Mass Alarms in Main Control Room Caused Condensate on the Instrumentation and Control Cards in Turbine Building

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Abstract

A bunch of alarms and trouble lights on the main control room simultaneously turned on during inspection and exchange of the coolers of the turbine building at pressurized water reactor of the Hanbit nuclear power plant No. 6. The main cause was condensate on instrumentation cards of plant control system (PCS) installed at enclosures in the turbine building which have mux cabinets to transmit signals between the main control room and local equipment. To control the temperature and humidity of the MUX cabinets, two coolers of the plant chilled water system supply air to the compact enclosures at turbine building where temperature and humidity is high in the summer.

It is an unusual experience that mass alarms abnormally were occurred in the main control room during normal plant operation phases. Spurious signals with unknown cause at control and instrumentation system occasionally may have an unnecessary actuation of monitoring equipment and a plant scram even. One of the main causes is humidity by a rapid temperature change of the control and instrumentation cards. Dew on the instrumentation cards could form an abnormal short circuit in printed circuit board with the compact circuits and make any malfunction of the related system. Instrumentation and control cards with integrated circuits are vulnerable to high humidity and temperature where the system is enclosed in a small housing or enclosure surrounding with hash environment such as a turbine building. It was found that there was no functional degradation of the safety systems and no outsides releases of radioactive materials by this occurrence.

1. Introduction

Hanbit units 5&6 are located on the shores of the Yellow Sea in the western part of Korea peninsula. The two-loop pressurized water reactors were manufactured by Doosan Heavy industries/Combustion Engineering Corporation. The reactor core is designed for a thermal output of 2,825 MWth. The turbine generator has a rated electrical output of 1,050 MWe, supplied by Doosan Heavy industry in Korea [1]. Figure 1 shows the layout of the unit 5&6 of Hanbit site.

At 13:28 on August 7, 2013, trouble lights and related alarms were raised simultaneously on the switch board of the main control room at unit 6 in Hanbit nuclear power plant site, operators have not been experienced such a large number of indications of an unexpected occurrence during normal operation since the unit commercial operation. Maintenance engineer stopped a cooler No.05 at turbine building for an inspection which is a three monthly checking of the coolers as to maintain integrity of plant chilled water cooling system before replacement of other chiller. Root cause of the alarm and indication was a rapid increase of humidity and temperature of the inside of enclosure at the turbine building. There are many instrumentation and control cards and modules of the plant control system (PCS) installed in the enclosure at which local equipment such as valves and pumps were operated signals from main control room through MUX cabinets of the PCS.

The PCS, illustrated in Figure 2, is designed to perform data acquisition and transfer function via communication data links to control most of the field components such as pumps, fans, valves, dampers and circuit breakers. The system is composed of the safety related and non-safety related cabinets that are installed to the printed circuit boards based on microprocessor. Safety related functions are provided by redundant trains of microprocessor based single loop controllers with direct connections to the field input/output instruments to control the components associated with Engineered Safety Feature Actuation system. Most of non-safety related components are controlled remotely over communication network which performs the signal transmission with the input/output boards and fiber optic cables through several interfaces from the controllers to the field sensors [2].

