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Study on the application of the Common Cause Failure (CCF) between EDG and AAC DG

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1. Introduction

The basic design principle for securing Nuclear Power Plant (NPP) safety can be called redundancy and diversity. Nevertheless, to secure safety, the Alternative Alternating Current Diesel Generator (AAC DG) is a shared facility used to provide emergency power to the equipment necessary to safely shut down the reactor in the event of a Station Blackout (SBO) in which the on-site/external AC power and the Emergency Diesel Generator (EDG) are lost at the same time. Although the AAC DG is a non-safety-grade facility, it is credited by the Probabilistic Safety Assessment (PSA) and is a major shared facility that affects the level 1 internal event model between units from the PSA point of view. And, these credits depend on the characteristics of Common Cause Failure (CCF) between EDG and AAC DG, and this interdependence can greatly affect the frequency of SBO.

This study examines historical failure data for each subsystem and component are reviewed and a comparative study of significant events is conducted to review the feasibility of applying CCF to specific plants' EDGs and AAC DGs.

2. Design requirements

In the light-water reactor regulatory standards and regulatory guidelines, alternative AC power sources should be designed according to the design requirements for diversity, multiplicity and independence to minimize the possibility of common cause failure with the priority power system and/or safety class 1E emergency AC power source. It stipulates that no single fault-vulnerable part of an alternative AC power source or a weather-related event shall not be lost simultaneously with the priority power system or safety class 1E emergency AC power source. [1]

In terms of quality assurance, it is stipulated that the systems and devices installed in accordance with the power plant blackout accident regulations should be installed so as not to affect the existing safety-related systems.

3. PSA Modeling

EDGs and AAC DGs have operational similarities and are tied to a CCF in the management of PSA internal events at domestic nuclear power plants. In order to evaluate the CCF similarity rate between emergency diesel generators (EDGs) and alternative alternating current diesel generators (AAC DGs), it is most desirable to estimate CCF factors based on plant-specific or Korean industry generics. But, since CCF events are rare, detailed CCF analysis at PSA generally requires CCF event data from other power plants [2,3]. So currently, it is evaluated based on the general coupling factor of CCF. In this regard, by examining the actual operation failure history of the AAC DG installed to ensure safety, the CCF management with the EDG in PSA management is reviewed.

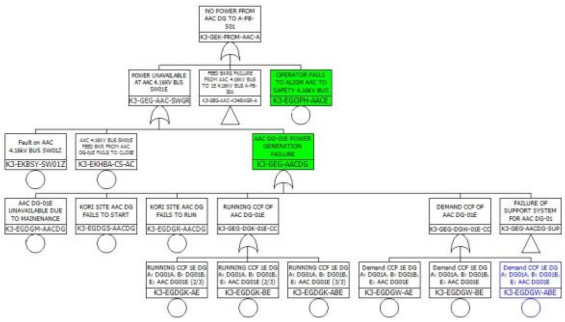

Figure.1 K34 AAC DG CCF FT Concept

4. Actual data review

4.1 Design review

The table data presented below is the design specifications of EDGs and AAC DGs, which have been investigated to understand the current situation.

Unit	Quantity (ea)	Capacity (kW)	Manufacturer (Engine/Generator)
Kori #2	2	4,400	GMD/WH
Kori #3/4	**4**	**7,000**	**Cooper/GEC**
AAC #2,3,4	**1**	**5,500**	**Doosan-MBD/Hyundai**
Shin-Kori #1/2	4	6,000	Doosan-SEMT/Alstom
AAC #1,2	1	7,200	Doosan-SEMT/Alstom
Shin-Kori #3/4	4	8,000	Doosan-MDT/Alstom
AAC #3,4	1	7,200	Doosan-MDT/Alstom
Hanbit #1/2	**4**	**7,000**	**Cooper/GEC**
AAC #1,2	**1**	**5,500**	**Doosan-MBD/Hyundai**
Hanbit #3/4	4	6,500	Doosan-SACM/JeumontSch.

