

A Study on Improvements and Harmfulness for the Automatic Diagnostic Test of Interposing Logic System in NPPs

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1. Introduction

An Interposing Logic System (ILS) is designed and manufactured by Forney International Inc. Multiple microprocessor-based, single-board computers in the ILS control various Fans, Breakers, Compressors, Pumps and Valves. The ILS has been using the Auto Diagnostic Test(ADT) which calls IOCTST and INTEST in order to check its self-diagnostic. Recently the Failed IO board issued an unexpected output trip signal triggering closed the Reactor Coolant Pump(RCP) circuit breaker, therefore RCP operations are shut down in any Nuclear Power Plant(NPP). As a part of solving the root cause, we are investigating that the ADT is necessary for the system function. We've found that the ADT could not catch the system problem. Even if the core components are removed on its IO board, the ILS is working well. We would like to introduce the research results regarding the harmfulness and improvements of ADT for ILS.

2. Status and Analysis

In this section, the concept of the ILS is described and the problems of auto diagnostic test are presented.

2.1 Concept of the ILS

The ILS controls various Fans, Pumps, Breakers, Valves and Compressors in nuclear power plant. The NPP operators may give a command to components that he wants to control by using hand switch. Figure 1 gives a brief explanation.

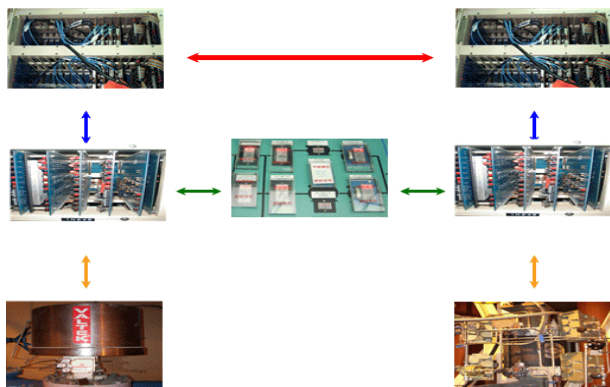


Fig. 1. The associated components

2.2 Concept of the Auto Diagnostic Test

The types of the Auto diagnostic tests are shown in the table 1.

| Type | Function |
|--------|--|
| INTEST | <input type="checkbox"/> Test period : every 5 minutes <input type="checkbox"/> Test component : EPROM, RAM on control board |
| IOCTST | <input type="checkbox"/> Test period : every 5 minutes <input type="checkbox"/> Test component : Input, Output channel on I/O Board |

Table 1. The Types of auto tests

The INTEST is to check the all of the memories and board functions which are controlled properly.

The IOCTST is to check the all of the Input channels and Output channels on IO boards. This test signal is generated a square wave every 5 minutes from the control board. The duration time of a square wave is 16usec. See the figure 2 below.

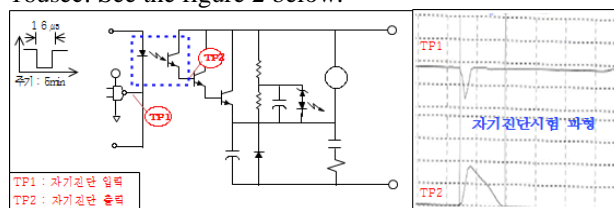


Fig. 2. The circuit of IO board and the wave of ADT

2.2 The harmfulness of the Auto Diagnostic Test

Whenever the control board sends a square wave to IO board, the actual output is turning from Off to ON in an instant. That indicates that a component may be actuated by an unexpected output signal in case of abnormal wave. Refer to the normal and abnormal wave forms in Fig. 3 below.

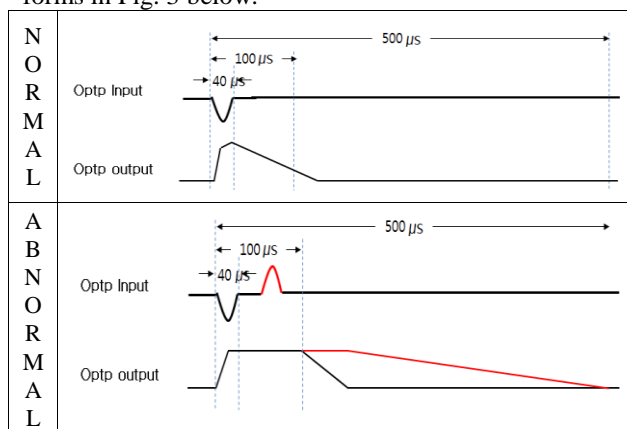


Fig. 3. Normal and Abnormal waveforms

The abnormal wave lasts for 500usec as per the above figure. That means that the abnormal wave is about 31 times as compared with a normal wave. Actually the reactor coolant pump in the Hanbit nuclear power plant has been shut down due to the abnormal wave.

Also, auto diagnostic test cannot detect IO board troubles. The Opto-coupler chip from the IO board has been removed. But control board recognized that the IO board was working well.