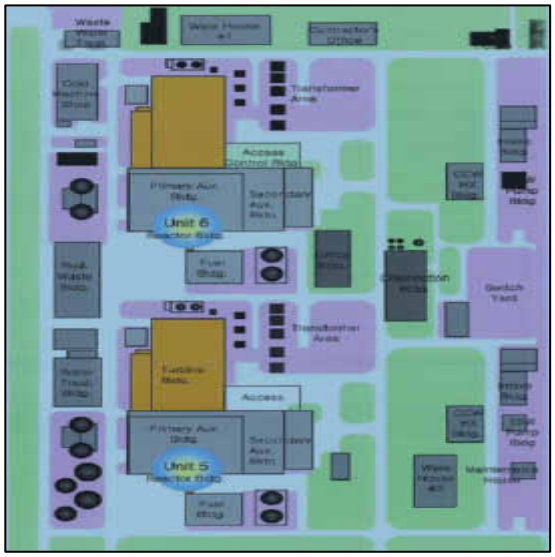

Figure 1. Hanbit 5&6 site layout

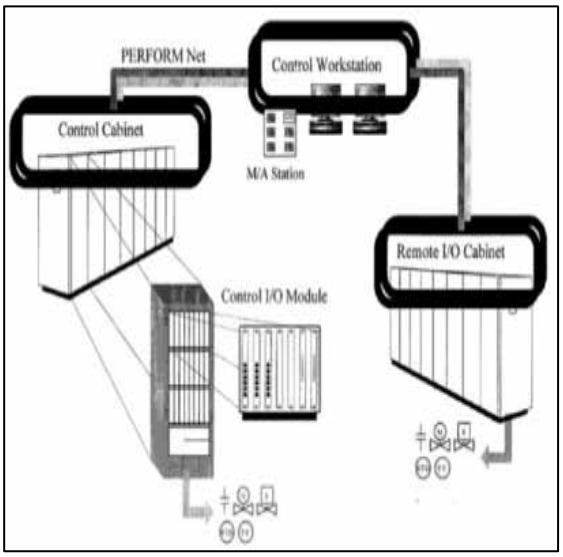

Figure 2. Configuration of the PCS

2. Overview of Event

2.1 Event Sequence

The turbine building chilled water system is designed to provide adequate quantity of chilled water at approximately 42 ℉(6 ℃) to the turbine building area coolers, the high voltage distribution room air handling units, and area cooler cooling coil. The turbine building chilled water system consists of two 100% capacity chiller with its corresponding chilled water circulating pump, an air separator, a compression tank, a chemical additive tank, associated piping, controls and instrumentation. During normal operation, one of two chillers is operating and the other is on standby. Air separator and compression tank are provided to accommodate trapped air, and accommodate system expansion and contraction due to temperature variation in the system. The turbine building chillers condensers are cooled by the turbine building closed cooling water system [3].

The following sequence illustrates the situation at that time.
Event sequence (August 7, 2013)
13:20 Perform the test procedure of inservice surveillance-3632 in the plant chilled water system, cooler No.5 was stopped in the turbine building.
13:28 Alarm occurred “PCS MUX 16 Humidity Hi”
13:31 Alarm occurred “PCS MUX 13 Humidity Hi”

13:28 ~ 13:35 A bunch of alarms and indicators turned on simultaneously on the switch boards in main control room.
13:40 Immediately start of cooler No.4 immediately at the turbine building.
13:46 Alarm reset "PCS MUX 13 Humidity Hi"
13:52 Alarm reset "PCS MUX 16 Humidity Hi"
13:46 ~ 14:00 Control switch trouble reset in the mail control room.

2.2 Cause and Analysis of Event

There are eight cabinets of PCS MUX in the turbine building which are installed in the separate five enclosures scattered in several locations in the building. Two chillers supply cooled water to the coolers and air handling units (AHU) for the cooling of the major equipment of PCS MUX cabinets, main feed water pump turbine control panel and exciter. Table 1 shows the cooling air supply facility and the major loads in the turbine and generator building. Each four coolers were serving to the turbine generator building level 73´ and 100´ respectively where four cooler supply cooling air to the building of 73´ and 2 cooler and 2 AHU in 100´. Two chillers supply cooled water to the heat exchanger coils of the cooler and AHUs in the turbine generator building in which only one chiller operates and the other is on standby during summer. Figure 3 illustrate the layout and arrangement of the coolers and AHUs in the building.

Table 1. Cooling air supply facility and loads

Cooling air supply facility	Major loads
TGB 100´ Cubicle Cooler HV01	PCS MUX Cabinet 15/16
TGB 100´ Cubicle Cooler HV02	PCS MUX Cabinet 13 MFWP TBN Control Panel
TGB 73´ Cubicle Cooler HV03	PCS MUX Cabinet 11/12
TGB 73´ Cubicle Cooler HV04	PCS MUX Cabinet 09/10
TGB 73´ Cubicle Cooler HV05, HV06	
TGB SWGR Room Supply AHU HV08, HV09	PCS MUX Cabinet 14
TGB Supply AHU HV10, HV11	
Exciter Room Cubicle Cooler HV12	Exciter

For removing of the heat in the cabinet, cooler and AHU supply air to the enclosures through ducts and two additional air conditioners in the enclosure where one always operates in summer and the other is standby. According to the National Weather Service, the local temperature and humidity near the plant was 36.0 ℃ and 84.1 % respectively. PCS MUX Humidity alarms were occurred after 8 minutes of the chiller stopping to exchange with a standby chiller by manually. Normal replacement time is usually about 10 minutes, but the time was delayed 20 minutes at that time. The air in the turbine building with a high temperature and humidity rapidly permeated to the enclosure with a small space. The temperature and humidity increased to 6.1 ℃and 35 % in an enclosure contained PCS MUX 16 shown in Table 2.

