A Study on the Operating Scenario Development for BNPP CPS HFE Validation

Chanho Sung*, Jooyoul Lee, Yongsoo Kim
KHNP Central Research Institute, 70 1312-gill, Yuseung-daero, Yuseung-gu, Daejeon, Korea
**Corresponding author: chsung95@khnp.co.kr*

1. Introduction

Korea APR1400 type nuclear power plant has been being constructed in UAE. KHNP CRI is supposed to supply UAE BNPP (Barakah Nuclear Power Plant) with CPS which is recently being modified with two column format (TCF). The TCF CPS has a character that shows instructions and contingency actions simultaneously on the operator's display screen. For applying the TCF CPS, it is necessary to verify and validate the modified design, therefore the V&V in the view of HFE for the TCF CPS was performed by CRI and WEC based on NUREG-0711.

This paper describes the developed operating scenarios for the TCF CPS design validation. This validation was to evaluate availability and usability of CPS using the nuclear power plant simulator. For the validation, 5 scenarios including SBO (Station Blackout) were developed, and the validation based on the scenarios was conducted 4 times including pre-validation.

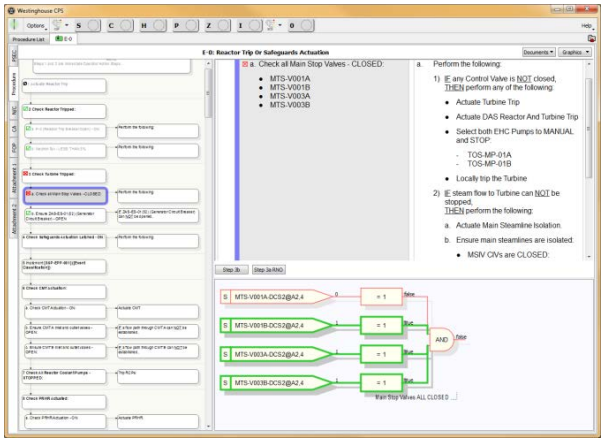

Fig. 1. BNPP CPS with two column format

2. Methods

It is important to develop scenarios for validating the TCF CPS. The scenario should include the purpose of the validation and specific events including CPS failure as well as normal situation in the plant.

The followings describe the objective of this validation and the criteria for developing this scenario:

2.1 Objectives of TCF CPS Validation

- Validate that TCF CPS design has adequate capability for alerting, informing, controlling, and feedback such that personnel tasks are successfully completed during accident response.
- Validate specific personnel tasks can be accomplished within specific time and performance criteria.
- Validate that TCF CPS minimize personnel error and assure error detection and recovery capability when errors occur.
- Validate that the personnel can effectively transition between the HSIs and procedures in accomplishing their tasks and that interface management tasks, such as display configuration and navigation, are not a distraction or an undue burden.
- Validate that TCF CPS supports coordination among crewmembers
- Validate that TCF CPS supports team awareness
- Validate that TCF CPS supports operator to evaluate objectives of steps
- Validate that TCF CPS is well integrated to other MMIS
- Validate that place keeping mechanism of TCF CPS is adequate

2.2 Criteria to Develop Scenarios

- Useful to evaluate HFE issues of TCF CPS
- Scenario utilizing both NOP based on paper and EOP based on CPS
- Objective performance of plant is clear.
  - ✓ Critical operator actions are performed successfully
  - ✓ The injected events are diagnosed
  - ✓ The events are mitigated within time limit
- CPS failures are considered
  - ✓ CPS failure from initially
  - ✓ CPS failure during the scenario
- Anticipated events should be included
  - ✓ Starting Up Plant
  - ✓ Design Basis Event
  - ✓ Equipment Rotation Operation
  - ✓ Known and Unknown Component Trouble
  - ✓ Electric related Trouble

3. Results

Since BNPP CPS is only available with AOP and EOP, thus GOP and NOP are performed with paper based procedures. Crew has to perform the scenarios using both paper procedures and TCF CPS. The scenarios were developed considering DBA (Design Basis Accidents) such as ESDE, LOCA, SGTR and SBO. Overall direction of each scenario is that NOP (or GOP), AOP, and finally EOP are executed gradually. Each scenario consists of initial condition, latent malfunction, first event, second event, third event and forth event.

