Computerized Procedure System centered HFE V&V for Shinkori Units 5&6

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1. Introduction

CPS (Computerized Procedure System) is a representative system of main control room for APR1400 type nuclear power plant. Shinkori units 3&4(SKN3&4) have been using the CPS for commercial operation for several years since 2016. Also Shinhanul units 1&2(SHN1&2) and Shinkori units 5&6(SKN5&6) are supposed to use CPS. All the CPS in SKN3&4, SHN1&2, and SKN5&6 were designed by KHNP CRI, and the CPS has been upgraded gradually for improving usability in each construction project such as SHN1&2, SKN5&6. The CPS for SKN5&6 has been upgraded based on user experience of previous plants.

KHNP CRI conducted the CPS centered HFE V&V for SKN5&6 twice in 2016 and 2020~2021. This paper describes the result of CPS HFE V&V in 2020~2021. The V&V was conducted in two installments and two operation teams from SHN1&2 participated each in the V&V.

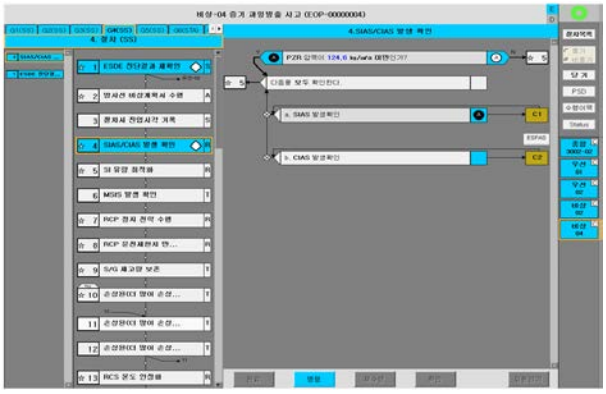

Fig. 1. CPS User Interface for SKN5&6

2. Methods

The second round of CPS centered V&V in 2020~2021 was conducted in two installments, with two operation teams as subjects, and MCR operation expert, HFE expert as evaluators, and CPS designer. The V&V required operation teams to carry out 4 scenarios including design basis accidents, and was conducted based on the evaluation of the appraiser and the results of the operator's survey.

2.1 Overview of V&V

Table I: Overview for CPS V&V [1]

	1st Instalment	2nd Instalment
Date	Oct. 2020	Feb. 2021
Place	APR MCR(at CRI)	APR MCR(at CRI)
Operation Group (test subject)	Team **A**	Team **B**
Evaluator	HFE expert, Operation expert	
Evaluation Tool	Operation Scenarios(4), NASA-TLX, SART, BARS, Issue Questionnaire	
Number of target issues	15	

2.2 Target Issues of CPS

Target Issues in the V&V included one HED (Human factors Engineering Discrepancy) in SKN5&6 PV (Preliminary Validation, 2016) and 14 expected issues following design improvement after SKN5&6 PV**.** The detailed issues are as follows:

(1) Recognition of automatic logic result display of bidirectional instructions (HED in PV)
(2) Usability of automatic logic of instructions in procedures
(3) Usability of the MCR crew for CCF abnormal procedure
(4) Usability for deleting "CALL" button
(5) Usability for 'Override' function enhancement in parent instructions
(6) Usability for automatic logic disable indication
(7) Usability for action target in browser mode
(8) Usability for on-line hard copies in 2D overview pane
(9) Cognitive for all CPS client failure
(10) Usability for temporary storage and re-execution of procedures in progress
(11) Usability for procedure in browser mode
(12) Usability for HSI improvements in CPS
(13) Usability of plant states and settings in task groups
(14) Usability for Human error prevention technique in CPS
(15) Usability for 2D overview pane

2.3 Operation Scenarios for CPS V&V

CPS for SKN5&6 is available in EOP (Emergency Operating Procedure), AOP (Abnormal Operation Procedure), ARP (Alarm Response Procedure), GOP (General Operating Procedure), except for SOP (System Operating Procedure) which is paper based procedure. Thus crew has to perform the scenarios using both CPS and paper procedures if the scenario requires SOP. The scenarios were developed considering DBE (Design Basis Events) such as ESDE, LOCA, LOAF and SGTR. Overall direction of each scenaro is that GOP (or AOP), AOP, and finally EOP are executed gradually. Each scenario consisted of initial condition, latent malfunction, first event, second event, third event and forth event. Fig.2 shows scenario overview for the CPS V&V.