Table 2. Variation of the temperature and humidity

Enclosure	Temperature [℃] ※ Alarm Set Point: 35	Humidity [%] ※ Alarm Set point: 75	Position
MUX 09/10	23.4 → 24.0 (Δ 0.6)	55.7 → 68.8 (Δ 13.1)	TGB 73'
MUX 11	27.1 → 27.5 (Δ 0.4)	59.4 → 63.3 (Δ 3.9)	TGB 73'
MUX 12	27.3 → 27.3 (Δ 0)	54.0 → 55.3 (Δ 1.3)	TGB 73'
MUX 13	24.0 → 27.8 (Δ 3.8)	60.2 → 83.3 (Δ 23.1)	TGB 100'
MUX 14	27.3 → 29.2 (Δ 1.9)	45.0 → 64.9 (Δ 19.9)	TGB 100'
MUX 15	23.2 → 27.5 (Δ 4.3)	65.8 → 67.9 (Δ 2.1)	TGB 100'

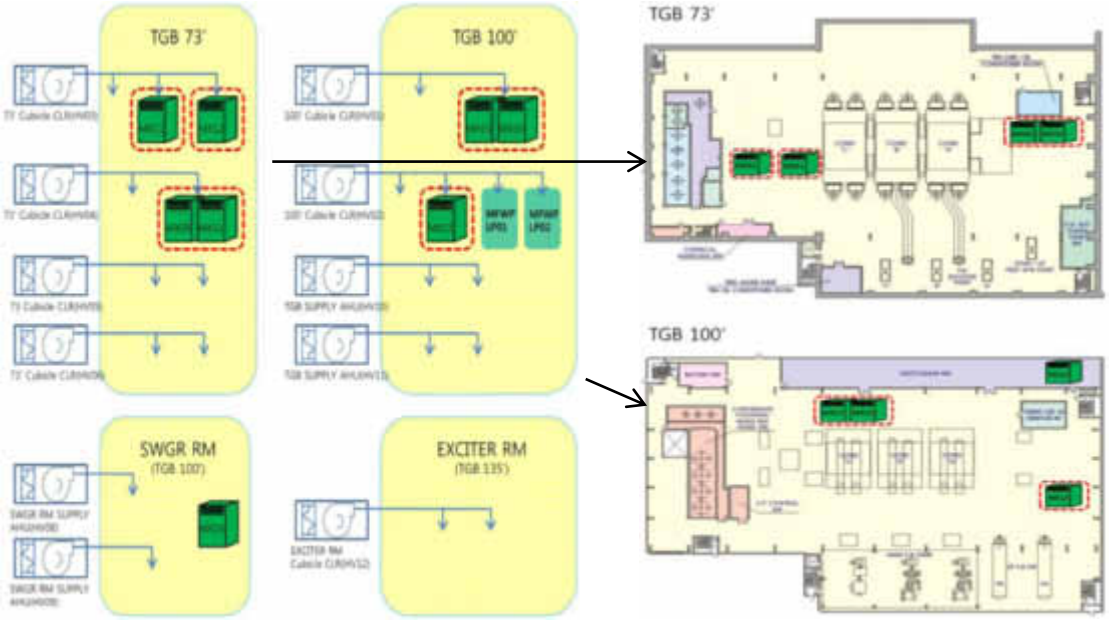

Figure 3. Cooler and Mux cabinet arrangement in the turbine and generator building

