Supplement 1.

3. Estimation of fire ignition frequency for Hanul 3&4

3.1 Plant partitioning

Plant partitioning was conducted in accordance with NUREG/CR-6850. NUREG/CR-6850 uses the term "compartment" to define a discrete physical analysis units (PAUs). The Hanul 3&4 physical analysis units are based on the Fire Hazard Analysis Report[5]. A Hanul 3&4 fire area is generally bounded on all sides by rated fire barriers or by substantially constructed walls exempted from rating requirements, whereas fire zones are within a fire area. Hanul 3&4 consists of 119 fire areas.

3.2 Fire Ignition Frequency

3.2.1 Generic Fire Ignition Frequency. The updated generic ignition frequencies were used to develop the values for the Hanul 3&4 fire PSA. The generic frequencies are arranged in "Bins". The generic frequency bins are general categories for typical plants, some of which are not applicable to the Hanul 3&4 fire PSA due to the different type of reactor or other design features. Bins that are not applicable to the Hanul 3&4 fire PSA include Bin 20(Off-gas/H_2 recombiner), Bin 28(Transformer-Non Catastrophic), Bin 29(Transformer -others).

3.2.2 Fixed Ignition Sources. The methodology for calculating the fire ignition frequency values for fixed ignition sources requires the counting of equipment in each of the plant fire analysis units. The component counting methodology is consistent with NUREG/CR-6850 Supplement 1, Task 6 and FAQ 12-0064[6]. Plant walkdowns were performed for all reasonably accessible zone. Typical fixed ignition sources include equipments such as pumps, motors, electrical panels, transformers, fans etc. For all identified components in a fire zone, a count or relative size weighting factor of the source was determined and recorded. The contents of the inaccessible zone are typically estimated based on the plant drawings. The walkdown sheets were developed in walkdown reports in the FIFA[7] database. The number of fixed ignition sources of Hanul #3 is shown in Table 1. The various fire zones are assigned to a plant location so that the appropriate generic frequency can be allocated in accordance with the

assumption used in the development of the generic frequencies. These locations consist of eight categories: battery room, containment, control room, control/ auxiliary/reactor building, diesel generator room, plant wide components, transformer yard and turbine building. The Hanul 3&4 has no shared equipment, the location weighting factors for all locations are set to 1.0.

Table 1: Fixed Ignition Sources

Bin	Location	Ignition Source	Count	Generic Frequency	
				6850	2169
1	Battery Room	Batteries	12	3.26.E-04	1.960E-04
2	Containment	Reactor Coolant Pump	4	2.35.E-03	1.370E-03
4	Control Room	Main Control Board	11	8.24.E-04	4.910E-03
8	Diesel Generator Room	Diesel Generators	4	5.04.E-03	7.810E-03
9	Plant-Wide	Air Compressors	8	4.65.E-03	4.690E-03
10	Plant-Wide	Battery Chargers	14	1.18.E-03	1.120E-03
13	Plant-Wide	Dryers	3	4.20.E-04	3.660E-03
14	Plant-Wide	Electric Motors	80	3.41.E-03	5.430E-03
15	Plant-Wide	Electrical Cabinets-Non HEAF	1,949	2.36.E-02	3.000E-02
16.a	Plant-Wide	HEAF for Low-Voltage(480-1000V)	131	2.71.E-04	1.520E-04
16.b	Plant-Wide	HEAF for Medium-Voltage(above 1000V)	134	7.89.E-04	2.130E-03
16.1	Plant-Wide	Bus Duct	436	1.27.E-03	1.100E-03
16.2	Plant-Wide	Iso Phase Bus	1	8.24.E-04	5.910E-04
17	Plant-Wide	Hydrogen Tanks	1	1.18.E-03	4.930E-03
18	Plant-Wide	Junction Boxes	1,060	1.11.E-03	3.610E-03
19	Plant-Wide	Misc. Hydrogen Fires	1	1.24.E-03	4.820E-03
21	Plant-Wide	Pumps	278	1.42.E-02	2.720E-02
22	Plant-Wide	RPS MG Sets	2	9.33.E-04	2.310E-03
23	Plant-Wide	Transformers	131	8.02.E-03	9.560E-03
26	Plant-Wide	Ventilation Subsystems	248	6.12.E-03	1.640E-02
27	Transfomer Yard	Transfomer-Catasrophic	9	1.62.E-03	6.610E-03
30	Turbine Building	Boiler	1	9.78.E-04	1.090E-03
32	Turbine Building	Main Feedwater Pumps	3	5.44.E-03	4.380E-03
33	Turbine Building	Turbine Generator Exciter	1	2.10.E-03	8.360E-04
34	Turbine Building	Turbine Generator Hydrogen	1	3.23.E-03	4.120E-03
35	Turbine Building	Turbine Generator Oil	1	3.89.E-03	5.490E-03
		SUM	4,524	9.50.E-02	1.55.E-01

3.2.3 Transient Ignition Sources. NUREG/CR-6850 Task 6, Fire Ignition Frequencies, provides that the fire PSA use plant specific inputs to develop transient fire frequencies from generic information. There are four main influence factors: hot work, maintenance, occupancy, storage that affect the likelihood of a transient fire within a fire zone. All fire zones are assigned ranking values for each of the transient fire influencing factor categories. The influence factor ratings are used to establish a relative ranking of the fire zones by fire contributing activities. The ranking values are then used to develop weighting factors used to allocate the generic fire ignition frequencies to each fire zone. The generic locations for transient fire ignition frequency allocation are containment (PWRs), control/ auxiliary/reactor building (CAR), turbine building (TB), plant wide (PW).

