Enhancement of Diverse Indication System

Sangeui Hong*, Hyunjeong Kim, Yoonhee Lee
KEPCO E&C Company Inc., 989-111 Daedeokdaero, Yuseong-gu, Daejeon, 34057, Republic of Korea
**Corresponding author: sehong@kepco-enc.com*

1. Introduction

The digital instrumentation and control (I&C) safety systems including software cannot be proven to be error-free, and therefore is considered susceptible to common cause failure (CCF). The Diverse Indication System (DIS) provides the sufficient information under the CCF of digital I&C safety systems to support operator's actions.

DIS is newly designed system in Shin-Kori Nuclear Power Plant Units 3 and 4 (SKN3&4) to satisfy the requirement of secretary (SECY) 93-087 and NUREG-0800 branch technical position HICB-19.

In Shin-Kori Nuclear Power Plant Units 5 and 6 (SKN5&6), the DIS design is changed to reflect the result of the human factors engineering verification and validation (HFE V&V). In this paper, the enhancement of DIS is described.

2. Comparison of DIS in each NPP

In this section the function of DIS and characteristics of each nuclear power plant (NPP) is described.

2.1 Function of DIS

The functions of DIS are as follows:

1) To display the sufficient information needed for operator to maintain the plant in a hot-shutdown condition, under the CCF of digital safety systems
2) To calculates a Representative CET temperature, reactor coolant saturation margins and reactor vessel water level
3) To control heated junction thermocouple (HJTC) heater power when CCF of digital safety systems occurs

2.2 Characteristics of DIS for Each Power Plant

The first generation of DIS for SKN3&4 and Barakah Nuclear Power Plant Units 1,2,3 and 4 (BNPP1,2,3&4) process its hardwired process inputs from signal splitters and isolators located in the Auxiliary Process Cabinet-Safety (APC-S) and Qualified Indication and Alarm System-P (QIAS-P). However, since DIS for Shin-Hanul Nuclear Power Plant Units 1 and 2 (SHN1&2), DIS receives its process inputs only from hardwired signal splitter and isolators located in the APC-S because of the space limitation of QIAS-P cabinet.

The DIS for SKN5&6 process its hardwired contact inputs from Engineered Safety Feature-Component Control System (ESF-CCS) and operator can check the parameters with DIS in MCR instead of component interface module.

There was feedback from operators to provide expedient display information in the emergency operation. As the result, the DIS for SKN5&6 drives two (2) flat panel displays (FPDs) to improve operator's convenience.

Table I: Characteristics of the DIS Design

	SKN3&4	BNPP 1,2,3&4	SHN1&2	SKN5&6
Process Input	APC-S & QIAS-P		APC-S	
Contact Input	-	-	-	ESF-CCS
Number of FPD	1	1	1	2

3. Enhancement of DIS

The enhancement of DIS includes adding parameters, applying mimic and optimizing display pages. This is based on the result of Preliminary HFE V&V and HFE V&V at the first integrated system validation (ISV).

3.1 Enhancement Process of DIS

A total of three HFE V&V are performed for SKN5&6: Preliminary Validation, first ISV and second ISV. Operators perform the scenario assuming the CCF situation and evaluate the DIS during these validation process. In addition, third-party reviewers and authorization agencies observe the validation to increase reliability. The DIS is enhanced by solving the human engineering discrepancies (HEDs) found in the HFE V&V. (refer to Fig 1).

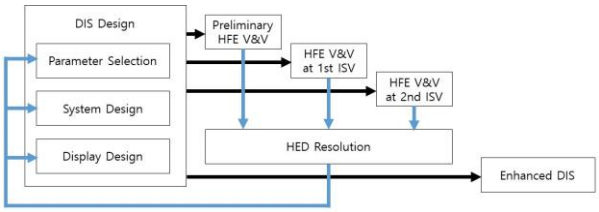

Fig 1. Enhancement Process of DIS

The operator's main comment for DIS in HFE V&V is to display more parameters and apply mimic display.

3.2 Addition of DIS Parameters

To improve the convenience of operator, the DIS provides additional parameters. Addition for emergency operation related parameters are selected using Emergency Operating Guideline (EOG).

