Analysis of Electrical System Related Incidents and Implications

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1. Introduction

Analysis of nuclear power plant accidents is important in terms of accident prevention, and power plant safety can be improved through high-level analysis in each field. In the European Union, incident investigation reports are prepared by topic through EU JRC Clearinghouse reports to provide insight into preventing nuclear power plant accidents. However, there are no reports analyzing Korea's nuclear power plant incidents by specialty or major events. In this study, incident cases were analyzed and implications were derived, limited to the electrical system field.

Among the 780 incidents that occurred between 2000 and 2022 in the Nuclear Power Plant Safety Operation Information System (OPIS) [1], 104 power system-related incidents were analyzed. Power-related incident cases were limited to incidents that were caused by power equipment or had an impact on power equipment due to the effects of the event. Classified into a total of 8 categories, including faulty devices, direct causes, root causes, and electrical phenomena, and created a database.

2. Analysis of electrical related NPP incidents

2.1 Incident classification

There are 8 incident classifications, divided into SBO/LOOP/loss of essential power system, power plant status, circumstances, direct cause, root causes, consequences, type of equipment failed and electrical phenomena. Although only one representative electrical phenomenon is indicated, there are many cases where several phenomena occurred simultaneously. (e.g. ground fault + overvoltage, etc.)

The classification criteria were created by referring to the JRC Clearinghouse reports of EDG-related incident [2], LOOP and SBO-related incident [3], and essential power system loss incident [4]. Other criteria such as electrical phenomena are added and incident summaries included in the database.

2.2 Analysis results

Analysis results are shown in Table 1. The majority of the incidents occurred during normal operation, accounting for 91 (88%) and 78 (75%) respectively, concerning plant status and circumstance. Of these, 78 (75%) were due to electrical causes. The type of equipment failed were numerous and diverse, with the following order: grid, relay, and circuit breaker. Electrical phenomena constituted the majority, with 33 cases of ground faults (32%) and 30 cases of loss of voltage (29%).

Table 1. Number of electrical-related incidents by category

SBO/LOOP/ESSENTIAL LOSS			TYPE OF EQUIPMENT FAILED/CONCERNED		
Others	94	90%	Grid	16	15%
LOOP	8	8%	Relay	14	13%
Loss of essential power system	2	2%	Breaker	11	11%
SBO	1	1%	Transformers	10	10%
PLANT STATUS			Cable	8	8%
Normal Operation	91	88%	etc	8	8%
No mode	8	8%	Generator	7	7%
Cold shutdown	2	2%	SWYD	6	6%
Hot shutdown	2	2%	CT/PT	6	6%
Permanent shutdown	1	1%	IPB/GIB	5	5%
CIRCUMSTANCES			MG-SET	4	4%
Normal operation	78	75%	Motor	3	3%
Testing or maintenance	16	15%	EDG	2	2%
Stopping or starting	10	10%	Switch	2	2%
DIRECT CAUSE OF EVENT			Inverter	1	1%
Electrical deficiency	78	75%	GCB	1	1%
Environmental	12	12%	ELECTRICAL PHENOMENA		
Human factors	9	9%	Ground fault	33	32%
I&C system failure	4	4%	Loss of voltage	30	29%
Mechanical deficiency	1	1%	Others	12	12%
ROOT CAUSES			Flashover	9	9%
After construction	48	46%	Overcurrent	6	6%
Design, production and construction	26	25%	Short circuit	4	4%
External (typhoon)	12	12%	Poor insulation	4	4%
Human factors	10	10%	Poor contact	4	4%
External (lightning)	5	5%	Overvoltage	1	1%
External (wildfire)	3	3%	Voltage drop	1	1%
CONSEQUENCES					
Reactor shutdown	71	68%			
EDG start-up	18	17%			
Reactor shutdown and EDG start-up	8	8%			
Others	7	7%			

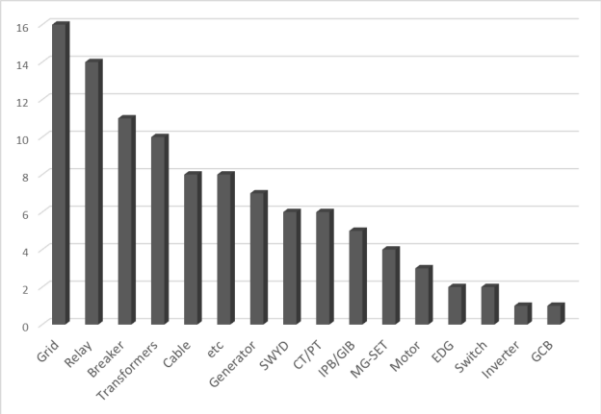

Figure 1. Number of electrical-related incidents by type of equipment failed/concerned

The results of classifying each event by representative electrical phenomenon were high, with 33 cases of ground fault (32%) and 30 cases of voltage loss (29%), followed by other causes including false signals, flashover, and overcurrent. Ground faults, poor

insulation, overcurrent, and poor contact are likely to occur together, but are classified as representative phenomena in incident investigation reports.

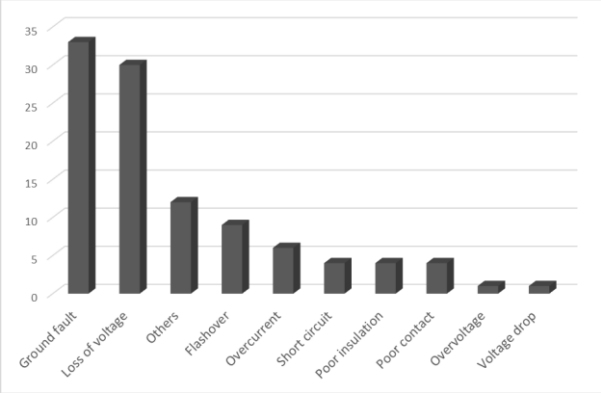

Figure 2. Number of electrical-related incidents by Electrical phenomena

2.3 Implications

Five out of seven LOOP incidents have occurred due to typhoons since 2020, so preventive measures against typhoons are necessary.

Both incidents of loss of essential power systems occurred in off-site power grids, and it is important to review the impact of external transients on essential power systems.

Out of the 16 incidents caused by transmission line failures, 12 were caused by external events (typhoons, lightning strikes, wildfires). Among these, it is presumed that fault currents flow into the on-site power system due to lightning strikes, but there are some incidents where it is difficult to clearly identify the cause.

Out of the 11 incidents classified as circuit breaker failures, 6 cases were due to mechanical causes such as compression springs, tulip connections, and lubrication of driving parts, and 5 cases were due to electrical causes such as control cards and manual circuit false signals. There were three incidents due to poor contact at the tulip connection, including the transformer.

Among the 10 incidents classified as transformer failures, insulating oil- related incidents were the most common, with 4 cases of gas in oil, 2 cases of insulating oil leakage, and 2 cases of poor contact at the tulip connection.

Out of the 11 cases where transfer failed, 5 were caused by failure of the circuit breaker itself, 2 were caused by errors in design logic, and 4 were caused by unsatisfactory input conditions.

3. Conclusion

Among the 780 incidents reported between 2000 and 2022 in the Nuclear Power Plant Safety Operation Information System (OPIS), we focused on 104 electrical system related incidents. The analysis categorized incidents into several distinct categories, including faulty devices, direct causes, root causes, and electrical phenomena, thus constructing a comprehensive database for further study and implementation of preventive measures.

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