

Submission of a “Report on Failure/Event of the Nuclear Installation” for Takahama Unit 4 (Subject: Takahama Unit 4 Automatic Reactor Trip Following Automatic Generator Trip)

March 9, 2016

The Kansai Electric Power Co., Inc.

**We submitted a “Report on Failure/Event of the Nuclear Installation” for Takahama Unit 4 automatic reactor trip following automatic generator trip to the Nuclear Regulation Authority today.**

**1. Discussion about the event**

At Takahama Unit 4 (pressurized water reactor, rated electric output: 870MW, rated thermal output: 2,660MW), which was undergoing the 20<sup>th</sup> periodic outage inspection beginning on July 21, 2011, the turbine and reactor automatically shut down at p.m. 14:01 on February 29, 2016 following automatic generator trip when actions to connect the generator in parallel<sup>\*1</sup> were taken.

Generator-related alarms, “main transformer/generator internal failure” and “PT<sup>\*2</sup> failure” were actuated in the main control room when the generator automatically shut down. Subsequently, to determine the causes of “main transformer/generator internal failure” alarm which triggered automatic generator trip, the local protective relay panel was checked for potential components actuating the alarm. As a result, it was found that main transformer ratio differential relay<sup>\*3</sup> (hereafter called “M87B”) and generator backup lockout relay<sup>\*4</sup> (hereafter called “86BU”) were actuated.

There have been no fluctuations in the indications of Takahama Unit 4 vent stack monitor and environmental monitors surrounding Takahama Nuclear Power Station. The event has not caused any radioactive release to the surrounding environment.

\*1: actions to connect the generator to the grid

\*2: a transformer to measure the generator voltage

\*3: a relay to detect main transformer failures

\*4: A relay transmitting a signal to disconnect the generator from the grid following the detection of a failure of the generator and transformer

## 2. Results of Cause Investigation

(Plant status when generator paralleling operations were performed)

- It was confirmed that operators took correct actions according to the procedure and there were no abrupt changes in the generator output and no abnormal fluctuations in the transmission system.

(Confirmation of equipment integrity)

- Insulation resistance measurement and other inspections of the generator, main transformer and other equipment revealed no abnormal conditions.
- The instrument (synchronization detecting circuit), which was used in paralleling operations, was tested using simulated signals and the result showed no failure of the instrument.
- The concerned relay is designed to measure the current flowing through the main transformer via the current transformer. Insulation resistance measurement and other inspections of the current transformer were conducted and then it was verified that there was no internal failure.
- Regarding the “PT failure” alarm, there was no internal failure in the concerned potential transformer and other equipment and it was estimated that the alarm actuation was a correct response to a detected decrease in the system voltage following automatic generator trip.

(Investigation results of power flow from the transmission system)

- Transient power flow may occur instantaneously during paralleling operations due to a phase difference between the generator and transmission system. It was confirmed that when operators took actions to connect the generator to the grid at Takahama Unit 4, currents exceeding the relay actuation set point at 30% flowed from the transmission system toward the generator.

(Investigation results of relay set point)

- The concerned relay is designed to measure the current of the main transformer on both the generator and transmission system sides and become actuated when the difference between the currents reaches 30% due to an internal failure or other malfunctions of the transformer.
- We discussed with the manufacturer of the relay panel about the set point of the concerned relay, and concluded that the set point needed no change considering past experience at other plants in which an equivalent relay was used as an alternative to

detect generator internal failure during generator paralleling operations and that the set point had a sufficient margin against the generator output.

- It was revealed that potential effects of instantaneous power flow during paralleling operations had not been assessed in determining an appropriate set point.

### 3. Event Causes

- The operation method of the concerned relay was changed so that it would detect the current flowing through the entire system rather than detecting differential current flowing through the main transformer. However, in determining the relay set point, potential effects due to instantaneous power flow arising from the phase difference between the generator and the transmission system were not taken into account. Therefore, it is estimated that the concerned relay detected a transient power flow from the transmission system toward the generator, and then became actuated.
- When placing an order to replace the concerned relay panel to the manufacturer, we did not ask them to evaluate the validity of the relay set point considering the plant system configuration.
- Our evaluation items did not include the assessment of potential changes in current value following a transient.

