An Evaluation of KSNP SGTR Recovery Strategy

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1. Introduction

The Steam Generator Tube Rupture (SGTR) recovery guideline of the Korean Standard Nuclear Power Plant (KSNP) Emergency Operating Guidelines (EOG) provides operator actions which must be accomplished in the event of an SGTR [1]. The goal of the guideline is to safely establish Shutdown Cooling System (SCS) entry conditions while minimizing radiological releases to the environment and maintaining adequate core cooling.

An evaluation has been performed to verify the effectiveness of SGTR recovery strategy for an SGTR occurred in lower power condition as well as full power operation condition, especially in view of the affected steam generator level and pressure controls.

2. SGTR Recovery Strategy

Figure 1 shows the schematic diagrams of the SGTR recovery strategy. As shown in this figure, the SGTR EOG strategy uses the control-grade turbine bypass valves for the initial rapid RCS cooldown when the steam dump path to condenser is available. However, under Loss Of Offsite Power (LOOP) condition, which leads to the loss of control-grade normal steam dump path, the recovery strategy requires immediate isolation of the affected steam generator prior to initiating rapid RCS cooldown using the intact steam generator ADV only.

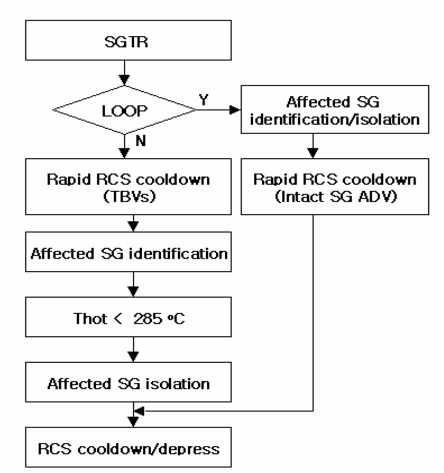

Figure 1. Schematic diagram of the SGTR recovery strategy

During the subsequent RCS cooldown and depressurization to minimize the leak flow to the affected steam generator, the level and pressure of the affected steam generator are major parameters to be controlled.

3. Analysis Methods

For the evaluation, single-tube ruptured SGTR events occurred at full power operation and at hot standby (HSB) condition with all control systems available have been selected. In both simulation cases, the applicability and effectiveness of SGTR recovery strategy has been evaluated from the standpoint of controlling the affected steam generator pressure and level. For an SGTR with LOOP, the recovery strategy for the affected steam generator level and pressure controls already has been verified [2].

Operator recovery actions according to the SGTR EOG are assumed to start 10 minutes after the reactor trip for full power case and 10 minutes after the event initiation for HSB case considering time expected to be required for conducting the Standard Post Trip Actions (SPTA) and the Diagnostic Actions (DA) before entering the SGTR recovery guideline.

The analysis has been performed using the Nuclear Plant Analyzer (NPA) computer code [3]. The NPA is an engineering simulation software program that can be used for real-time, best-estimate simulations of wide range variety of hydraulic and thermal transients in nuclear power plant systems. The NPA consists of has the process model that can simulate the overall power plant systems and an advanced Graphical User Interface (GUI) function. It is possible to simulate the behavior of a plant in normal and abnormal operating conditions as well as hypothetical design basis accident conditions with an accuracy comparable to that of computer codes used in design of nuclear power plant.

Table 1. Safety functions control

Parameters	Range
PZR level	33~77%
RCS subcooled margin	> 27 °F
RCS cooldown rate	< 100 °F /hr
RCS-SG pressure difference	< 50 psi
Affected SG level	70~90% WR
SG pressure	< 1188 psia
Manual system operation	- Safety injection - PZR spray - TBVs

Safety functions, as shown in Table 1, required to mitigate the consequence of the event are controlled by manual operator actions. The operator actions are taken to safely establish SCS entry conditions while minimizing radiological releases to the environment and maintaining adequate core cooling are shown in Table 1.