Table 2: Transient Ignition Sources

Bin	Location	Ignition Source	Generic Frequency	
			6850	2169
3	Containment (PWR)	Transients and Hotwork(at power)	2.34.E-03	4.21.E-04
5	Control/Aux/Reactor Building	Cable fires caused by welding and cutting	1.25.E-03	7.83.E-04
6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	2.46.E-03	4.44.E-03
7	Control/Aux/Reactor Building	Transients	4.81.E-03	3.33.E-03
11	Plant-Wide Components	Cable fires caused by welding and cutting	9.43.E-04	2.77.E-04
12	Plant-Wide Components	Cable Run (Self-ignited cable fires)	1.32.E-03	7.02.E-04
24	Plant-Wide Components	Transient fires caused by welding and cutting	3.65.E-03	4.79.E-03
25	Plant-Wide Components	Transients	8.28.E-03	8.54.E-03
31	Turbine Building	Cable fires caused by welding and cutting	4.50.E-04	3.47.E-04
36	Turbine Building	Transient fires caused by welding and cutting	7.55.E-03	4.67.E-03
37	Turbine Building	Transients	3.41.E-03	6.71.E-03
		SUM	3.65.E-02	3.50.E-02

3.3 Fire Ignition Frequency (FIF) Calculations

The fire ignition frequency for each fire area (FA) was calculated using the above factors, the fixed ignition source count and the generic fire ignition frequencies in NUREG-2169.

For fixed ignition source frequency (FISF) contributions, the following equation is used:

FIFS = Sources(Fire Area)/Sources(Plant Location) x Fire Frequency x Location Weighting Factor .....(1)

For transient ignition source frequency (TISF) contributions, the following equation is used:

TISF = Transient Weighting Factor x Fire Frequency x Plant Wide Weighting Factor .....(2)

The individual contributions are summed to determine the overall FA fire frequency.

FA Fire Frequency (FFP) = $\Sigma FISF_{b,J} + TISF_{b,J}$ .....(3)
Where: FFP = Fire frequency for each FA
b = all bins
J = for each FA J

Final estimation of Hanul Unit 3&4 fire frequencies was conducted with the consideration of their availability, 0.95.

Figure 2 and Figure 3 show the fire ignition frequency of specific fire areas for fixed ignition sources and transient ignition sources, respectively.

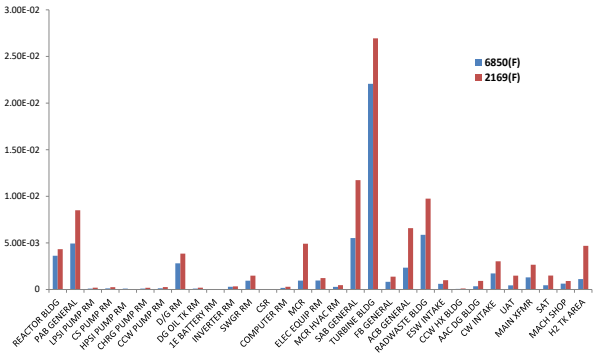

Figure 2 Comparison of fixed bin fire ignition frequencies using recent FEDB

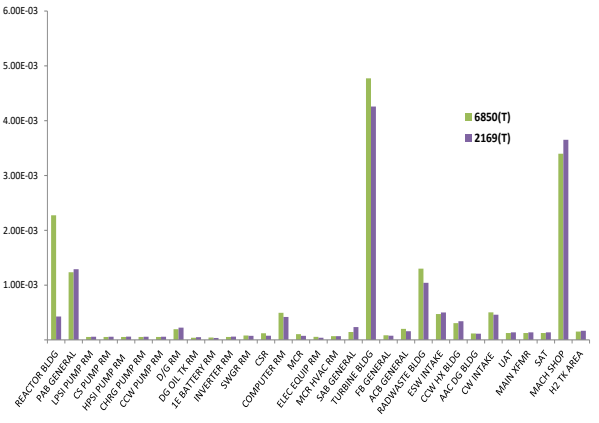

Figure 3 Comparison of transient bin fire ignition frequencies using recent FEDB

4. Results

As shown in Fig. 2, the fire ignition frequency of the fixed ignition source is higher than that of the NUREG/CR-6850. This is because the generic fire ignition frequency of NUREG-2169's fixed ignition sources have increased 36%. In the case of the MCR(Main Control Room), the generic fire ignition frequency of the main control board(bin 4) increased from 8.24E-04 to 4.91E-03, and the fire ignition frequency values by the fixed ignition source was the highest from 9.49E-04 to 4.91E-03. In addition, the PAB(Primary Aux. Bldg.) and SAB(Secondary Aux. Bldg.) general areas, turbine buildings, access control buildings, and hydrogen storage areas were evaluated as high values.

For the transient fire ignition Source, as shown in Fig. 3, the fire ignition frequency of NUREG-2169 is calculated to be lower than that of NUREG/CR-6850. The fire ignition frequency for transient ignition sources in reactor buildings has been reduced from 2.27E-03 to 4.27E-04.

For the realistic calculation of fire frequency for Hanul Unit 3&4, more efforts are required to collect the fire ignition data for the domestic NPPs.

Acknowledgements

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