The Fig 2 depicts the following parameter selection steps:

1) Identify all parameters in EOG
2) Find the parameters that operator checks after taking action
3) Categorize selected parameters into three (3) groups by priority, refer to table II. This grouping is only for additional parameters.
4) Select the parameters of group 1 and 2 as DIS parameters

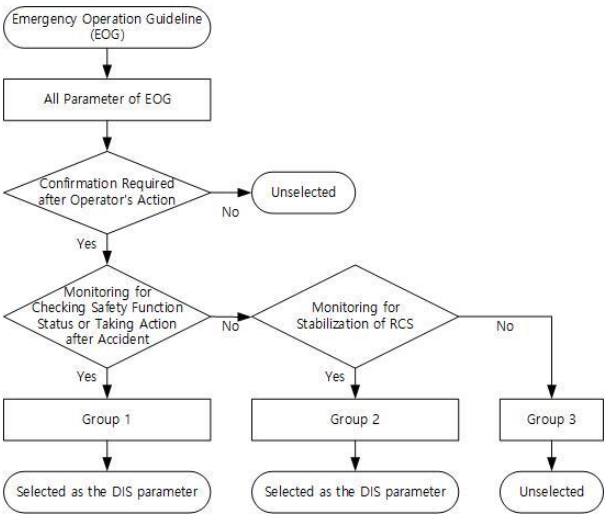

Fig 2. Selection Process of EOG parameters for DIS

Table II. Group of EOG Parameters

	Description
Group 1	• Highest priority • Parameters monitored to check the safety function status • Parameters monitored for operator's action after an accident
Group 2	• Second priority • Parameters monitored to stabilize the reactor coolant system (RCS)
Group 3	• Lowest priority • Parameters that can be replaced by other parameter • Parameters that have a little effect on RCS stabilization

3.3 Application of Mimic Display

The DIS for SKN3&4, BNPP1,2,3&4 and SHN1&2 is a text-based arrangement of the parameters (refer to Fig 3). However, considering the increase in the number of parameters, mimic display is required for convenience and fast recognition.

Some of DIS displays for SKN5&6 are changed to apply mimic display. And these DIS display pages refer to the QIAS-P display design to maintain similarity of the information for parameters. The changed DIS display applying mimic are implemented as Fig 4 and Fig 5. In Fig 4, parameters are displayed at the corresponding positions in the drawing of reactor vessel and steam generators. In Fig 5, the status of valves is displayed by symbols and flow path directions are indicated by arrows. Therefore, operator can check the information intuitively.

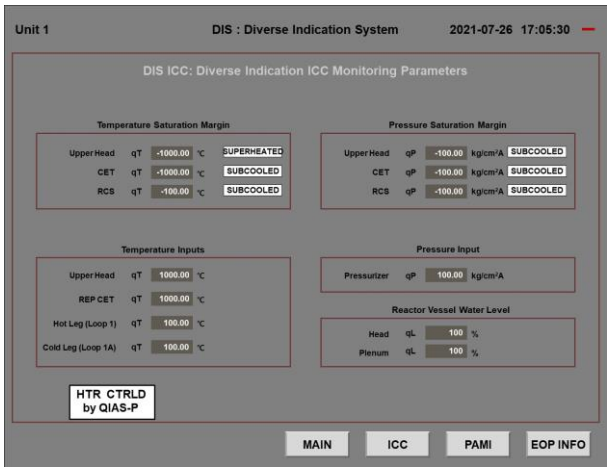

Fig 3. ICC Display Page with Text Based Arrangement

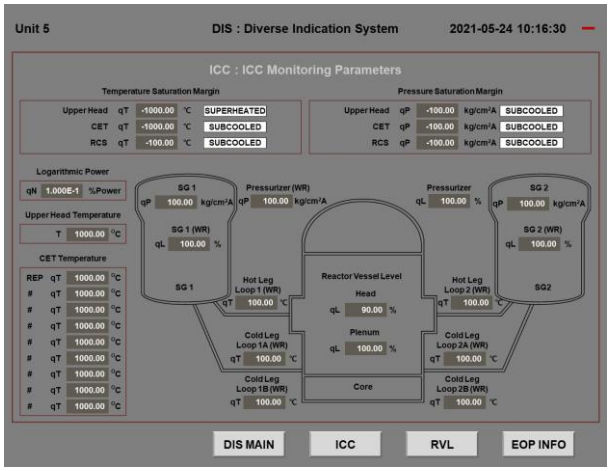

Fig 4. ICC Display Page with Mimic

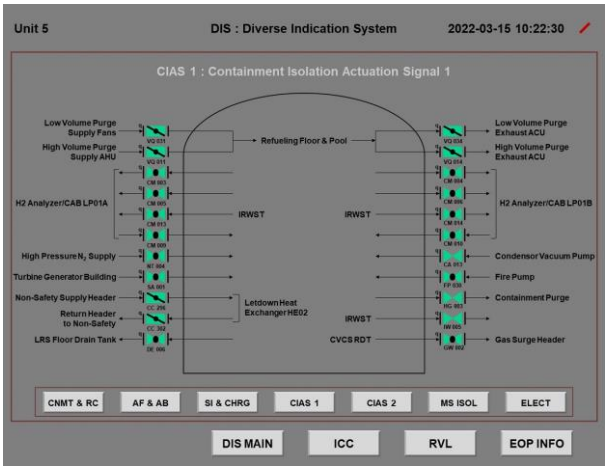

Fig 5. CIAS 1 Display Page with Mimic

3.4 Optimization for the Location of DIS Parameters

As parameters are added and mimic is applied, the location of the parameters are rearranged to optimize the display space.