3.1 Scenario-1: Excessive Steam Demand Event

This scenario is that crew starts the main feedwater pump and then stops start-up feedwater pump to raise the RTP (reactor thermal power) from 2% to 5%. In the meanwhile, SBCS valve fails and SIAS malfunction is generated. And then, Main Steam Line breaks outside containment when EDG in SIAS AOP is stopped. Crew starts emergency operation with SPTA and performs diagnostic action. According to the result of accident diagnosis, crew enters the ESDE procedure. After crew isolates the failed SG and stabilizes RCS below 250℃, this scenario is stopped.

This scenario's running time is about 100mins, and about 10 procedures including GOP, NOP, AOP, EOP are used.

3.2 Scenario-2: Large Loss of Coolant Accident

This scenario is that crew swaps CCW pumps per monthly equipment rotation schedule at the RTP 100%. After that, SG 2 economizer feedwater controller fails high. Crew verifies proper actions were taken per AOP to maintain the SG level. In the meanwhile, a small earthquake occurs and then LLOCA occurs followed by reactor trips and safety injection. Crew starts emergency operation with SPTA and performs diagnostic action. According to the result of accident diagnosis, crew enters the LOCA procedure. When crew confirms safety injection flow adequate to cool the core, this scenario is terminated.

This scenario's running time is about 80mins, and two AOPs for earthquake and for high RCS are performed at the same time by crew.

3.3 Scenario-3: Station Blackout

This scenario is that crew starts a CW pump and stops another pump under operation per monthly equipment rotation schedule at the RTP 100%. RCP abnormal event occurs during CWP rotation. And then an MFW pump trips and crew stabilizes plant with AOP (MFW Pump trip). While performing the related AOP, station blackout occurs, the crew recognizes the reactor tripped and enters SPTA procedure and diagnostic action. According to the result of accident diagnosis, crew enters the SBO procedure. When the crew has reenergized a C-1E 4KV bus from the AAC diesel generator and stabilized the plant, the scenario is terminated. This scenario's running time is about 80mins. This scenario is that crew performs equipment rotation at plant steady state with full power and during the rotation, RCP abnormal and MFW pump trip occur. In the middle of performing AOP, suddenly SBO occurs and crew should respond to the unexpected emergency situation with CPS.

3.4 Scenario-4: Small Loss of Coolant Accident

This scenario starts that TBN startup was completed and the plant is ready for synchronization at the RTP 15%. While crew is synchronizing the generator, AFAS2 inadvertent actuation occurs. Crew performs AOP for AFAS Malfunction. About 5 minutes after AFAS2 malfunction, RCS leak occurs. It takes about 30 min to handle two malfunctions simultaneously. RCS leakage develops into a SLOCA. Crew should perform a manual trip by interrupting power to MG sets because DPS and ATWT are already failed in latent malfunction condition. Crew enters SPTA and performs DA. While performing DA, CPS failure occurs. Crew should transfer from CPS to PBP (paper based procedure) for backup.

In this scenario crew should recognize and cope with the situation in the latent malfunction conditions. And also crew should cope with CPS failure while performing EOP. This scenario's running time is about 100mins.

3.5 Scenario-5: Steam Generator Tube Rupture using PBP

This scenario starts with CPS failure in initial conditions. Therefore crew should perform all the scenario using PBP without CPS. The scenario includes CCW abnormality, steam generator tube leak, and steam generator tube rupture. In this scenario, the usability and suitability of PBP is validated as backup hardcopy of CPS.

4. Conclusions

5 scenarios were developed to validate the design and usability of TCF CPS. Each scenario consisted of NOP, GOP, AOP, EOP based on the design basis accidents and each scenario also considered the balance of workload for crew operators.

REFERENCES

[1] KHNP, BNPP CPS Centered HFE V&V Scenario Development Report, Rev 2, 2019
[2] KHNP, BNPP CPS Centered HFE V&V Report, Rev 4, 2020