시나리오(SC)	SC-1	SC-2	SC-3	SC-4
DBE	ESDE (with CCF)	LOCA	LOAF	SGTR (with CPS fail)
시작 조건	100% IC-602	100% IC-602	100% IC-602	100% IC-502
시작 상태	-	-	모든 CPS clients Fail	-
1차 Event (GOP or AOP)	가압기 압력채널 100% Fail Lo 경보 발생	출력감발 100%->75% CPS Auto logic fail(공지)	CVCS 계통 충전펌프 교체운전	출력감발 100%->75%
2차 Event (AOP)	CCF 발생	SG2 수위제어채널 고장	주급수펌프 01A 정지	SG1 Tube Leak 발생
3차 Event (EOP)	CV 내부 주증기관 파열 - DPS에 의한 원자로 자동정지	RCS LOOP C/L 2A 파단	모든 주급수/보조펌프 정지 및 보조급수밸브 고장	SG1 Tube Rupture 발생
4차 Event	-	LOCA 진입후 CPS auto logic 복구	보조급수 밸브 (movAF045/046) 고장 복구	CPS Fail 발생 (우선-02 진입후)
사용 절차서	[비정상] 비정상-3431-09(가압기 압력제어계통 고장) 비정상-3751-04(공통유형고장시 조치) 비정상-3751-05(CCF를 동반한 DBA시 조치) [우선/비상] 우선-01 원자로 트립후 조치 우선-02 사고진단 비상-04 ESDE	종합-3003-02(출력 100%->25%) 계통-3511-01(터빈발전기운전) 계통-3451-01(화학 및 체적제어계통) [비정상] 비정상-3540-01(증기발생기 수위제어 비정상) [우선/비상] 우선-01 원자로 트립후 조치 우선-02 사고진단 비상-02 LOCA	계통-3451-01(화학 및 체적제어계통) [비정상] 경보-3526-107(FW MFW PMP PP01 Stop) 비정상-3500-03(주급수펌프 트립) [우선/비상] 우선-01 원자로 트립후 조치 우선-02 사고진단 비상-05 LOAF	종합-3003-02(출력 100%->25%) 계통-3511-01(터빈발전기운전) 계통-3451-01(화학 및 체적제어계통) [비정상] 비정상-3431-03(증기발생기 튜브누설) [우선/비상] 우선-01 원자로 트립후 조치 우선-02 사고진단 비상-03 SGTR
검증 현안	현안-02, 03, 05, 15	현안-01, 02, 05, 06, 14, 15	현안-04, 05, 09, 15	현안-08, 10, 13, 14, 15

Fig. 2. Scenario Overview for CPS centered V&V [2]

3. Results

For the target issues, four identical scenarios were performed by 2 MCR operation teams of SHN1&2. The results are as shown in Table II [3]. Table II is the result summary from comprehensive debriefing after the V&V, and the final result is currently being analyzed. This V&V ended nine of the 15 pending issues, and six of them needed to be supplemented. In addition, two new issues were drawn.

Once the HED (Human factors Engineering Discrepancy) is derived after analyzing the data such as the results of evaluation, debriefing, and survey with operators. The HED and remaining issues will be re-verified in SKN5&6 ISV (Integrated System Validation).

Table II: Result of CPS V&V Debriefing

No.	Target Issue	Completed	Not completed	Note
(1)	Recognition of automatic logic result display of bidirectional instructions (HED in PV)	√		-
(2)	Usability of automatic logic of instructions in procedures		√	Need to strengthen indication of "logic disable"
(3)	Usability of the MCR crew for CCF abnormal procedure	√		-
(4)	Usability for deleting "CALL" button	√		-
(5)	Usability for 'Override' function enhancement in parent instructions	√		-
(6)	Usability for automatic logic disable indication		√	Need to review the design
(7)	Usability for action target in browser mode	√		-
(8)	Usability for on-line hard copies in 2D overview pane		√	Need to reconfirm
(9)	Cognitive for all CPS client failure	√		-
(10)	Usability for temporary storage and re-execution of procedures in progress	√		-
(11)	Usability for procedure in browser mode	√		-
(12)	Usability for HSI improvements in CPS		√	Monitoring pane sorting error
(13)	Usability of plant states and settings in task groups		√	Need to check automatically in SFSC
(14)	Usability for Human error prevention technique in CPS		√	Need to review the design of concurrent/independent verification
(15)	Usability for 2D overview pane	√		-
New (1)	-		√	Need to review where the start step in EOP
New (2)	-		√	Need to review applying bidirectional instruction in SPTA procedure

4. Conclusions

CPS centered V&V activities for SKN5&6 have been carried out continuously since 2016. This paper introduced the 2nd CPS centered V&V for SKN5&6, but the final outcome (i.e. HED items) was not described because the assessment results are currently being analyzed.

In the second half of 2021, Integrated System Validation (ISV) is scheduled for SKN5&6, and the usability of CPS will also be evaluated in the ISV.

REFERENCES

[1] KHNP, SKN5&6 CPS Centered HFE V&V Plan, Rev 1, 2020
[2] KHNP, SKN5&6 CPS Centered HFE V&V Scenario, Rev 7, 2021
[3] Operator's Survey Results for CPS centered V&V, 2020, 2021