Framework for Operator Manipulation Validation System using Plant Parameter Prediction

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1. Introduction

In an emergency situation of a nuclear power plant (NPP), operators in a main control room (MCR) should accomplish operation tasks which are described in emergency operation procedures (EOPs). Those operation tasks include checking alarms, measuring parameters, diagnosing the current situation and manipulating devices [1]. Especially, manipulation tasks cover lineups of valves, controls of pumps and signal actuations for safety systems. Those actions can change the plant parameters immediately. Therefore, manipulation errors of the MCR operators can worsen the integrity of an NPP in short time. Thus, manipulation errors should be detected in early stage to recovery them. This article suggests the framework for a validation system, which detects manipulation errors using plant parameter trends prediction results.

2. Operator Manipulation Validation System

A human error detection system is proposed to detect manipulation errors of operators. Two future plant parameter trends are predicted to validate operator manipulations in this system. The first prediction is based on the current plant state and the second prediction is based on the assumed plant state. The future critical safety functions (CSFs) integrities of two trends are assessed and compared in this system. Operator manipulations are identified as human errors when the CSF assessment result indicates that operator manipulations degrade the future integrity of the CSFs.

Figure 1 shows the overall structure of the manipulation validation system. This system includes six functions: a plant state assumption function, two parameter prediction functions, a CSF assessment function, a prediction model selection function and an operator interaction function. The instrumentation and control system of an NPP offers the current plant state and a computerized procedure system (CPS) offers the current procedure steps, postulated manipulations and executed manipulations. If an operator action is classified as the human error, the operator interaction function shows the warning and the reason why it is classified as the human error with predictions and assessment results.

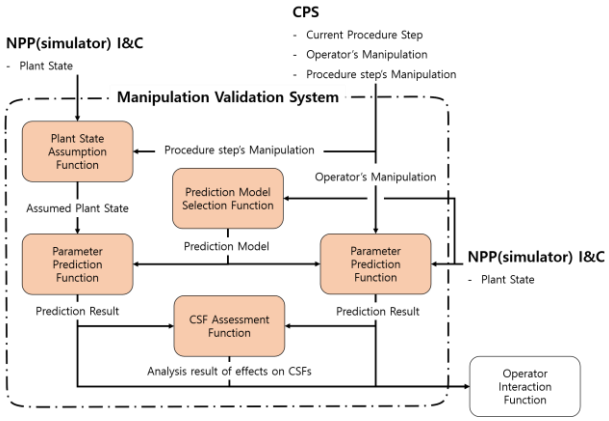

Fig. 1. Overall framework of manipulation validation system

2.1. Plant State Assumption Function

In this framework, the assumed plant state is implemented as the inputs of the one parameter prediction function. Assuming a plant state imply the modification of device states from the current. The operation actions can be classified as five cases based on the current EOP step and the operator action.

- The current procedure includes manipulation tasks.
  1. Operator executes it.
  2. Operator manipulates different devices.
  3. Operator manipulates nothing.

- The current procedure does not include manipulation tasks.
  4. Operator manipulates some devices
  5. Operator manipulates nothing.

The first case is the case which the operator follows the EOP step properly and the fifth case does not have any manipulation tasks in the procedure step and operator's action. Thus, in the first and fifth cases, this system does not involve.

The plant assumption function differently modifies the current plant state depending on which case it is. For the second case, this function assumes that the current operator manipulations have been rebutted, and devices state has been controlled following the current procedure step. For the third case, it is assumed that controlling of devices has been accomplished as written in the current procedure and for the fourth case, it is assumed that no manipulation has been conducted.

2.2. Plant Parameter Prediction Function and Prediction Model Selection Function

The plant parameter prediction function forecasts the future trend of parameters needed for CSF integrity check. It is assumed that there will be no additional operator actions in a future, after the current action is executed. To reduce an effect of manipulation error, this system should validate operator manipulations in short time. In addition, the prediction result should be accurate in order to use prediction results as an evidence for validation. Thus, the two requirements of this function are speed and accuracy.

A thermal hydraulic code, which is widely used in a safety assessment, can predict future trends with high accuracy. However, it requires a long computational time. Consequently, it is hard to apply the thermal hydraulic code for the plant parameter prediction.

In this framework, the artificial neural network (ANN) predicts future plant parameters. The various industrial area, such as electricity and water resource management has implemented the ANN [2][3]. The significant advantage is short computational time for calculating output. It is short enough to be used in the real-time manipulation validation system. The accuracy of ANN highly depends on the number of data sets implemented. Thus, it is necessary to gather numerous emergency operation data for an accurate prediction.

The model selection function changes the ANN to be used for prediction. Because there are many possible operation states that can be occured during emergency situations, ANN training for all possible state is complicated and inefficient. Therefore, multiple ANNs has been trained ahead and are implemented, depending on the situation. This function selects the ANN trend based on the current conducted EOP and plant states.

2.3. CSF Assessment Function and Operator Interaction Function

The CSF assessment function evaluates the integrity of the future plant state using the output of the plant parameter prediction function. An CSF status tree arranges operator tasks to efficiently manage an emergency situation based on a potential outcome of the current state. Thus, logical statements in the CSF status tree can be a criterion for an assessment of plant state. This function implements the CSF status tree and assesses future trends of plant parameters with the current plant state and assumed plant state. If the assessment result imply that the current plant state degrades the CSF integrity comparing with the assumed plant state, this function determines that operator manipulation is the human error. The operator interaction function shows up a pop-up window to notify the human error. The parameter prediction and CSF integrity assessment results are provided in order to help recovery planning of operators.

3. Conclusion

This research suggests the operator manipulation validation system, which detects the manipulation error of MCR operators in emergency situations. This system consists of six functions. The plant state assumption function modifies the current plant states into assumed plant states according to the tasks included in the EOP steps and operator action and provides it into the parameter prediction function. Two parameter prediction functions forecast future trends based on the current plant states and assumed plant states. And the CSF assessment function compares the future CSF integrities of prediction results. Operator manipulation is identified as the human error when it degrades the future CSF integrity.

This system has two limitations. First, it can be applicable to only manipulation error, not all operator task in emergency situations. In addition, the plant parameter prediction function assumes that no more operator actions are executed after the current operator actions. This assumption can distort the intention of operators

ACKNOWLEDGEMENT

This work was supported by KOREA HYDRO & NUCLEAR POWER CO., LTD (No. 2017-RFP-안전-1)

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