Normal State Detection Capability of an Operator Support System that Detects a Plant State

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1. Introduction

It is important from the perspective of safety to quickly and accurately determine the operating state of a nuclear power plant [1]. When an operator detects an abnormal condition, the nuclear power plant process can be kept in a safe state according to the procedure corresponding to the abnormal condition. In general, the faster the detection time, the greater the contribution to the safety of the nuclear power plant. In order to expect the operator of the main control room to quickly and accurately detect all abnormal conditions, it should be based on providing active support means because of human physical and cognitive constraints.

As the latest technology to meet these expectations, artificial intelligence technologies based on big data analysis have been surely recommended. In the field of artificial intelligence, detection of abnormal conditions is recognized as a problem of classification [2]. For example, in the case of supporting detection of abnormal conditions, artificial intelligence acquires knowledge of various abnormal conditions through data learning and is applied to the field as a support system to always monitor the nuclear power plant process and presents it to the operator whether or not an abnormal event occurs in a specific situation. In an ideal case, an artificial intelligence-based support system should be able to detect all abnormal conditions possible in the nuclear power plant. This would be what the operator expects. However, it is difficult for a support system developer to develop a support system that detects all the abnormal conditions that may occur at a nuclear power plant.

In reality, it is common to develop based on specific operating areas, systems, or procedures. These realistic constraints can cause problems for operators who must recognize the occurrence of abnormal conditions and devise countermeasures.

In this paper, it aims to look at human factor concerns that may arise when the abnormal state detection information produced by an artificial intelligence-based support system (AISS) with realistic constraints is presented to the operator.

2. Methods and Results

In this section, considerations for individual situation in which support information (diagnosis results) presented to the operator are described according to the states that AISS can classify. The meaning of classifying an abnormal state or detecting an abnormal state in this paper represents a clear distinction of a particular abnormal state from many abnormal states.

The case where the AISS has the function of detecting the abnormal state of a nuclear power plant is explained in this paper. Usually it is expected there are two states, normal and abnormal, that the AISS generates.

In addition, it is assumed in this paper that emergency and DEC (Design Extension Condition) are not classified by the AISS.

2.1 CASE 1: AISS detects a part of abnormal states and doesn't detect any normal state.

It is expected to account for most of cases of developing a support system. It is the case that the AISS is developed to detect most of abnormal states but cannot detect all abnormal states due to realistic constraints.

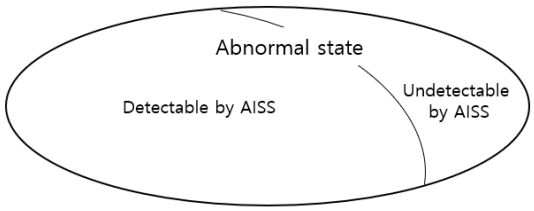

Fig. 1. Classification of abnormal states based on the limited AISS abnormality detection capability.

In this case, it is frequently or without doubt assumed that situations except for some situations where AISS detects an abnormal state are considered as the normal state (no information provided). This may cause problems if supportive information that the AISS generates is not provided to the operating crew in the main control room of a nuclear power plant. As a situation is an abnormal state which the AISS cannot detect, the AISS doesn't generate information about the abnormal state.

It may have the operating crew believe the current state is the normal state or out of abnormal states. Although the plant is in an abnormal state, the operating crew may not be able to recognize the abnormal state in a timely manner so that the condition of the nuclear

power plant can get worse than they detect an abnormal state early.

In terms of HMI (Human-Machine Interface), there is no means to inform the abnormal state that the AISS cannot detect to the operating crew visually or auditory.

2.2 CASE 2: AISS detects a part of abnormal states and a part of normal states

A normal state is defined as a situation that is not an abnormal or emergency situation, which does not require actions by the operating crew. As the normal state means an operational situation in which there is no hazard nor risky factors, the AISS may accurately determine some (not every) normal states and inform the operating crew of them.

