Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Analyses of Anticipated Transient without Scram Events in SMART

Hyungrae Kim*, Ji-Han Chun, Soo Hyoung Kim, Soo Hyung Yang, Kyoo Hwan Bae,
Suhn Choi, Young Jong Chung
Korea Atomic Energy Research Institute
**Corresponding author: khr@kaeri.re.kr*

1. Introduction

SMART is a small integral reactor, which was developed at KAERI[1] and acquired standard design approval in 2012. SMART works like a pressurized light-water reactor in principle though it is more compact than loop-type large commercial reactors. ATWS(Anticipated Transient Without Scram) event is an AOO(Anticipated Operational Occurrence) where RPS fails to trip the reactor when requested. SMART incorporated a DPS(diverse protection system) to protect the reactor system when RPS(reactor protection system) fails to trip the reactor[1]. The results of transient analyses show that DPS in SMART effectively mitigates the consequence of ATWS.

2. Event description and acceptance criteria

ATWS is not a design basis event and is highly unlikely to occur. However, it is very significant in reactor safety since RCS(reactor coolant system) pressure may rise beyond a design limit and fuel rod assembly may be damaged. The consequence may result in core melt or release of radioactive material to the environment. Thus, regulations [2,3] require a DPS to mitigate the consequence in case of RPS failure.

The major concern in ATWS is peak RCS pressure. The sequence of ATWS has been analyzed for the representative events. The representative events are uncontrolled withdrawal of control element assemblies, loss of normal feedwater, and complete loss of reactor coolant flow. The events are typical transients which result in over-pressurization of RCS which is a primary safety concern in ATWS. The transient were analyzed for the cases with and without DPS to assure effective mitigation of the consequence by the intervention of DPS.

In ATWS, the consequence is mitigated by DPS, PRHRS (Passive Residual Heat Removal System) , and PSV (Pressurizer Safety Valve). DPS is activated by high pressurizer pressure, high containment pressure, or operator action. DPS initiates reactor trip by opening the contactor in motor-generator set to CRDM power line. Scram rods drop into the reactor as CRDM lost the power. The undervoltage relay in the CRDM generates turbine trip signal. DPS also raises PRHRAS (Passive Residual Heat Removal Activation Signal) when feedwater flowrate falls below a setpoint. PRHRAS from DPS is physically wired to PRHRS. Fig. 1 shows a block diagram of DPS and RPS. PSV mitigates over-pressurization of RCS by releasing steam to RDT(reactor drain tank). PSV is designed to keep RCS pressure below 110% of the design pressure in design basis events.

Main safety objective for ATWS is to keep the peak pressure in reactor pressure boundary below 3200 psig (22 MPa)[4].

3. Analysis method

3.1 Mathematical model and code

The transients are analyzed by using TASS/SMR-S code[5] which simulates thermal-hydraulic behavior by solving basic conservation equations on mass, momentum, and energy. In addition, TASS/SMR-S has built-in kinetics model, helical steam generator model, and reactor coolant pump model required to simulate the transients.

3.2 Analysis conditions

Parametric analyses have been performed for the typical events by core cycle, fuel burnup, initial power level, and etc. The initial conditions are nominal conditions at a selected core cycle, fuel burnup, and initial power level. Parameters dependent on core cycle, burnup, power level are: reactivity feedback by fuel and moderator temperature, axial power shape, radial peaking factor, lifetime of delayed neutron, and fuel gap conductivity. Analysis setpoint of PSV is 17.27 MPa. Control system is not considered unless it worsens the consequence.

4. Analysis results

The limiting ATWS event in SMART is CEA withdrawal whereas LNF or loss of load is limiting in conventional large LWR plants. This is due to design characteristics of SMART such as high reactivity worth per CEA and negative MTC(moderator temperature coefficient) as low as to mitigate over-pressurization.

The peak pressures of RCS in LNF(Loss of Normal Feedwater) and CLOF(Complete Loss Of reactor coolant Flow) are calculated to be lower than that of CEA withdrawal. The core power is decreased by negative reactivity feedback in case of LNF and CLOF. While in CEA withdrawal event, the negative reactivity feedback by the moderator temperature increase is insufficient to suppress the positive reactivity insertion by the CEA withdrawal.

Figs. 2 and 3 show RCS pressure by fuel burnup in ATWS initiated by CEA withdrawal without DPS. The results shown in Figs. 2 and 3 are for initial core which shows more severe pressurization than for equilibrium core. The results show that peak pressure exceeds the acceptable pressure below 600 EFPD(effective full power day) for 20% initial power and 300 EFPD for 50% initial power. Peak pressure does not rise beyond the acceptable limit under full power condition.

