Diagnostic Strategy in APR1400

*Dongyoung Kim, Jonghyun Kim,
KEPCO International Nuclear Graduate School, 1456-1 Shinam-Ri, Seosaeng-Mueon, Ulju-Gun,Ulsan
**Corresponding author: blessing4u4@naver.com*

1. Introduction

APR1400 is the first nuclear power plant in Korea which fully applies digital technology to control room design. Some of the features that distinguish digital control rooms from conventional, analog rooms in nuclear power plants include advanced alarm system, graphic information display system, computerized procedure system, and soft control. These features may bring out changes in operator tasks, changing the characteristics of tasks, or creating new tasks [1].

Diagnostic strategy for identifying anomaly may be different especially in APR1400 from that in the analog control room due to the change of human-system interface, i.e. alarm system and display system. Since the first plant of APR1400 is being built at this moment, it is not known what strategies the operators will adopt in diagnosis tasks in the new operating environment.

In this light, this paper aims at investigating operator's diagnostic strategies which are appropriate for APR1400. In order to collect data, several different approaches which are complementary are used to identify diagnostic strategies in the digital control room: 1) analysis on audio/video recording of operation, 2) observation in the simulator, and 3) interview with the operators. The result shows that the digital control room introduces new strategies in the diagnosis, compared with the analog control room, and also changed the characteristics of strategies, mostly, by getting more support from the computerized system.

2. High level process for diagnosis in abnormal situation

Several different approaches are used to identify diagnostic strategies in the digital control room: 1) analysis on audio/video recordings for the 17 scenarios, 2) observation of training session in the simulator for one week, and 3) interview with the five operators in about 45 minutes.

Fig. 1 shows the high level process of diagnosis in abnormal situations of APR1400 which this paper identified. This process consists of five activities and five states.

The high level process is summarized as follows: First, if an abnormal situation occurs, the alarm system alerts operators to the need for action. Second, in the Perception activity, the operators perceive the alarms of the plant. As a result of this activity, relevant alarms for the situation are identified. Third, in the Identification of Urgency activity, the operators determine whether the relevant alarms require urgent actions or not. Fourth, in the Seeking activity, the operators identify an abnormal system based on relevant alarms. Through this activity, the abnormal system is determined. Fifth, in the Searching activity, the operators identify abnormal components or their location by adopting diagnostic strategies. As a result of this activity, the abnormal component or location is determined. Sixth, in the Selection activity, the operators select proper Abnormal Operation Procedure (AOP) to cope with the abnormal situation.

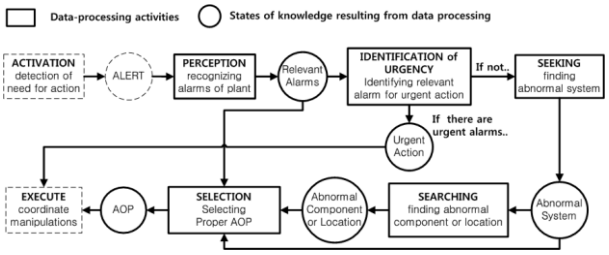

Fig. 1. High level process for diagnosis in abnormal situation.

3. Diagnostic strategies in the activities

In the activities of Fig. 1, the operators may apply different types of diagnostic strategies adaptively. This section introduces briefly the operator's strategies in each activity that results from the investigation.

Perception: The main tasks of this activity are to select alarm display system and to pick out relevant alarms from alarm systems. The interview with the operators indicates that they consider five factors in selecting alarm display systems. These factors are in order of high priority: 1) detail of information, 2) readability, 3) accuracy, 4) plant situation, and 5) salience. Second, the interview indicates that operators pick out relevant alarms from the alarm system based on 4 strategies, in the order of high priority: 1) sequencing alarms, 2) prioritizing alarm, 3) correlating alarm (nuisance alarm), and 4) filtering alarms based system knowledge and recent/frequent experience. The influencing factors on choosing strategies are system knowledge, experience, and training.

Identification of Urgency: The main task is to determine whether there are urgent alarms in the relevant alarms. If the relevant alarms include any urgent alarm, the operators should take urgent actions to prevent a reactor scram. If not, the operators move to next activity.