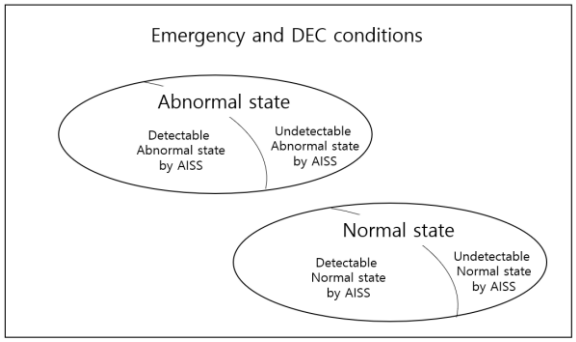

Fig. 2. State classification according to the AISS detection capability.

This case causes a more serious problem than the previous case. There are four types of information that have to be delivered to the operating crew, but the AISS cannot discriminate some abnormal states and normal states. Thus only three information is provided from the AISS: normal, abnormal, and unknown.

It is desirable to inform the operating crew of normal or abnormal condition. However, if an ‘unknown’ is transmitted to the operating crew, they will be confused and, as a result, give the smaller trustworthiness to the AISS.

2.3 CASE 3: AISS detects normal states and a part of abnormal states

If all the normal states can be clearly defined and the AISS can clearly distinguish the normal state from abnormal states, better results can be expected than the previous cases.

The AISS can now provide three type of supportive information (normal, abnormal and unknown) to the operating crew by clearly distinguishing the normal state. The difference from the precious section 2.2. is that the operating crew’s interpretation of ‘unknown’ is clearer. When an ‘unknown’ is indicated to them, the operating crew can sure the current situation is abnormal that the AISS cannot detect.

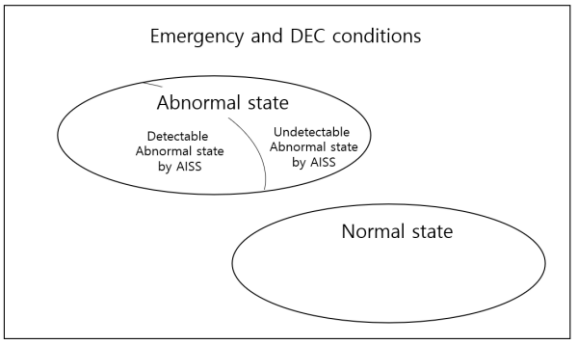

Fig. 3. State classification in case that the AISS detects all normal states clearly.

2.4 Summary of case analysis

The following table shows whether the state abs supportive information match for each case discussed in the previous sections.

Table I: Summary of cases

case	AISS detection capability			# of supportive information types	# of true plant states
	a part of abnormal states	a part of normal states	all normal states		
1	O	X	X	2 (abnormal, normal)	3 (abnormal, normal, undetectable abnormal)
2	O	O	X	3 (abnormal, normal, unknown)	4 (abnormal, normal, undetectable abnormal, undetectable normal)
3	O	X	O	3 (abnormal, normal, unknown)	3 (abnormal, normal, undetectable abnormal)

Case 1and 2 show inconsistency between two numbers. Inconsistency means that the AISS is not providing accurate supportive information, which can confuse the operating crew and weaken the trustworthiness of the AISS, which is bound to be limited in obtaining the operator support effect.

To the contrary, the number of supportive information and the number of plant states are same for the case 3. In this case, the operating crew can easily discriminate all the plant states clearly based on the supportive information given to them because an ‘unknown’ indication means the current situation is an abnormal state that the AISS cannot detect.

3. Conclusions

An AI based support system that helps to quickly detect abnormal states that may threaten the safety of nuclear power plants can be effective in preventing events such as unplanned shutdowns. When developing such a support system, it is easy for developers to put a lot of effort into detecting abnormal states, but it is very difficult to detect all abnormal states completely. It can be said that a more effective development strategy is to more clearly define and discriminate normal states.

In this paper, it has been shown that a support system that detect all normal states perfectly rather than just detect abnormal states only is an effective means to deliver accurate information to the operating crew without confusion and damage to trustworthiness of the system.

In this paper, a support system with only abnormal state detection function was analyzed but it is believed that the results are also applicable to support systems with other state classification functions.

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