Fig. 4 is RCS pressure with DPS in action. The figure shows that the peak pressure is kept below the acceptable limit. DPS initiates reactor trip when pressurizer pressure reaches at its setpoint. Turbine trip is assumed to occur without any time delay when rector trips. Turbine trip causes loss of off-site power. The peak pressure reaches PSV setpoint for 50% power level since higher initial core power results in more heat imbalance in RCS before scram by DPS. Once DPS shuts off reactor power RCS pressure stabilizes at an equilibrium condition which is lower than its initial pressure.

5. Conclusions

ATWS events are analyzed for the typical over-pressurizing events to ensure that DPS in SMART effectively mitigates the consequence of the events. The limiting event is found to be CEA withdrawal. The peak pressure of RCS does not exceed the acceptable limit of 22 MPa during the transients when DPS initiates reactor trip and activates PRHRS as designed.

REFERENCES

[1] SMART Standard Safety Analysis Report, KAERI, 2012.
[2] NRC 10 CFR 50.62, "Requirements for Reduction of Risk from Anticipated Transient Without Scram Events for Light-Water-Cooled Nuclear Plants," 1997.
[3] 교육과학기술부령 1 호, "원자로시설 등의 기술기준에 관한 규칙," 제 27 조, 2008.
[4] 경수로형 원전 안전심사지침, 분류번호: 15.8, 제목: 원자로정지불능 예상과도, 개정 3, KINS, 2009.
[5] Kim et al., TASS/SMR-S code technical report, 2011.

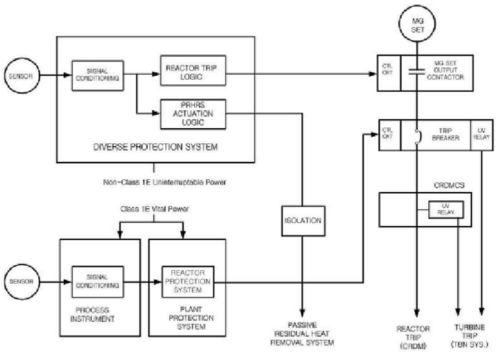

Fig. 1 RPS/DPS block diagram

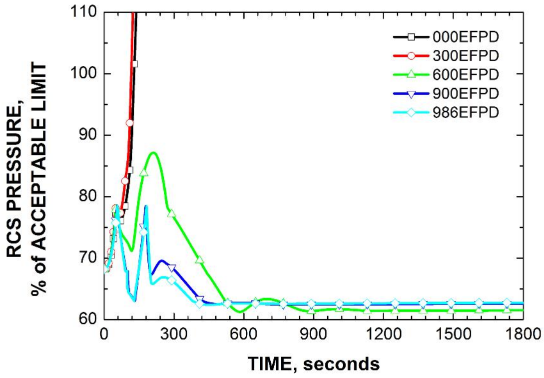

Fig. 2 RCS pressure by burnup (20% power, initial core) without DPS for CEA withdrawal

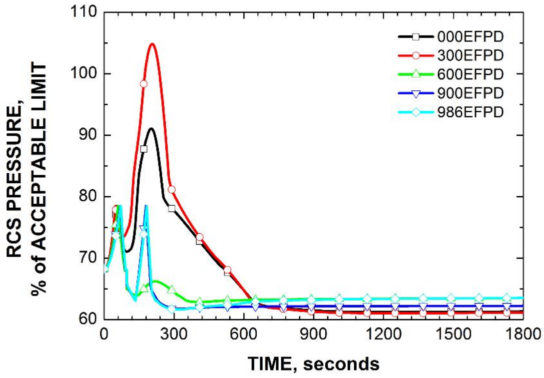

Fig. 3 RCS pressure by EFPD(50% power, initial core) without DPS for CEA withdrawal

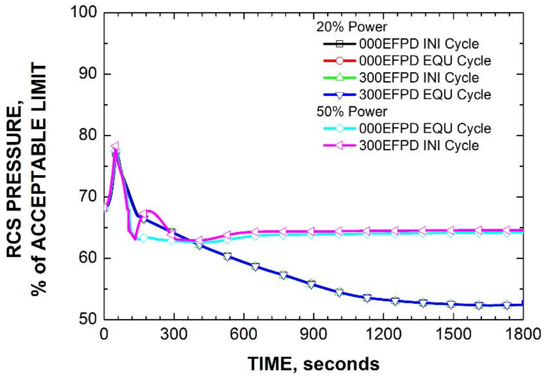

Fig. 4 RCS pressure with DPS in action for CEA withdrawal