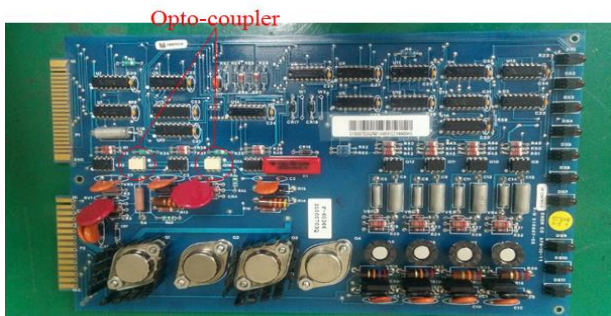


Fig. 4. IO board

The same waveforms are monitored when Opto-coupler is installed or removed on the IO board. Thus, the control board recognizes the normal status for IO board. See the waveforms shown in Figs. 5 and 6 below.

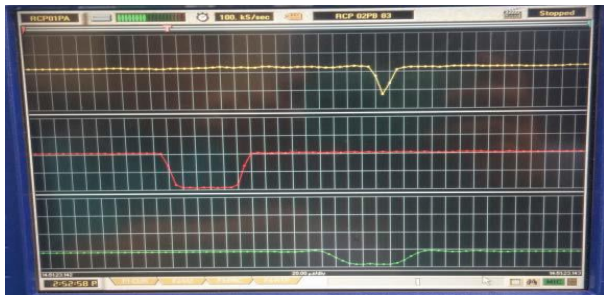


Fig. 5. Waveform of Installed Opto-Coupler

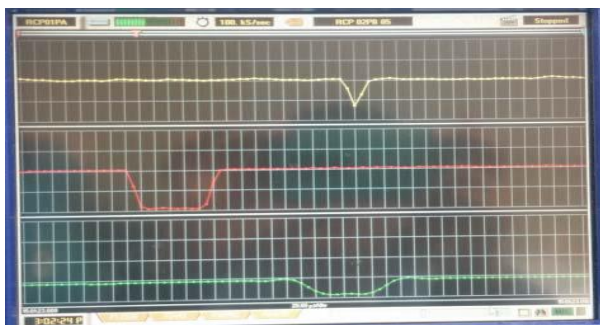


Fig. 6. Waveform of Removed Opto-Coupler

3. Methodologies and Improvements

In this section, the methodologies and the improvements of the ADT are described.

3.1 Concept of the modified ADT

As ILS did not appear to need IOCTST, a decision was made to delete the IOCTST from the program patch. See table 2.

| PROGRAM PATCH | | |
|-----------------------------|------|----|
| PATCH | FROM | TO |
| 1 | 6 | 2 |
| 2 | 8 | 0 |
| 3 | 0 | 8 |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | | |
| 13 | | |
| 14 | | |
| 15 | | |
| FOR CONTINUATION SEE FID | | |

→

| PROGRAM PATCH | | |
|-----------------------------|------|----|
| PATCH | FROM | TO |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | | |
| 13 | | |
| 14 | | |
| 15 | | |
| FOR CONTINUATION SEE FID | | |

Table. 2. Modified program patch

Program patch is loaded in EPROM on the control board. Once the patch is applied, control board indicates what kinds of IO boards being in the system. In the table, the number 6 in the “FROM” column means an input channel number. The number 2 in the “TO” column specifies output channel number. The control board doesn’t recognize the IO board when the numbers from the program patch are deleted. Eventually, the control board doesn’t send the IOCTST signal in order to test the IO board anymore.

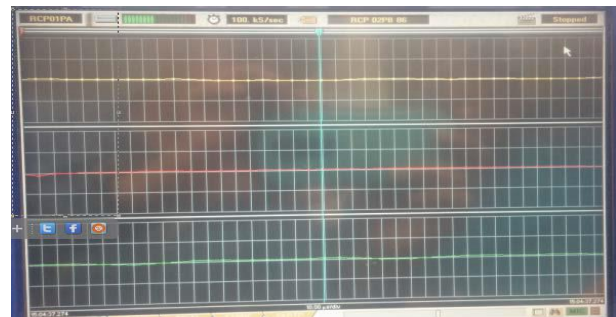


Fig. 7. Waveform without IOCTST

Checking the IO board by the control board is performed by the complement error detector every 100msec instead of IOCTST.

3.2 Verification of experiments

The system has to be verified to see if it works properly. The performance test was done by using the ILS simulator after deleting the program patch inside EPROM. The contents of performance tests are below.

- Function Test
- Stability Test

The performance tests are continued for 50days and completed successfully. The manufacturer of ILS agreed

to this design change since no impacts has arisen in the system.

3.3 System application

This modified ADT has been applied for 45 loops such as RCP, 13.8KV Feed PCB and others 3months ago. The ILS system has been working well so far.

4. Conclusions

This study is conducted to solve the chronic trouble in the ILS. A lot of troubles of the ILS have been issued after commercial operation. But most of them have disappeared without any corrective actions. Unnecessary ADT seemed to cause the troubles. This study is very important as the manufacturer admitted their design mistake. It has improved the system performance and reliability for the ILS. Accordingly nuclear power plant will become safer.

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