4. Simulations and Results

Figures 2 through 5 show the analysis results of SGTR events occurred in full power and HSB condition. It is assumed that an SGTR is occurred in SG 2. For both cases, SG pressures are well controlled within recovery control range, but the affected SG levels pose overfill concern without immediate control actions.

For full power case, the SG level is increased after reactor trip by automatic control of feedwater control system prior to manual operator actions. For HSB case, there is less margin of the affected SG level to the upper limit compared to the full power case because there is no level shrink effect after reactor trip as in full power case.

The affected SG levels can be controlled within the control range by initial rapid cooldown of Reactor Coolant System (RCS) using turbine bypass valves and following immediate depressurization of RCS using pressurizer spray.

5. Conclusion

The analysis results shows that the overfill of the affected steam generator for a SGTR occurred in lower power operation as well as full power mode can be prevented by initial rapid cooldown of RCS and balancing the RCS-SG pressure difference to terminate the leak flow.

Based on the simulation results, it is found that early isolation of feedwater to the affected SG, when the event is determined during DA, is recommended for the affected SG level control.

It is concluded that the KSNP SGTR recovery strategy can provide operator actions for controlling the affected SG pressure and level, applicable to events occurred not only in power operation mode but also in lower plant operation modes.

REFERENCES

1. KOPEC, "Korean Standard Nuclear Power Plant Emergency Operating Guidelines" (2003).

2. J. H. Lee, et al., "Development of SGTR Recovery Strategy," Proc. of ICAPP '04, American Nuclear Society, Pittsburgh, PA USA (2004).

3. KOPEC, "Development of the Plant Analyzer for Korean Standard Nuclear Power Plants" (2000).

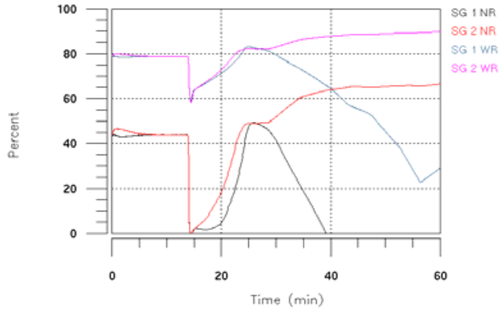

Figure 2. Steam Generator Level (full power)

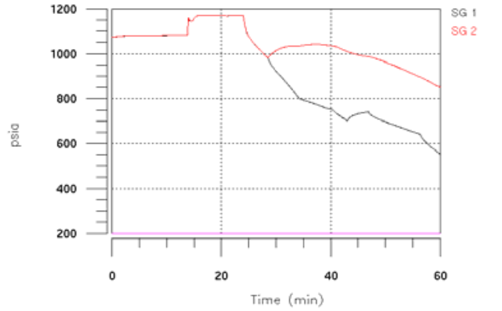

Figure3. Steam Generator Pressure (full power)

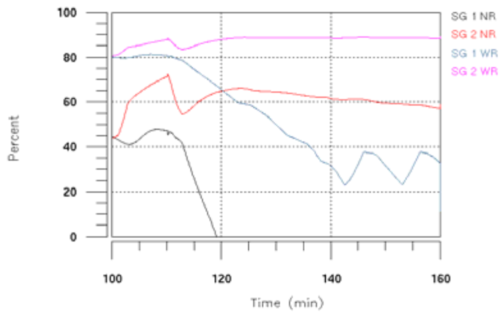

Figure 4. Steam Generator Level (HSB)

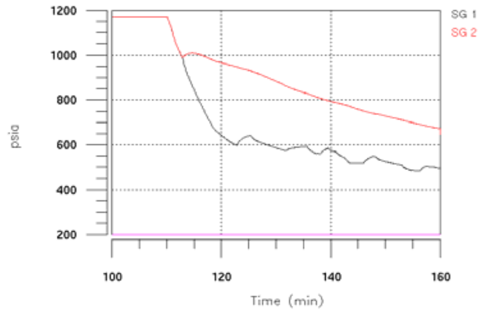

Figure 5. Steam Generator Pressure (HSB)