We can see a variation of temperature and humidity shown in figure 5 and 6 before and after the events in which humidity in enclosure increase rapidly than temperature and made condensation on the surface of cards in the MUX cabinets. Condensation water could be a circuit in the printed circuit board that may be a root cause of the alarms and indication in the main control room. Operating and maintenance manual describes a ground fault detection to detect ground failure that a power supply monitor contains three ground fault detection circuits. One circuit determines if catastrophic current leakage has occurred between control common and case ground. Similarly, the other circuits detect catastrophic current leakage from logic common and field common to case ground. Any current leakage between control common and case ground appears as a voltage across a resistor. No leakage yields a relative ground. Leakage of approximately 3.14 μA in either direction trips the window comparator sinking current to ground. As a result, the CONTROL POWER GND FAULT indicator lights on the front panel. And the window comparator energizes a solid state relay grounding the ground fault indication (GFI) line. The logic and field ground failure detection circuits operate in the same manner as the control ground-failure detection

circuit. However, 7.5V biases the logic circuit. As a result, the window comparator limits are approximately ∓0.981 V and the current leakage limit is approximately 0.981 μA.

The three solid state relays that control the GFI line are wired in parallel. As a results, control, logic or field common leakage to case ground, grounds the GFI lines. The corresponding GND FAULT indicator lights on the front panel, to identify the faulty ground connection [2]. Figure 6, logic diagram, shows the process of the indication as a result of faults from the remote MUX cabinets, verifying an assumption that the root cause of the event is the condensation by rapid change of temperature and humidity in the enclosure. Leakage current through the bridge of water made a circuit to flow current over the ground fault limit.