### 4. Corrective Actions

- To prevent the effect of an equipment failure from spreading into the transmission system (current greater than the rated current by a factor of 7 or 8 can interrupt the stable condition of the transmission system), the concerned relay set point will be changed to 90% to allow for a sufficient margin against the current that may temporarily flow into the transmission system when generator paralleling actions are taken.
- The internal rule will be changed so that a requirement for the manufacturer to perform quantitative assessment of current should be specified in the purchase order and we should confirm the assessment result. In addition, a check sheet will be introduced for the confirmation of potential transient increase in the current in checking the set point of a protective relay.
- An education and training program will be introduced for our employees regarding possible changes in the power flow in case of a transient.
- We will follow up the manufacturer's corrective actions to be taken.

#### 5. Efforts to Prevent Recurrence of a Similar Event

- Among all the modification works conducted during this refueling outage period, additional installation, replacement and removal of equipment will be extracted, and then protective relays, level meters, alarms and other instruments will be checked for the validity of their set points.
- For temporary wiring and system configuration to be tentatively introduced after the start of final heatup process, their capabilities to cope with potential transients will be confirmed.

We will work on company-wide initiatives involving manufacturers and partner companies to enhance field inspection and to re-confirm the points to be noted in the modification work results. We will continuously make an utmost effort to assure the safety of our plants through these voluntary activities.

[Attachment]

- Attachment 1: Takahama Unit 4 Automatic Reactor Trip (Causes/Corrective Actions)

Takahama units 3 and 4 is KEPCO's first unit that has passed the safety screening against the new regulatory requirements which took effect on July 8, 2013 taking into account the lessons learned from the TEPCO's Fukushima Daiichi NPP accident and latest technical findings collected from across the world.

We will continue to make an utmost effort to improve the safety and reliability of our nuclear power plants by collecting and analyzing latest technical information collected at home and abroad. At the same time, we set our goal at achieving the world's highest level of safety while pursuing voluntary safety improvement measures on a continuous basis even beyond the framework of the new regulatory requirements.