The DIS for SKN3&4, BNPP1,2,3&4 and SHN1&2 divide the displays according to the situation. On the other hand, as the number of parameters are increased, the DIS displays for SKN5&6 were divided based on similar characteristics between parameters.

The parameters of the page named 'PAMI' are distributed across the page named 'ICC', 'CNMT & RC' and 'AF & AB' in order to avoid displaying the same parameters on multiple display pages. The page named 'RVL' is newly designed. As many Emergency Operation related parameters are added, one (1) display page named 'EOP INFO' is changed to seven (7) display pages named 'CNMT & RC', 'AF & AB', 'SI & CHRG', 'CIAS 1', 'CIAS 2', 'MS ISOL' and 'ELECT'.

The hierarchy of the DIS display for SKN3&4, BNPP1,2,3&4 and SHN1&2 is shown in Fig 6 and for SKN5&6 is shown in Fig 7.

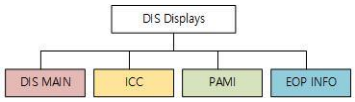

Fig 6. Hierarchy of the DIS Display
(SKN3&4, BNPP1,2,3&4 and SHN1&2)

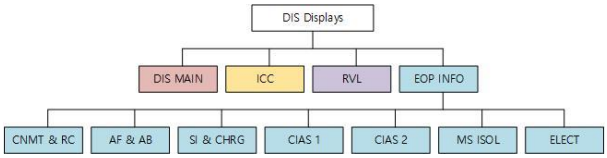

Fig 7. Hierarchy of the DIS Display (SKN5&6)

Table III. DIS Display Pages and Parameters
(SKN3&4, BNPP1,2,3&4 and SHN1&2)

	Title	Parameters
1	DIS MAIN	Summary of ICC parameters and PAMI parameters
2	ICC	Inadequate Core Cooling Monitoring Parameters : The saturation margins and their input signal
3	PAMI	Post Accident Monitoring Instrument Parameters
4	EOP INFO	Emergency Operation related Parameters

Table IV. DIS Display Pages and Parameters (SKN5&6)

	Title	Parameters
1	DIS MAIN	Type A Parameters defined in USNRC Reg. Guide 1.97
2	ICC	Inadequate Core Cooling Monitoring Parameters : The saturation margins and their input signal
3	RVL	Reactor Vessel Level Parameters : The reactor vessel water levels and HJTC temperatures
4	EOP INFO	N/A (Only provides navigation buttons)
5	CNMT & RC	Containment related Parameters and Reactor Coolant Related Parameters
6	AF & AB	Auxiliary Feedwater related Parameters and Auxiliary Building related parameters
7	SI & CHRG	Safety Injection related parameters and Charging Flow
8	CIAS 1	Containment Isolation Actuation Signal related parameters : CIAS related valves status
9	CIAS 2	Containment Isolation Actuation Signal related parameters : CIAS related valves status
10	MS ISOL	Main Steam Isolation related parameters : MS Isolation related valves status
11	ELECT	Electrical System related parameters : Power status and voltage status

4. Conclusions

The DIS provides the information under the CCF of digital I&C safety system. In SKN5&6, massive design enhancement was carried out and techniques such as enhancement process, selection of parameters and application for mimic display ware introduced.

Changed DIS display is the result of reflecting the operator's review and experience. Therefore, the enhancement of DIS allows operator to check more information about plant status in MCR. Furthermore, this enhancement will contribute to the operator's quick and precious decision even in abnormal plant condition.

REFERENCES

[1] The Staff Requirements Memorandum on SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to

Evolutionary and Advanced Light-Water Reactor (ALWR) Designs", 1993
[2] NUREG-0800, Branch Technical Position HICB-19, "Guidance for Evaluation of Defense-in-Depth and Diversity in Digital Conputer-Based Instrumentation and Control Systems", 1997
[3] USNRC Reg.Guide 1.97, "Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants", 2006