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Verification of Severe Accident Management Strategy Based on CANDU Reactor

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1. Introduction

The objective of this paper is to optimize strategies, identify any conflicts or problem areas in severe accident management guidelines (SAMG). This verification processes works to test usability of SAMG in as realistic an environment as possible. Validation and verification prove the basic technical information for severe accident management strategies in CANDU reactor. Being similar to typical PWR Plants, severe accident management guidance for CANDU plants have been developed during a last few years. Responses to CANDU severe accident initiators are verified uniquely with using abundant water inventories in the various process systems and in the containment to limit the core damage. Also, the containment safeguard systems are verified as keeping the containment pressure below the failure threshold in most cases.

2. Methods and Results

In this section, verification Method and results for the CANDU plants are described. [1] Basically the same methodology used for PWRs is applied to CANDU plants. Two accident scenarios to each plant (Wolsong nuclear power unit) are selected for SAMG verification of CANDU reactor.

2.1 Scenarios Selection for CANDU Plant Verification Model

First of all, probabilistic safety assessment (PSA) results are basically useful information for plant specific SAMG validation. Plant specific core damage sequences delivered from the results of Level 1 PSA analyses are grouped into plant damage states (PDSs) to reduce the number of sequences for the back-end analyses (Level 2 PSA).

Based on Level 1 & Level 2 PSA results, major event scenarios are selected as below.
-2 initiating internal events such as feeder break accident and total loss of Class IV power are selected a for Wolsong-1 plant
-2 initiating internal events such as total loss of Class IV power and total loss of instrument air are selected a for Wolsong-2, 3, 4 plants

Major verification lists are as below

- Logic, reasons and usefulness of information for severe accident management guidance
- Consistence between user recovery actions and component effectiveness as technical specifications for accident progress
- Practice to test plant information and data availability
- Findings of linkages and contradictions between abnormal operating procedures and SAMG
- Modification of improper guidance issued during verification process

2.2 Preparing Template for Selected Sequences at Scenario Model

Typical templates as proper validation scheme are developed in detail for validation of the selected scenarios with fully logical recovery action. Various paths sometimes show multiple possible scenario branches with arrows direction as fig. 1. Flow chart in template shows how much coolant injection into containment control containment pressure as a spray function during any severe accident.

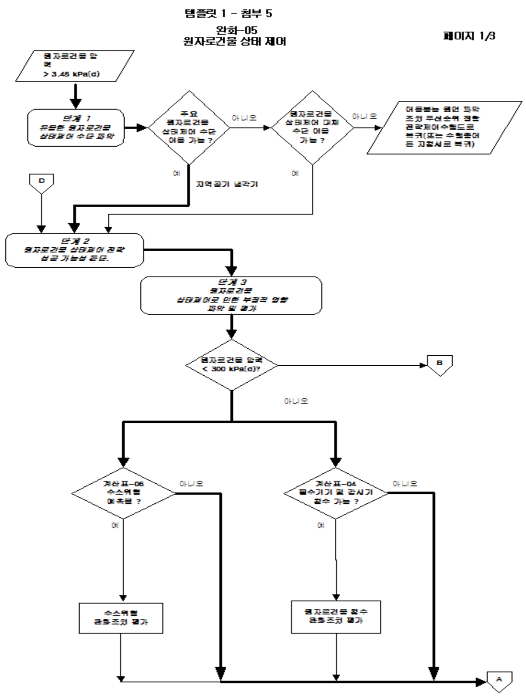

Fig.1. Typical Actual Template for Containment Control for PHWR Severe Accident Management

	Containment Spray Pump	
	1A	1B
Pump (Ref. Check Table #1)		
Pump Availability	yes/no	yes/no
Suction Source (Ref. Check Table #2)		
RWT	yes/no	yes/no
Containment Sump	yes/no	yes/no
Flow Path(Ref. Check Table #3)		
Spray Head line	yes/no	yes/no

	Containment Fan Cooler			
	1A	1B	1C	1D
Fan Cooler Availability	yes/no	yes/no	yes/no	yes/no

Fig.2. Typical Actual Information for Containment Control Table for PHWR Severe Accident Management

The plant status and accident sequences are fully verified as requested with a large water inventory of moderator and in the calandia vault, moderator and shield cooling capability, containment dousing system and local air coolers. Spray status related to potential containment failure modes and mechanisms which are suggested in NUREG-1335[1] are considered in the development of containment event tree (CET). [2] Fig. 2 shows typical spray and fan cooler workable or not. The progression of severe containment damage in CANDU would be terminated by adding enough water to the containment by the operation or restoration of spray before containment fails. Restoration of fan cooler for a loss of offsite power case or availability of fan cooler after the temperature-induced failure during a high pressure sequence is also considered to mitigate the accident. Due to the characteristic of CANDU plants, some cases of sequence leading to severe accident state are verified as a representative transient with the moderator cooling system and/or the emergency core cooling systems available. In this sequence, due to the effective removal of the decay heat and the stored heat using these systems.