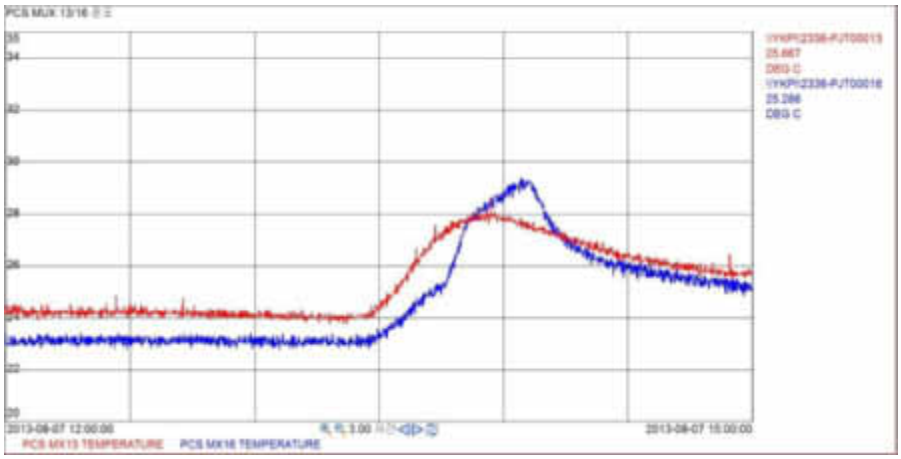

Figure 4. Temperature variation in the MUX 13(red) and 16

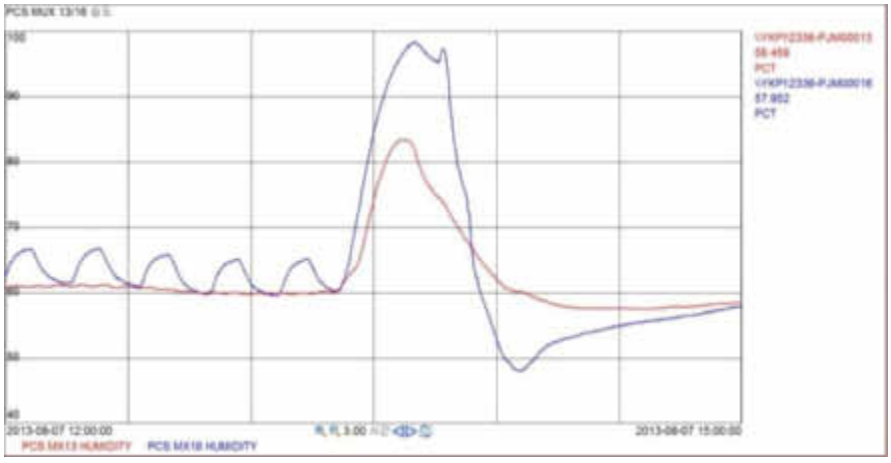

Figure 5. Humidity variation in the MUX 13(red) and 16

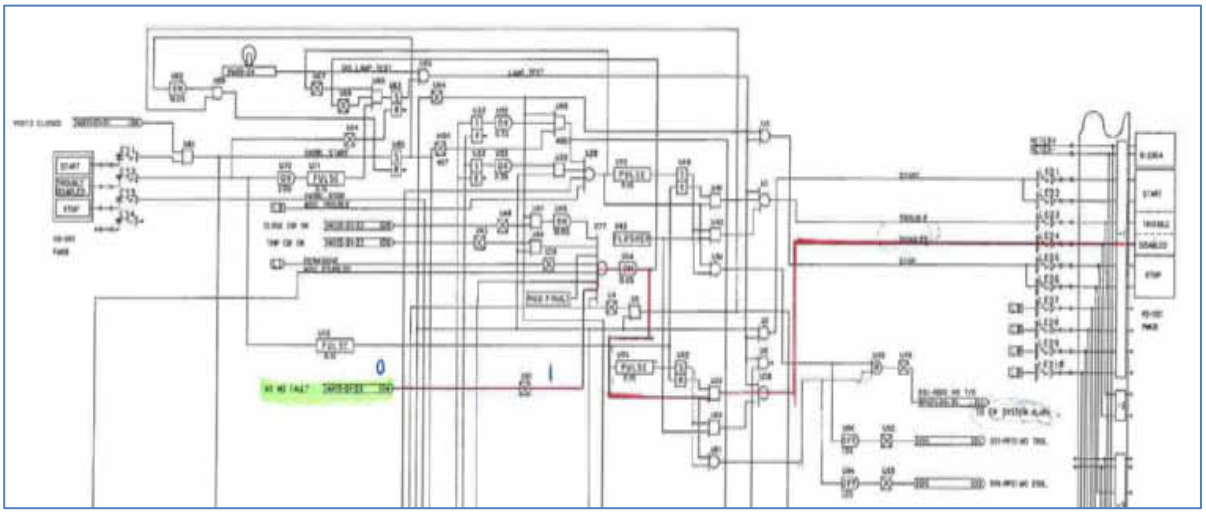

Figure 6. One of functional interconnection diagrams for fault indication

3. Corrective Actions

To prevent from reoccurrence of similar practices during plant normal operation, we have investigated the results and cause of the event and revised procedures related to the event such as a plant chilled water cooler checking that has been performed at three months intervals and adjusted a schedule of the cooler replacement to avoid a humidity increase in the MUX cabinets. Also it was recommended that staff involved into the maintenance and replacement should be trained about activities including cooler operation, replacement and emergency operation of two chiller failures.

4. Conclusion

The same operational activity can lead to a different result due to environment and times, making an unexpected event which will be a minor incident or severe accident in some cases that is depend on a plant and environmental condition. We need a consideration that cabinet located local area should be managed carefully in order to prevent a rapid change of temperature and humidity because of the control and instrumentation cards are vulnerable to the environment. Investigation of procedures and adjustment of in-service schedules can be useful to avoid unplanned scram, reducing an unexpected occurrence due to the instrumentation and control system failures.

5. References

[1] Final Safety Analysis Report of Hanbit Nuclear 5&6 units,
[2] Plant Control System Operating &Maintenance Manual, Korea Electric Power Corporation Hanbit Nuclear Power Plant Units 5 & 6
[3] Operational Experience Report of Hanbit Nuclear Power Plant No.6.
[4] Functional Interconnection Diagram, Rev. 3, Korea Hydro & Nuclear Power Co., LTD.

Mass Alarms in Main Control Room Caused Condensate on the Instrumentation and Control Cards in Turbine Building

April 4, 2014

KINS, Cheol-Soo Goo

Contents

Introduction

- A bunch of alarms and trouble lights on the main control room simultaneously
- The main cause was condensate on instrumentation cards of plant control system (PCS)
- No functional degradation of the safety systems and no outsides releases of radioactive materials by this occurrence

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Introduction

- Hanbit units 5&6 is two-loop pressurized water reactors
- Thermal output of 2,825 MWth
- The turbine generator has a rated electrical output of 1,050 MWe