Seeking: The main task is to identify an abnormal system and navigate to the system in the display. The operators utilize several strategies for finding and selecting an abnormal system, as follows in the order of frequency: 1) identifying a system based on the first-out alarm and the alarms of priority in relevant alarms, 2) identifying a system based on system correlation, 3) identifying a system based on recent/frequent failures, and 4) identifying a system based on the training. If operators identify a postulated, abnormal system, they need to navigate to the system in the display pages.

Searching: The main task is to search an abnormal component or location in the abnormal system. The interview indicates that operators may use the Topographic search [2] or the integration of Topographic and Symptomatic searches.

The integration of Topographic and Symptomatic searches is illustrated in Fig. 2. This strategy combines two strategies. The Symptomatic search is usually used to make a list of components or locations suspected abnormal. The operators use Symptomatic Search to narrow down suspicious components or locations. This list is used as an input in the Tactical Search activity of Topographic search. Then, tactical rules of search are generated to control the search sequence [2]. The Topographic Search is used to find an abnormal component or location accurately.

Selection: The main goal is to select a proper AOP to cope with the abnormal situation. In this activity, operators carry out pattern matching between the list of symptoms in an AOP and the actual plant phenomena, such as relevant alarms, the abnormal system, and the abnormal component or location.

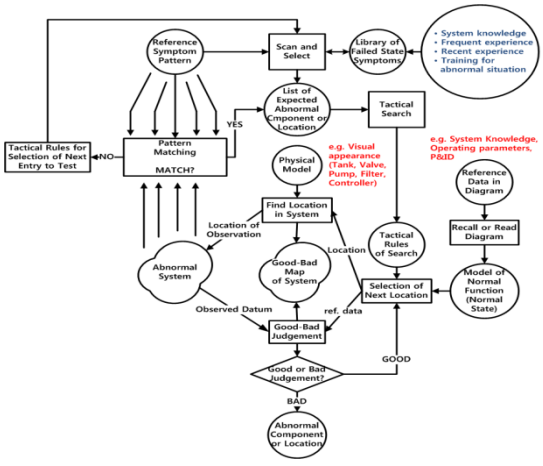

Fig. 2. The integration of Topographic and Symptomatic searches.

4. Impact by using the digital control room

This section discusses how similar or different the diagnostic strategies are in both advanced and analog control rooms. As shown in Table I, the new systems introduce new strategies in the diagnosis, such as selecting alarm display systems and navigating to the system. Some of the strategies are similar, but more supported by the new systems.

Table I. Comparison with APR1400 and the conventional plant for the diagnostic strategies.

Activity	Strategy	Remark
Perception	Selecting alarm display	This strategy is new in the advanced control room.
	Sequencing alarms	This strategy is basically similar to the analog control room. However, it is more supported in the advanced control room.
	Prioritizing alarm	
	Correlating alarm	This strategy is basically similar to the analog control room.
	Filtering alarms based system knowledge and experience	
Identification of Urgency	Identifying urgency	This strategy is basically similar to the analog control room.
Seeking	Identifying a system based the first-out alarm and the alarms of priority in relevant alarms	This strategy is basically similar to the analog control room. However, it is more supported in the advanced control room.
	Identifying a system based on system correlation	
	Identifying a system based on the training	This strategy is basically similar to the analog control room.
	Navigating to the system in the display pages	This strategy is new in the advanced control room.
Searching	Topographic search	This strategy is basically similar to the analog control room. However, it is more supported by the display system of the advanced control room.
	Symptomatic search	This strategy is more effective in the analog control room.
	Integration of Topographic and Symptomatic searches	This strategy is a little different from the analog control room. It is more supported by the advanced control room, especially the alarm system and the display system.
Selection	Pattern matching	This strategy is supported by the advanced control room, especially the computerized procedure system.

5. Conclusions

This paper investigated how the digitalized control room may influence operator's diagnostic strategies. Several different approaches, i.e., audio/video record, observation of training, and the interview with operators, were used to gather information about the operator's behaviors. As a conclusion, this paper figured out that the digital control room introduces new strategies in the diagnosis, compared with the analog control room, and also changed the characteristics of the strategies, mostly, by getting more support from the computerized system. The operators interviewed also commented that the diagnosis in the APR1400 is quicker, more correct, and easier, compared with the analog control room.

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