

## Diagnosis support frame between alarm and abnormal status in NPP

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### 1. Introduction

For the digital main control room in nuclear power plant(NPP), the various operator support system has been developed. One of promising application is diagnosis and decision support system [1, 2, 3, 4]. Operator support system provide information to the operator. Some of the information are urgent messages such as an indication of abnormal event. This information should be notified by operator immediately like important alarms to support monitoring activity of operator.

Monitoring individual parameters, component states, and plant conditions and detecting anomalies can be an overwhelming task because of the size and complexity of the plant. Therefore, an alarm system supports plant personnel in these activities. The alarm system is one of the primary means by which abnormalities and failures come to the attention of the personnel [5].

Therefore, the functional review of alarm system and operator system in point of view of annunciation function is needed to provide useful information for safety of NPP.

This paper reviews current relation between the diagnosis of plant event and alarm system and provide the frame for diagnosis message.

### 2. Diagnosis of event in nuclear power plant

#### 2.1 Design basis accident and emergency operating procedure.

When an event occurs in the NPP, the operator is needed to diagnosis the event and execute proper operating procedure for the event. For the design basis event, the NPP will be tripped by protection system. After the trip, the operator executes standard post trip procedure to check the plant safety of plant and the integrity of safety functions. Then, the operator diagnosis the event according to the diagnosis procedure. The diagnosis procedure guide operator in detail process. It means that for the design basis event, there are solid guideline for the operator to diagnosis the event.

#### 2.2 Diagnosis abnormal event and abnormal operating procedure.

However, for the abnormal event, the operator needed to diagnosis the event according to his own cognition process which has been built from his expertise and trainings.

Figure 1 show the diagnosis process for event in NPP. When there is abnormal event, the operator is needed to diagnosis the event with alarms and plant process

variables. When the operator diagnosis the event as one of abnormal event, the abnormal operating procedure(AOP) is to be executed by the operator. Each abnormal operating procedure describes the list of alarms for that abnormal event. And many of alarm response procedure(ARP) indicate abnormal operating procedure which should be considered from the alarm. The relation between abnormal procedure and alarms is not one to one correspondence. Therefore, diagnosis process of abnormal events is depending on the operator.

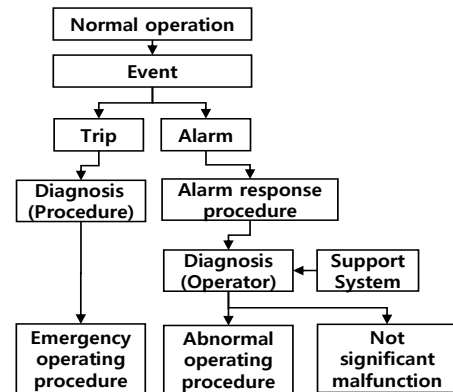


Fig. 1. Diagnosis process for event

The alarm system is design to annunciate 1) component and process alarm 2) equipment status alarms 3) plant status alarms. However, alarms are based on set point or component status. When there is complex event in the plant, numerous alarms are generated simultaneously. NUREG-0700(rev3,2020) list up the challenges caused by alarm design deficiencies are (1) too many alarms, (2) too many false alarms, (3) difficulty distinguishing alarms from normal status indications, (4) poor alarm organization, (5) poor location, (6) insufficient salience coding, (7) inadequate message design, and (8) poor acoustic design [5]. In digital alarm system the design characteristics such as categorization, filtering and suppression has been applied to cope with concurrent various alarms.

Table 1 shows the number of alarm and abnormal operating procedure which indicated in alarm response procedure. For example, "RCS cold leg acoustic leak alarms" indicate that the abnormal operating procedure which name is "RCS leakage". However, many of APR do not indicate AOP because abnormal operating status related more than one alarm. Therefore, the AOP link is very limited for the diagnosis of abnormal event and operator support system is needed to provide information for the diagnosis.

Table 1. Number of alarms and related abnormal procedures

System*	Number of Alarm	ARP which indicate AOP**		Number of AOP
		Number	%	
RCS	407	232	57.0%	15
SI/SC	260	11	4.2%	2
MT	66	13	19.7%	2
FW	325	10	3.1%	7
PPS	488	70	14.3%	8

\* RCS: Reactor Coolant System, SI: Safety Injection, SC: Shutdown Cooling, MT: Main Turbine, FW: Feed Water, PPS: Plant Protection System.

\*\* ARP: Alarm Response Procedure, AOP: Abnormal operating Procedure

### 3. Design consideration of operator support system

There are many researches about operator support system. Through various methodologies the operator support system provides diagnosis result to the operator.

When there is an abnormal event in the plant, the related alarms are generated. Depends on the severity of the event, many alarms are generated in simultaneously. The operator support system also needs to generate the information for the abnormal status.

The design consideration for the format of diagnosis support has been proposed as follows.

1) The information for the diagnosis should not be displayed with the equivalent level of alarms. This information may have higher level of indication compare to alarms. 2) When the information provided with alarms the operator may not easy to distinguish this information from other alarms. 3) the information for the diagnosis should not be interference by other alarms and display. 4) The information should have link to the abnormal operating procedure.

Therefore, we have considered two kinds of display frames for the abnormal event diagnosis indication 1) Provide abnormal information in the alarm system (alarm integrated diagnosis system) 2) Provide separate independent system for the display. (Independent diagnosis annunciation system)

For the first one, operator can keep their knowledge system for the monitoring NPP with alarms. Operator do not need to monitor another system. However, when there are many alarms, the diagnosis message should be spatially dedicated and continuously displayed as post-accident display requirement.

For the second one, the design depends on the location of the display of design and annunciation method when the plant has been diagnosis as abnormal. The main display for the system can be located in one page of operator workstation display but it need to provide the annunciation. For the simple design for the annunciation is to use pop-up windows.

### 4. Operator support system annunciation for abnormal diagnosis.

The design for operator support system annunciation has been proposed to include both of above design

consideration and strength. Figure 2 show the draft design concept of operator support system annunciation. The annunciation is implemented in existing alarm system, but to distinguish other alarms, the information is to be fixed in upper part of alarm display. The existing audio and display alarm can be used as identical method of alarm system. The diagnosis message also provide link to abnormal operating procedure through abnormal diagnosis support display.

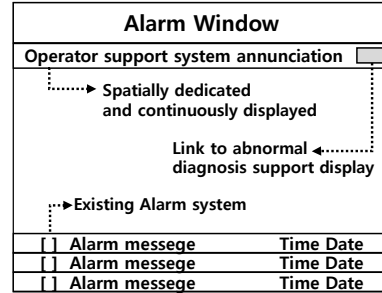


Fig. 2. Design concept of operator support system annunciation

### 5. Discussion

The advanced annunciation system is necessary which can provide plant status based on alarm and other plant process status. Operator support system may provide diagnosis support information to complement the limitation of component and process dependent alarm. Proposed design implemented including consideration of existing display framework and operator cognition of unexpected event. The advanced annunciation framework including operator support system may increase operator situation awareness and safety of NPP.

### REFERENCES

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