# Estimation of Human Error Probability in Analogue Channel Calibration in Kori Unit 2 RPS/ESFAS Systems

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## 1. Introduction

Probabilistic safety assessment (PSA) has had a growing amount of use in the electric power industry. To relax test interval reactor protection system and engineered safety features actuation systems (RPS/ESFAS) for Kori Unit 2, a risk-informed approach has been applied. Reliability data has been developed to quantify the risk increase due to test interval extension of Kori Unit 2 RPS/ESFAS. Among the reliability data developed for the project, I would like to introduce the data and method how to estimate human error probability in analogue channel calibration in Kori Unit 2 RPS/ESFAS.

## 2. System Description

The reactor protection systems (RPS) circuit consists of analogue channels, combination logic units, and trip breakers. The engineered safety features actuation system circuits are composed of analogue channels, combination logics, and actuation relays. Fig. 1 shows the block diagram of RPS/ESFAS and the test points.

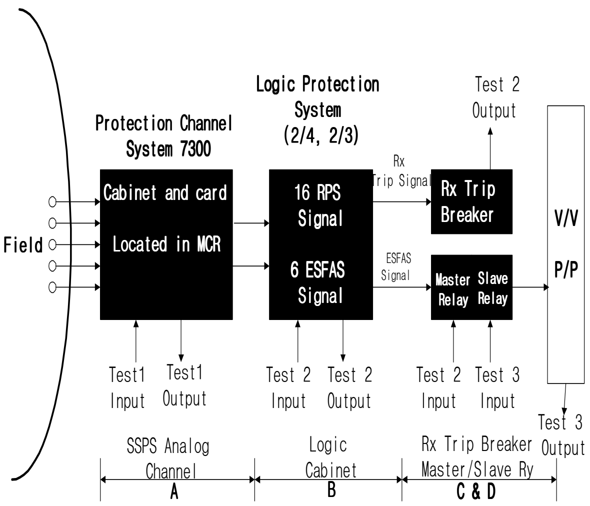


Fig. 1 Block Diagram of RPS/ESFAS for Kori Unit 2

## 3. Human Reliability Analysis

To analyze the impact of increasing AOTs and STIs on system unavailability, a fault tree analysis of the individual functions for the RPS/ESFAS was performed. The five major contributors which effect on unavailability are 1) random failures 2) maintenance 3) test 4) Human Error 5) Common cause failure.

Among the reliability data developed for the project, I would like to introduce the method how to estimate human error probability in analogue channel calibration in Kori Unit 2 RPS/ESFAS. Human error such as miscalibration or misposition of a component was modeled in the fault tree. NUREG/CR-1278 was used as a guideline in determining the human error probabilities. THERP (Technique for Human Error Rate Prediction) method was also applied to analyze human error probability. The possibility of an operator committing more than one of the same types of error was also considered. The potential common cause error was quantified using the following formula ;

$$Bh = (1+19N)/20$$

N : Probability of a single human error
Bh : Beta factor of human errors

$$Ph = Bh * P$$

Ph: Probability of more than one human error being committed
P: Probability of a single human error

## 4. Human Error Modeling for calibration

Human error was modeled on all analog channel, but not modeled on miscalibration or misposition on reactor trip breaker and bypass breaker. In determining the probability of miscalibration of analog channel, we count the number of components which should be calibrated.

a. Human error of individual analog channel component
b. Human error of analog channel components due to common cause

### A. Modeling Calibration Error of each analog channel

Calibration of analog channel consists of several steps and each step has its own human error as shown in table 1. Calibration error equals to 0.01 totally for sensor. However, human error committed by the first worker could be corrected by the second or third checker because usually 3 persons involved in calibration.

Table 1. Estimated HEPs for errors of commission in sensor calibration tasks

| Tasks | HEP Ave. | LOD | CHEP |
|---|---|---|---|
| Prepare Calibration | 0.00375 | - | 0.00375 |
| Record Voltage during Increasing Calibrator Output | 0.00125 | ZD | 0.00125 |
| Record Voltage during Decreasing Calibrator Output | 0.00125 | HD5 | 0.000625 |
| Calibrate Level Transmitter | 0.00125 | ZD | 0.00125 |
| Record Voltage during Increasing Calibrator Output | 0.00125 | ZD | 0.00125 |
| Record Voltage during Decreasing Calibrator Output | 0.00125 | HD5 | 0.000625 |
| Record Voltmeter Output | 0.00125 | ZD | 0.00125 |

Here,
LOD : Level of Dependence
CHEP : Conditional Human Error Probability

All values are based on skilled personnel involved in calibration. The probability that the second worker does not recognize the first worker's error is 0.01 per HRA handbook. Therefore the unavailability of sensor is calculated as following considering the low dependence and high dependence the first and second worker.

Unavailability (Sensor) = 0.01 * 0.145 * 0.55 = 8.0E-04

For the case of calibration of analog channel with four other components such as power supply, converter, channel test card and comparator with high dependence of each task, The unavailability could be calculated as following.

Unavailability (Analogue channel) = 8.0E-04 + 4 * 4.0E-04 = 2.4E-03

**B. Modeling Calibration Error of Analogue Channel by Common Cause**

The following explains how to estimate human error probability by common cause based on analogue logic. We estimated HEP for five cases as following.

a. One out of two Channel Common Cause :
In estimating human performance error probability of one out of two logic, the failure combination is that all two channels fail to calibrate correctly.
b. Two out of four Channel Common Cause :
The failure combination is that three channels fail to calibrate correctly.
c. Two out of tree Channel Common Cause :
The failure combination is that two channels out of three fail to calibrate correctly.
d. Two out of tree Channel Common Cause with one out of two loops :
The failure combination is that all two loops fail to calibrate correctly.
e. Two out of four Channel Common Cause with one out of two loops :
The failure combination is that all two loops fail to calibrate correctly.

**5. Conclusions**

The human error probability is estimated for the calibration of analogue channel. The results of the study are used to quantify the unavailability of each signal due to extend the test interval from 1 month to 3 months and prepare the licensing submittals for proposing to extend the current requirements of STI/AOT for RPS/ESFAS of Kori Unit 2. This project will contribute to reducing the plant staff's burden to perform the test, and to prevent the adverse effects to safety caused by human error during the test.

**REFERENCES**


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