Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2017

Unit Test for the Change of CCW Pump Control Logics

Chanho Sung*, Yeonsub Jung
KHNP Central Research Institute, 70, 1312beon-gil, Yuseong-daero, Yuseong-gu, Daejeon, 34101, KOREA
**Corresponding author: chsung95@khnp.co.kr*

1. Introduction

Component Cooling Water Pump (CCW-P) plays an important role of circulating water to cool components in NPPs. CCW-P system is a sub-system of the ESF-CCS (Engineered Safety Feature – Component Control System) of a nuclear power plant and generally controlled by control logics in PLC (Programmable Logic Controller) system.

There were design changes of CCW-P in Shin-Kori unit 3, that was CCW-P control logic changes in case of SIAS (Safety injection actuation signal) and LOOP (Loss of offsite power). Due to the control logic change, it needed a regression test to validate the changed logic software according to 'Shin-Kori 3&4 Software Program Manual' [1].

Generally, the regression test consists of module test, unit test and system test, but this logic change of CCW-P did not need module test because the proven modules without change such as type circuits (or typical logics) were used and there was only link logics change outside of the proven modules. Therefore, the performed tests related to this logic change were unit test and system test. This paper describes the unit test process and the test results of CCW-P.

2. Methods and Results

As CCW-P is one of safety class facilities in nuclear power plants, the change of control logic is needed to validate the logic software through regression test. The changed control logic of CCW-P is to run only one pump per channel when SIAS or LOOP occurs.

Software verification and validation should be performed according to V-model in Fig.1.

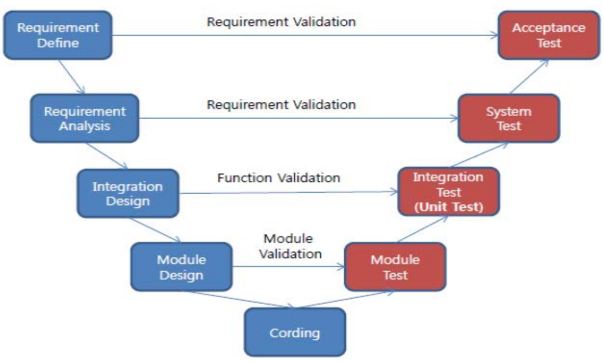

Fig. 1. V-Model for Software Verification and Validation

This case of CCW-P logic change for regression test is applicable to unit test in V-model because there is not any change for proven modules such as typical logics which are AND, OR, NOT, DELAY, SET/RESET and so forth.

2.1 Test Requirement

Table I shows the test requirement for the design change. Actually the changed requirement is that one pump keeps running and the other pump stops if SIAS or ESFAS occurs while two pumps are running. However, other related functional requirements as well as the changed requirement need to be tested for validating whether the other requirements are affected. Each channel has two pumps and the unit test should be carried out on each channel. Therefore 33 test cases were found out per channel and 66 test cases in total were used to meet the requirements [2].

Table I: Test Requirement for CCW-P

CCW-P Initial Status	Operating Condition	Requirements	
		Before Change	After Change
One pump is running	Normal	The pump keeps running and another pump is automatically standby	Not changed
	Abnormal	The pump stops and standby pump runs	Not changed
Two pumps stop	Start	Two pumps run manually	Not changed
	Shutdown	Two pumps run manually	Not changed
One pump is running	ESFAS or SIAS	The pump keeps running	Not changed
Two pumps are running	ESFAS or SIAS	Two pumps keep running	*One pump keeps running and the other stops*

2.2 Test Process

The process performed for the unit test of CCW-P is as follows:

- Uses the validation facility made of the same

PLC controller as ESF-CCS at Shin-Kori unit 3.

- Install the control logic program changed by CLD (Control Logic Diagram) and LSD (Loop Schematic Diagram) to the validation facility.
- Review and analyze signal connections and working specification with CLD and LSD.
- Develop the test cases corresponding to each requirement and define standard output values evaluated by input values.
- Feed the test cases into the PLC system of validation facility in regular order, check if the output values are equal to standard output values, and decide that each test case is pass or not.

2.3 Test Facility and Method

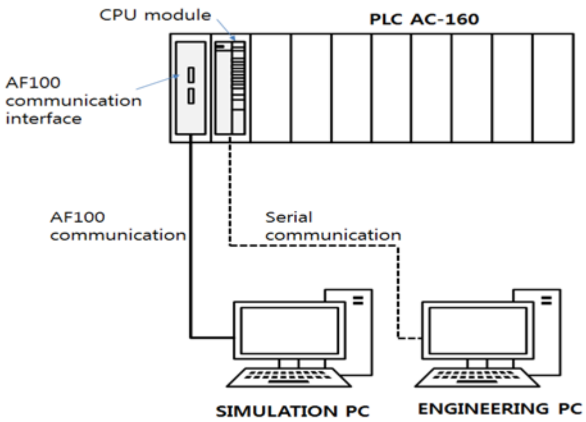

Fig. 2. Test facility for validating CCW-P control logics

The test facility for validation of CCW-P control logics was built with virtual simulator type and the facility consists of PLC system, simulation PC, and engineering PC. The PLC system was used with the same one at Shin-Kori unit 3 and has a CPU module and a communication interface for linking up with the Simulation PC using AF100 communication [3].

