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Development of Emergency Operating Strategies for Beyond Design Basis External Event(BDBEE)s in Korean WH Nuclear Power Plants

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1. Introduction

Nuclear power plant requires procedural guidance for Beyond Design Basis External Event(BDBEE)s using additional plant equipment after Fukushima event[1].

Westinghouse developed and connected emergency operating procedures into a set of FLEX Support Guidelines(FSGs)[2,3].

This paper explains that Korean WH(Westinghouse) type nuclear power plants develop emergency operating strategies for ELAP (extended loss of all AC power), which include guidelines to use permanent and portable equipment as necessary to prevent core damage until ac power is restored from a reliable alternate source of ac power.

2. Modeling of Accident Analysis

The extended loss of all ac power has been analyzed to identify the behavior of major NSSS process variables. In this analysis, RCP seal leak flow and steam generator depressurization/cooldown rate have been evaluated as major factor. The important assumptions used in the analyses are seal LOCA of 50 gpm /RCP and cooldown rate of 55℃/hour by operator's action.

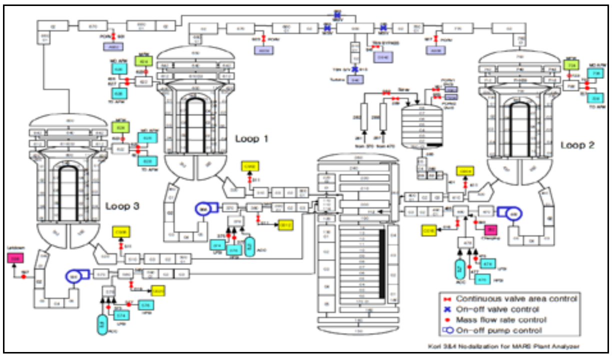

Fig. 1. Modeling for loss of all ac power

In this modeling for loss of all ac power, available equipment is passive system such as accumulators, pressurizer safety valve(PSV) and main steam safety valve(MSSV). All active equipment is unavailable.

3. Emergency Operating Strategies

Emergency operating strategies are declaration of ELAP and cooldown by operator during coping for an ELAP event. Head of TSC(technical support center) declares that the unit resides in an ELAP event when all unit specific ac busses cannot be recovered within SBO coping time. Plant operators reduce reactor coolant temperature below the value that ensures long term integrity of the RCP seals. Reducing the temperature and pressure of reactor decreases o-ring degradation of RCP seal and finally decreases potential seal leak flow.

4. Analysis Results

ELAP events were analyzed by Relap computer codes for Korean nuclear power plants. In these accident scenarios without operator action as shown in Fig.2, core exit void fraction increases rapidly in 1.84 hours after the event occurs because of having not been cooldown by steam dump in this case. Core uncovery and fuel damage will follow in 30 minutes.

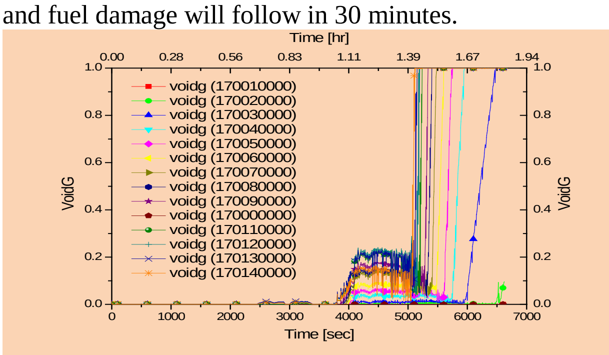

Fig.2. ELAP Events without operator action

In these accident scenarios with operator action as shown in Fig.2, core exit void fraction increases slowly in 33 hours after the event occurs because of having been cooldown by steam dump.

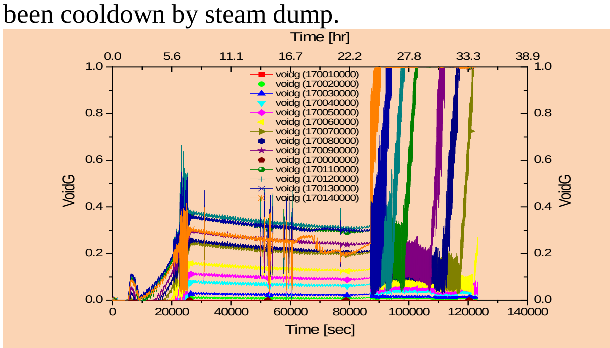

Fig.3. ELAP Events with operator action

The results of fuel cladding temperature as shown in Fig. 4&5 indicate that core damage in cases of core cooling and depressurization by operator action extends into 34 hours compare to 1.84 hour in analysis cases without operator action.

Plant personnel should prepare to operate FLEX equipments within the licensing basis SBO coping time considering the plant specific information if the unit resides in an ELAP. If the plants do not take the actions in that condition, operator will be blind to plant conditions. Also, it will be difficult to take symptom-based response to the ELAP event and the plant finally remains in unsafe condition.