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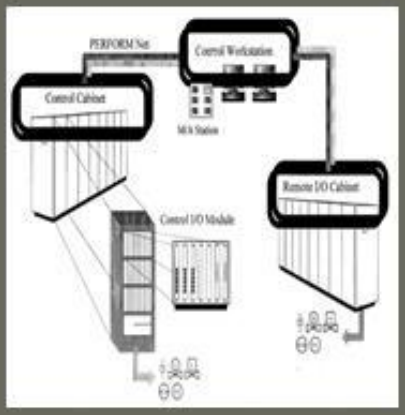
Introduction

- The PCS is designed to perform data acquisition and transfer function
- Control most of the field components such as pumps, fans, valves, dampers and circuit breakers
- Composed of the safety related and non-safety related cabinets
- Controlled remotely over communication network



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Overview of Event

- **Adequate quantity of chilled water at approximately 42°F(6°C)**
  - Turbine building area coolers
  - High voltage distribution room air handling units
  - Area cooler cooling coil
- **Two 100% capacity chiller**
  - One is operating and
  - The other is on standby

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Overview of Event

13:20 Perform the test procedure of inservice surveillance-3632 in the plant chilled water system, cooler No.5 was stopped in the turbine building.

13:28 Alarm occurred "PCS MUX 16 Humidity Hi"

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13:28 ~ 13:35 A bunch of alarms and indicators turned on simultaneously on the switch boards in main control room.

13:40 Immediately start of cooler No.4 at the turbine building.

13:46 Alarm reset "PCS MUX 13 Humidity Hi"

13:52 Alarm reset "PCS MUX 16 Humidity Hi"

13:46 ~ 14:00 Control switch trouble reset in the main control room.

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Cause and Analysis of Event

- Eight cabinets of PCS MUX in the turbine building
- Two chillers supply cooled water to the coolers and air handling units (AHU)

Cooling air supply facility	Major loads
TGB 100' Cubicle Cooler HV01	PCS MUX Cabinet 15/16
TGB 100' Cubicle Cooler HV02	PCS MUX Cabinet 13 MFWP TBN Control Panel
TGB 73' Cubicle Cooler HV03	PCS MUX Cabinet 11/12
TGB 73' Cubicle Cooler HV04	PCS MUX Cabinet 09/10
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TGB SWGR Room Supply AHU HV08, HV09	PCS MUX Cabinet 14
TGB Supply AHU HV10, HV11	
Exciter Room Cubicle Cooler HV12	Exciter

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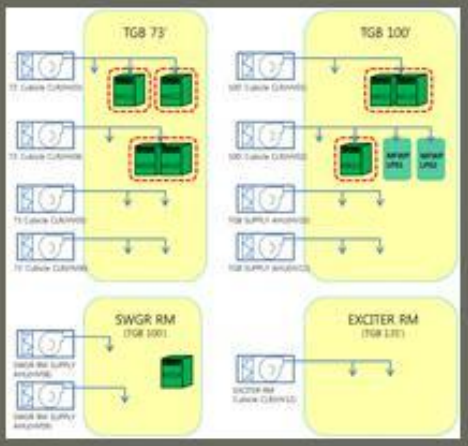
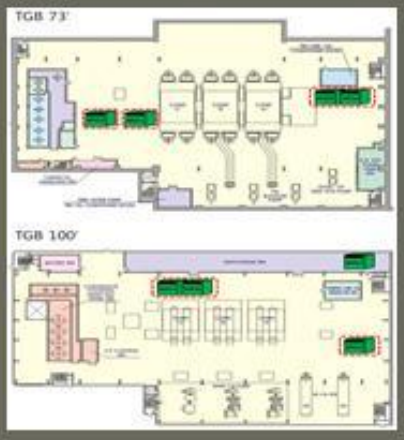
Cause and Analysis of Event





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Cause and Analysis of Event

- Local temperature and humidity near the plant was 36.0°C and 84.1% respectively
- Normal replacement time is usually about 10 minutes, but the time was delayed 20 minutes at that time.
- The air in the turbine building with a high temperature and humidity rapidly permeated to the enclosure.
- The temperature and humidity increased to 6.1°Cand 35% in an enclosure contained PCS MUX 16 shown in Table 2.