Engineering PC plays a role to alter the control logics based on the practical plant I/O (Input/Output) of the PLC control logics into control logics based on communication I/O for virtual simulation, and load the PLC control logics including altered I/O logics into CPU module of the PLC system through serial communication module, RS-232.

Simulation PC communicates with the PLC system by OPC server. That is, simulation PC transmits the inputs for test cases to PLC system, receives the outputs evaluated from control logics in PLC system, and compares standard output with the output from PLC system. For each test case, if all the outputs from PLC system are equal to the standard outputs then the test case is decided as “PASS”.

In this way, inputs and outputs of all test cases are validated automatically through the developed automatic test program in simulation PC. Figure 3 shows an example of test results performed by the test program.

LOOP CONTROLLER NO : LCCA07 (10001D08)
#-461-V-0296 : LETDWN HX SUPPLY CNMT ISOL VLV (SHEET 06)

<table>
<tr><th>TESTCASE NUM</th><th></th><th>0101</th><th>0102</th><th>0103</th></tr>
<tr><td colspan="5">INPUT PARAMETER</td></tr>
<tr><td>DI2817</td><td>R|B_IN1_1.1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>DI2818</td><td>R|B_IN1_1.2</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>DI2819</td><td>R|B_IN1_1.3</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>DI2820</td><td>R|B_IN1_1.4</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>A1</td><td>R|B_IN1_1.5</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>A3</td><td>R|B_IN1_1.6</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>A4</td><td>R|B_IN1_1.7</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>B0</td><td>R|V_IN1_1</td><td>0</td><td>72</td><td>72</td></tr>
<tr><td>A21</td><td>R|B_IN1_1.9</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>A2</td><td>R|B_IN1_1.10</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>DIBa</td><td>R|B_IN1_1.11</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>DIBb</td><td>R|B_IN1_1.12</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>DIBc</td><td>R|B_IN1_1.13</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>DIBd</td><td>R|B_IN1_1.14</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>DIBe</td><td>R|B_IN1_1.15</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="5">OUTPUT PARAMETER - Expected Result(Test Result)</td></tr>
<tr><td>DOAa</td><td>S|B_OUT1_1.1</td><td>0 (0)</td><td>0 (0)</td><td>0 (0)</td></tr>
<tr><td>DOAb</td><td>S|B_OUT1_1.2</td><td>0 (0)</td><td>0 (0)</td><td>0 (0)</td></tr>
<tr><td>B3</td><td>S|B_OUT1_1.3</td><td>0 (0)</td><td>0 (0)</td><td>0 (0)</td></tr>
<tr><td>B4</td><td>S|B_OUT1_1.5</td><td>0 (0)</td><td>0 (0)</td><td>0 (0)</td></tr>
<tr><td>B13</td><td>S|B_OUT1_1.6</td><td>0 (0)</td><td>0 (0)</td><td>0 (0)</td></tr>
<tr><td>B9</td><td>S|B_OUT1_1.7</td><td>0 (0)</td><td>1 (1)</td><td>0 (0)</td></tr>
<tr><td></td><td></td><td>PASS</td><td>PASS</td><td>PASS</td></tr>
</table>

Fig. 3. An example of test results for test cases

2.4 Unit Test Results

The unit test of CCW-P control logic was performed with 2 methods. One was that uses the plant simulator of Shin-Kori unit 3. The simulation test was carried out through the simulator loaded with the changed CCW-P logics and the results of all requirements were met. The other method was using the test facility as described in this paper. CCW-P has 6 functional requirements, and 66 test cases were developed and tested to meet the requirements. The results of 66 test cases were all ‘pass’ and the V&V coverage of the requirements was 100%. Accordingly, the unit test proved that the changed logics of CCW-P satisfied the functional requirements.

3. Conclusions

A regression test was needed due to the change of CCW-P control logics, and unit test and system test except for module test were carried out according to software verification and validation model (V-Model). Although this paper dealt with only the unit test and the result, the system test of CCW-P ended in success after the unit test.

In digital nuclear plants, it has become more important to enhance software reliability and integrity. Especially, the reliability of software in safety related facilities can affect nuclear plant safety. Therefore it needs continuous studies to develop practical and consistency methods for improving software V&V in nuclear plants.

REFERENCES

[1] KHNP, 3L186-IC-SM717, "Shin-Kori 3&4 Software Program Manual"

[2] KHNP CRI, The regression test report of CCW pump of Shin-Kori unit 3, 2016

[3] KHNP CRI, Shin-Kori units 3&4 ESF-CCS Control Logic V&V Report, 2015