2.3 Scenario Verification as Field Test

Finally, accident scenarios must be investigated in terms of field test at specific plant site. The evaluation performed to determine that the actions specified in the severe accident management guidelines can be followed by trained staff to manage a severe accident. For an example as SAMG verification case, total loss of Class IV power shows shortly the accident time progress for Wolsong unit 1 as below in fig. 3.

- Primary coolant pump trip after total loss of Class IV power, primary coolant decrease, main secondary feedwater pumps fail.
- Primary pressure increase to 10.24 MPa(g) , reactor shut occurred immediately.
- Condenser steam dump not available on loss of Class IV power, thus main-steam dump decrease steam-generator pressure.
- In order to verify the characteristics of CANDU plants, unique safety features are tested with computer simulation.

상황 번호	실제 시간 (훈련 시간)	사고 전개 내용	주제어실 조치 내용
1	H+00:00 (0:00)	o 월성 1호기 정상출력 운전중 4등급 전원상실 사고 발생	
2	H+00:00 (0:00)	o 원자로 트립 o 원자로냉각재펌프 트립 o 주급수 펌프 트립 o 비상발전기 기동 실패	o 비상운전절차 수행
3	H+00:05 (0:03)	o 백색 비상 발령	o 백색 비상 발령
4	H+00:30 (0:05)	o 비상기술지원실 발족	o 비상기술지원실 지시에 따름
5	H+02:47 (0:06)	o 증기발생기 고갈	
6	H+02:53 (0:07)	o 살수 시작	
	H+02:55 (0:08)	o 노심 노출 시작 (ROH 수위 0 m 미만)	
	H+03:16 (0:09)	o 살수 종료	
	H+03:48 (0:09)	o LOCA 신호 발생	
7	H+04:22 (0:10)	o 감속재 수위 6864 mm 이하로 감소 (SAMG 진입조건)	
	H+04:23 (0:11)	o 비상운전절차서 종료 결정	o 비상운전절차서 종료
	H+04:25 (0:12)	o 중대사고관리지침서로 전환 o 비상기술지원실 전략수행제어도 감시 시작	o 중대사고관리지침서로 전환
	H+04:30 (0:14)	o 피동촉매형수소재결합기 켬	o 피동촉매형수소재결합기 켬
8	H+04:35 (0:15)	o 완화-01 진입 - 조치 없음	o 원자로냉각재계통 냉각수 주입 수단 확인
9	H+04:45 (0:25)	o 완화-02 진입 - 조치 없음	o 감속재 주입 수단 확인
10	H+04:55 (0:35)	o 완화-03, 04 건너 뜀	
	H+04:57 (0:37)	o 완화-05 진입 - 조치 없음	o 지역공기냉각기 상태 확인
	H+05:07 (0:47)	o 완화-06 건너 뜀	
	H+05:16 (0:48)	o 전략수행제어도에서 SAMG 종료 조건 확인 o 전략수행제어도 반복 수행	

Fig.3. Typical Actual Time Sequence after Accident Initiation for PHWR Severe Accident Management

3. Conclusions

This validation processes enhance confidence in the SAMG. Plant personnel involved deeply in verification of recovery activity after accident scenarios. These review activities provide initial hands-on training and increase familiarity with guidelines to plant behavior. Based on throughout verification works, CANDU has different containment related design reasons from PWRs. The conditional containment failure probability of CANDU is lower than that of PWRs. One of the main reasons is the contribution of limited core damage sequences not causing fuel melting or channel disassembly, thanks to enough cooling water, spray and fan cooler.

REFERENCES

[1] USNRC," Individual Plant Examination: Submittal Guidance", NUREG-1335, August 1989KAERI, "Development of Computer Code for Level 2 PSA of CANDU Plant", KAERI/RR-1573/95, 1995
[2] 1989KAERI, "Development of Computer Code for Level 2 PSA of CANDU Plant", KAERI/RR-1573/95, 1995