AAC #3,4	1	6,500	Doosan-SACM/JeumontSch.
Hanbit #5/6	4	7,200	Doosan-SEMT/Alstom
Shin-Wolsung #1/2	4	6,000	Doosan-SEMT/Alstom
AAC #1,2	1	7,200	Doosan-SEMT/Alstom
Hanul #1/2	4	4,500	SACM/JeumontScheider
AAC #1,2	1	5,500	Doosan-MBD/Hyundai
Hanul #3/4	4	7,000	Doosan-SEMT/Alstom
AAC #3,4,5,6	1	7,000	Doosan-SEMT/Alstom
Hanul #5/6	4	6,500	Doosan-SEMT/Alstom

Figure.2 EDGs / AAC DGs operation of nuclear power plants in Korea

In the case of Hanbit Units 1(HB1) and 2(HB2) and Kori Units 3(K3) and 4(K4), which increased the output of the nuclear power plant, AAC DGs were additionally installed to increase safety. Therefore, it is also true that AAC DG is different from the existing EDGs in various aspects such as cooling method and safety function. Therefore, it is necessary to review the actual failure history between EDGs and AAC DGs of the above-mentioned power plants, which shows diversity in design specifications, as one of the reliability data for the CCF application of the two devices.

4.2 Historical failure review

The contents reviewed are data on EDG and AAC DG failure events for Hanbit Units 1 and 2, Kori Units 3 and 4 plants, which differ in the installation time, manufacturer, and some sub-systems of EDG and AAC DG, and from 2008 to 2021. Data, once trends are identified, individual events are reviewed for insight. The following is a review of whether there is a failure history with CCF elements applied to EDG and AAC DG so far for PSA management. (CCF between EDG and AAC DG of a power plant with the same manufacturer and installation specifications is not reviewed)

- Operational Performance Information System for Nuclear Power Plant (OPIS) data base
  - *No reported CCF-related events between EDG and AAC DG*

	Number of the Events	
OPIS total	160	Including the commissioning
Emergency Diesel	19	Including the unintended maneuver

Figure.3 The number of EDGs evets in OPIS (2008.1~2021.3)

The issuance of orders was characterized by regional characteristics, and the starting device was the largest proportion, followed by the I&C system. AAC DG was the largest proportion of I&C excluding other minor tasks specific sites failure lists. In order to extract valid data, the number of malfunctions by the diesel subsystem was re-examined. The loss of function criteria was based on the issuance of the Limiting Condition for Operation (LCO).

System Layout/Configuration	K3	K4	HB1	HB2	K3&4 AAC	HB1&2 AAC
Lubricant supply	22%	10%	0%	0%	0%	33%
Liquid Cooling	0%	15%	5%	17%	0%	33%
Fuel System	11%	0%	14%	0%	50%	0%
Starting Device	11%	20%	10%	33%	0%	0%
Safety, Control, Protection Device, Speed Monitoring	56%	40%	48%	50%	0%	33%
Exhaust system	0%	10%	10%	0%	0%	0%
Generator	0%	0%	0%	0%	50%	0%
Engine	0%	5%	14%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%

Figure.4 Failure mode ratio by subsystem of EDG and AAC DG

- Cases of function failure

There were a number of dissatisfied cases in the periodic tests of EDG and AAC DG from 2008 to 2021.3, such as turbocharger maintenance, but it was normalized and was not related to common cause failure.

By comparing the actual failure histories of subsystems and components of emergency diesel generators and alternative AC diesel generators, it was possible to examine the appropriateness of CCF application.

5. Conclusions

According to Korea's nuclear power system design regulation guidelines, it is necessary to have the independence, redundancy, and testability necessary to maintain their origin safety function even in the event of a single failure event, and add additional elements that may be vulnerable to internal or external hazards within the scope of the design criteria.

It is stipulated that the failure of the equipment should not affect the operation of the systems required for the design criteria (DBA). Nevertheless, EDG and AAC DG are grouped as CCF for PSA management in operating power plants. There are aspects that seem contradictory in design and management. Such PSA methodology can be viewed as a case in which the same active devices that do not consider diversity in the emergency diesel power system are applied in a redundancy design.

This study reviewed with actual failure data showed that at least for Kori Units 3 and 4 and Hanbit Units 1 and 2, the diversity and multiplicity of alternative alternating currents were reflected in accordance with the nuclear power plant design concept. In addition, in the Defense in depth (DID), the two facilities are in charge of Design Basis Accident (DBA) and Beyond Design Basis Accident (BDBA) separately in the classification of nuclear power plant conditions. In principle, although they are not safety facilities at the same level, it is necessary to seek the rationale for grouping and managing them as a common cause failure [4].

This dissertation suggests that a possible way to apply rational CCF management to NPPs should be discussed.

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