# Takahama Unit 4 Automatic Reactor Trip (Causes/Corrective Actions)

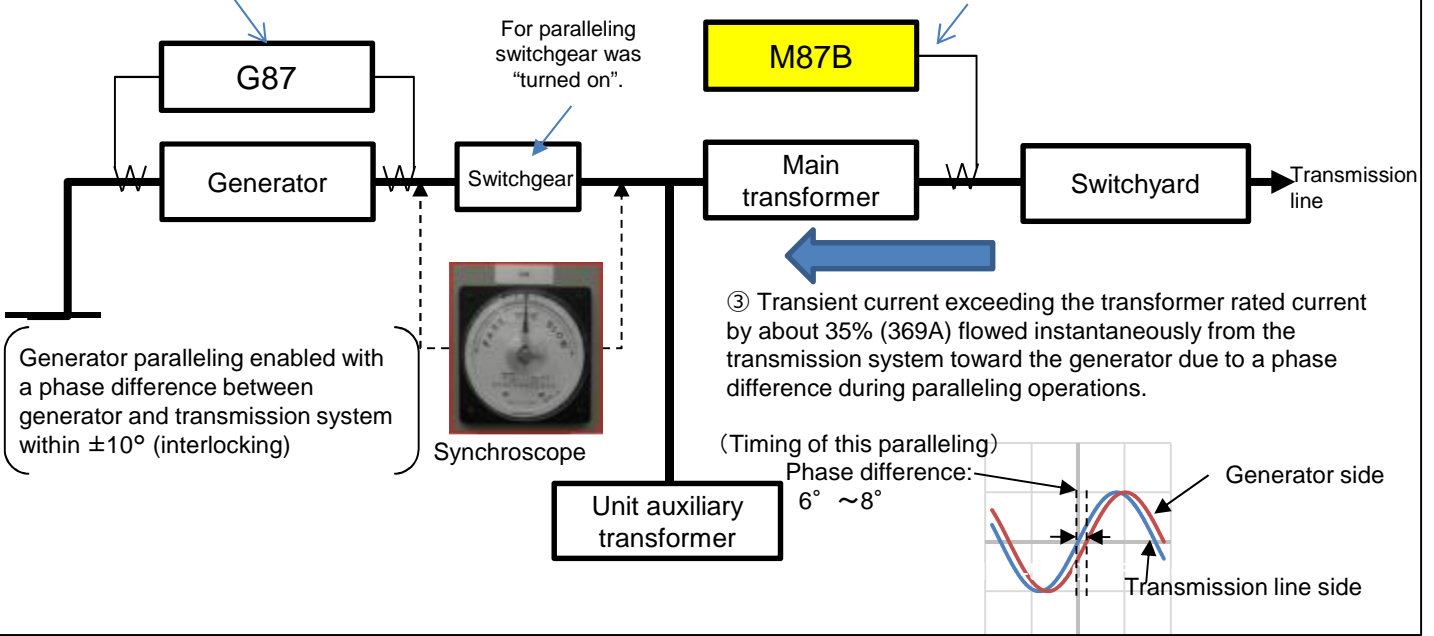
## <Generator paralleling operations>

### ① Relay (G87)

- Replaced during this refueling outage period
- Planned to place in service after confirming its integrity at 5% generator output

### ② Relay (M87B)

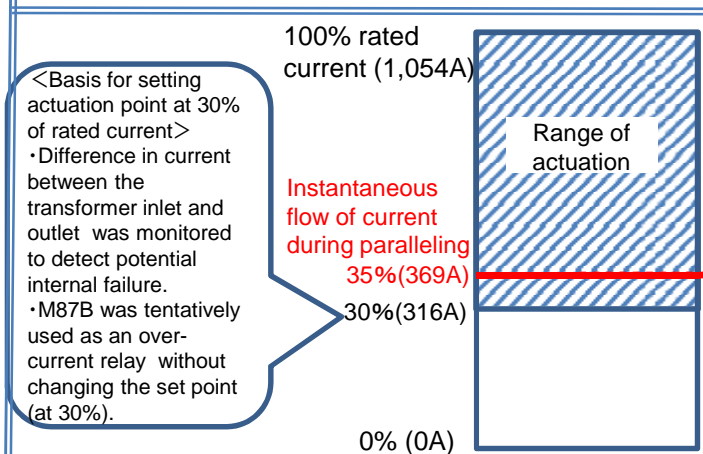
- Tentatively used as an alternative to G87
- Actuation point was set at 30% (316A) of main transformer rated current (1,054A).



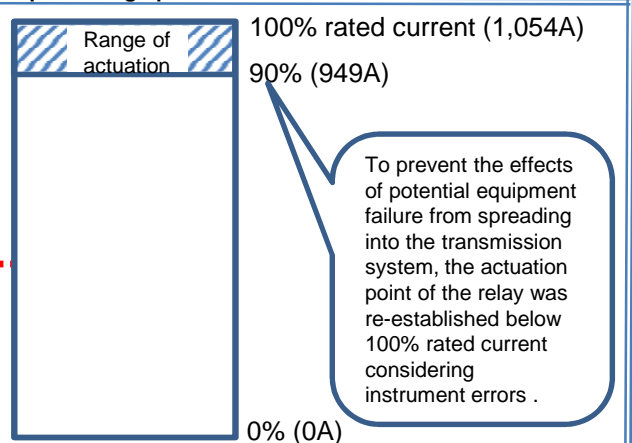
## <Factors caused this event>

- (1) When it was decided to tentatively use M87B as an alternative after the replacement of G87, its actuation point was set without considering potential transient current.
- (2) The manufacturer was not asked to assess potential effects of transient current in setting M87B actuation point when they received an order for the replacement of the relay panel.

### Before this event



### Corrective actions (up to generator output at 25% after paralleling operations)



## <Corrective actions>

- Ø The M87B actuation point will be tentatively set at 90% of rated current considering potential transient current during paralleling operations (increase in current within  $\pm 10^\circ$  phase difference).
- Ø A requirement for the manufacturer to quantitatively assess current including transient changes will be specified in the purchase order.
- Ø An education/training program for the employees of the responsible department will be introduced regarding power flow in case of a transient.
- Ø Following-up of manufacturer's corrective actions will be performed.

## <Efforts to prevent recurrence of a similar event>

- Ø Among all the modification works conducted during this refueling outage period (about 1,800 items), additional installation and modification of equipment will be extracted (36 items), and then protective relays, level meters and alarms will be checked for the validity of set points.
- Ø For temporary wiring and system configuration to be tentatively introduced after the start of final heatup process, their capabilities to cope with potential transients will be confirmed.