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Cause and Analysis of Event

Enclosure	Temperature [℃] ※ Alarm Set Point: 35	Humidity [%] ※ Alarm Set point: 75	Position
MUX 09/10	23.4 → 24.0 (Δ 0.6)	55.7 → 68.8 (Δ 13.1)	TGB 73'
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MUX 15	23.2 → 27.5 (Δ 4.3)	65.8 → 67.9 (Δ 2.1)	TGB 100'
MUX 16	23.0 → 29.1 (Δ 6.1)	63.1 → 98.1 (Δ 35.0)	TGB 100'

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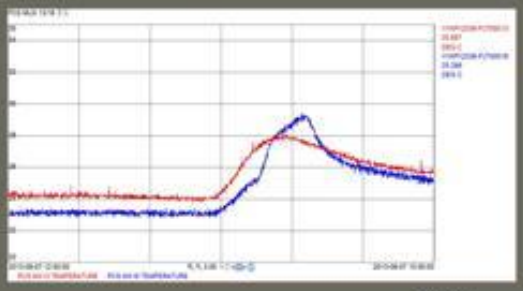
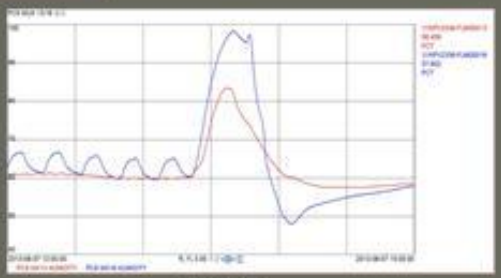
Cause and Analysis of Event





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Cause and Analysis of Event

- Humidity in enclosure increase rapidly than temperature
- Made condensation on the surface of cards in the MUX cabinets.
- Condensation water could be a circuit in the printed circuit board
- Leakage of approximately 3.14 μA in either direction trips the window comparator sinking current to ground
- The logic and field ground failure detection circuits operate in the same manner
- Current leakage limit is approximately 0.981 μA.

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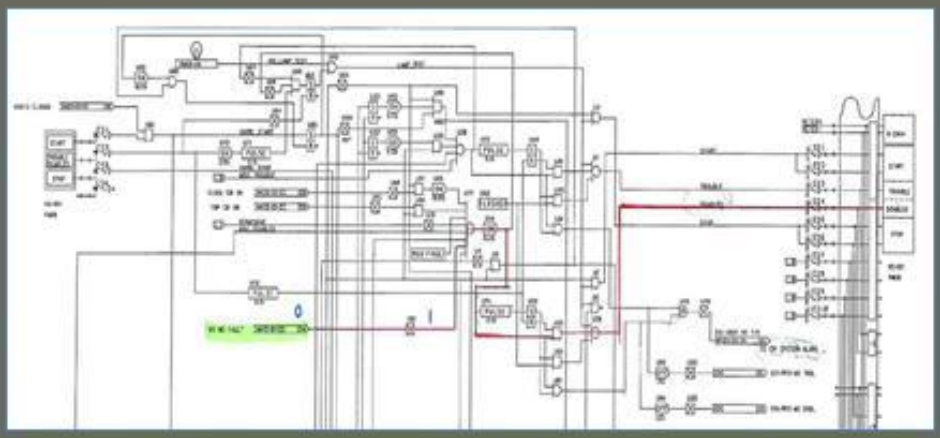
Cause and Analysis of Event



One of functional interconnection diagrams for fault indication

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Corrective Actions

- To prevent from reoccurrence of similar practices during plant normal operation.
- We have investigated the results and cause of the event and revised procedures
- Also it was recommended that staff involved into the maintenance and replacement should be trained about activities.

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Conclusion

- The same operational activity can lead to a different result due to environment and times, making an unexpected event.
- Consideration that cabinet located local area should be managed carefully to prevent a rapid change of temperature and humidity.
- Control and instrumentation cards are vulnerable to the environment.
- Needs investigation of procedures and adjustment of in-service schedules

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References

[1] Final Safety Analysis Report of Hanbit Nuclear 5&6 units

[2] Plant Control System Operating &Maintenance Manual, Korea Electric Power Corporation Hanbit Nuclear Power Plant Units 5 & 6

[3] Operational Experience Report of Hanbit Nuclear Power Plant No.6

[4] Functional Interconnection Diagram, Rev. 3, Korea Hydro & Nuclear Power Co., LTD