RCP seal leak flow	5 gpm	50 gpm	300 gpm
Core damage time in case without operator action	1.89 hr	1.84 hr	1.38 hr
Core damage time in case with operator action	72 hr	34 hr	4.59 hr

Table 1. Core Damage Time in WH type plant

If plants use FLEX equipment, instrumentation and control are available during 72 hours after the SBO stats. Analysis results of this paper show that the plants do not result in core damage if the operator takes an action for cooling and prepares to operate the FLEX equipments.

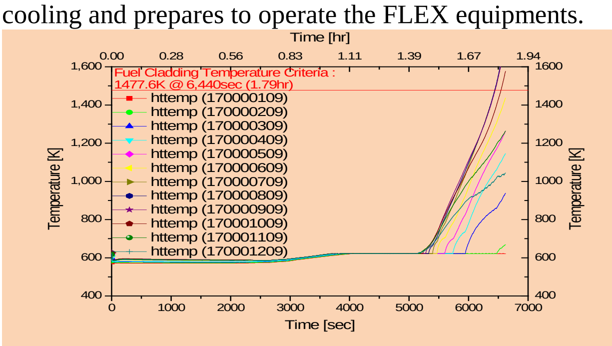

Fig.4. Fuel Cladding Temperature in ELAP Events without operator action

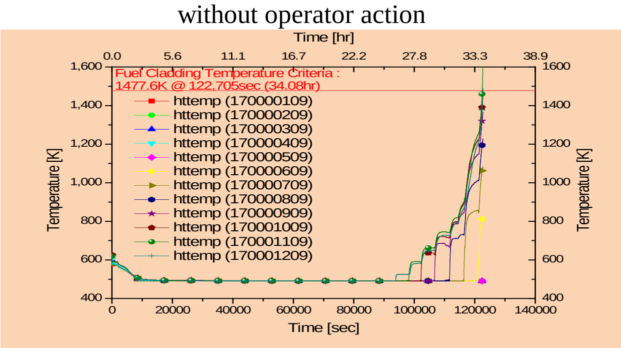

Fig.5. Fuel Cladding Temperature in ELAP Events with operator action

SBO Coping Times of Korean WH type nuclear power plants are 2-8 hours in PWR and 1 hour in PHWR as shown in Table 2. If a reliable ac power cannot be restored within the plants specific SBO coping time the SG PORVs should be controlled manually to accomplish plant cooldown.

Table 2. License Basis SBO Coping Time

Reactor	OPR1000/ APR1400	WH type	PHWR
DC Battery available time (hr)	4-8hr	2-4hr	1hr*

* Available time will be extend to 2.5 hours by shedding non-essential instrumentation & control

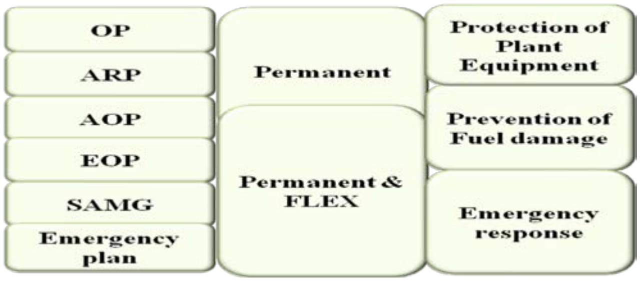

Fig.6. Response Procedures, Equipment and Missions in ELAP Events

The Korean WH emergency operating response strategies are designed to protect plant equipment and prevent fuel damage response to BDBEE with help of the FLEX equipments as shown in Fig.6

5. Conclusions

The Korean emergency operating response strategies were developed to cope with a ELAP such as Fukushima event. The strategies include guidelines to prevent fuel damage using the FLEX equipments. Operators should take actions to prepare FLEX equipments within license basis SBO coping time. The loss of all ac power has been analyzed to identify the behavior of major NSSS process variables using RELAP computer code. The accident analysis showed that the plant does not result in fuel damage in 72 hours after an ELAP if operators take actions to cool RCS with opening of SG ADV in 5 gpm seal leak case. In this scenario, because ELAP is in process and all power cannot be used, operator should operate the FLEX equipments in order to actuate active equipment using the EOP for SBO response. This strategy will prevent entering SAMG because this actions result in core cooling and stay in core exit temperature less than 650℃. Korean emergency operating guidelines (EOGs) will be developed using this strategies for response to the BDBEE. Also, FLEX operating guideline (FOG) will be prepared and frequently called interacting with abnormal operating guideline (AOG) and EOG in this accident scenario.

REFERENCES

[1] NEI 12-06, Diverse and Flexible Coping Strategies (FLEX) Implementation Guide, August 2012.

[2] WCAP-17601-P, Reactor Coolant System Response to the Extended Loss of AC Power Event for Westinghouse, Combustion Engineering and Babcock & Wilcox NSSS Designs, August 2012.

[3] WCAP-17792-P, Emergency Procedure Development Strategies for Extended Loss of AC Power Event for all Domestic Pressurized Water Reactor Designs, September 2013.