Recent Electrical and Instrumentation Systems for Geothermal Power Plants

Masaaki Okabe
Isao Watanabe

1. Introduction

The most serious problem facing the electrical and instrumentation systems for geothermal power plants is protecting the equipment from corrosion due to corrosive gas. This problem is discussed in Volume 55, No.8 of the Fuji Electric Journal (1982). In this paper we will describe the equipment used in the electrical and instrumentation systems for recent geothermal power plants.

2. Example of an Electrical System for Geothermal Power Plants

2.1 Generator and main transformer

In general, geothermal power plants are constructed in mountainous areas, far from places where there is a demand for electricity. This is true of the Malitbog Gothermal Power Plant (for details, please refer to another article found in this issue titled "Malitbog Geothermal Power Plant, Leyte, Philippines"), where a direct-current transmission system was applied to one part of a long transmission line. For this purpose, the customer requested a certain quantity of reactive power (power factor less than 0.85) to be supplied. This reactive power is supplied to the terminal point by the power plant.

We therefore utilized a generator having a large capacity of reactive power at a rated output and a main transformer of low impedance and with low reactive power consumption.

Specifications of the generator and the main transformer follow.

(1) Generator
  (a) Type: Horizontally cylindrical totally enclosed air-cooled type
  (b) Rated capacity: 94,100kVA
  (c) Rated voltage: 13.8kV
  (d) Rated power factor: 0.824
  (e) Rated frequency: 60Hz
  (f) Excitation system: Brushless excitation system
  (g) Rated speed: 3,600r/min
  (h) Short-circuit ratio: 0.599
  (i) Quantity: 3 sets

(2) Main transformer (with no-voltage tap change-over equipment)
  (a) Type: Oil natural forced air type (ONAF)
  (b) Rated capacity: 92,000kVA
  (c) Rated voltage: 13.8kV/230kV
  (d) Rated frequency: 60Hz
  (e) Connection: Delta/star connection
  (f) Impedance voltage: 10.5%
  (g) Quantity: 3 sets

2.2 Unit electrical system

This plant is installed in the Philippines, a country

Fig.1 Single line diagram

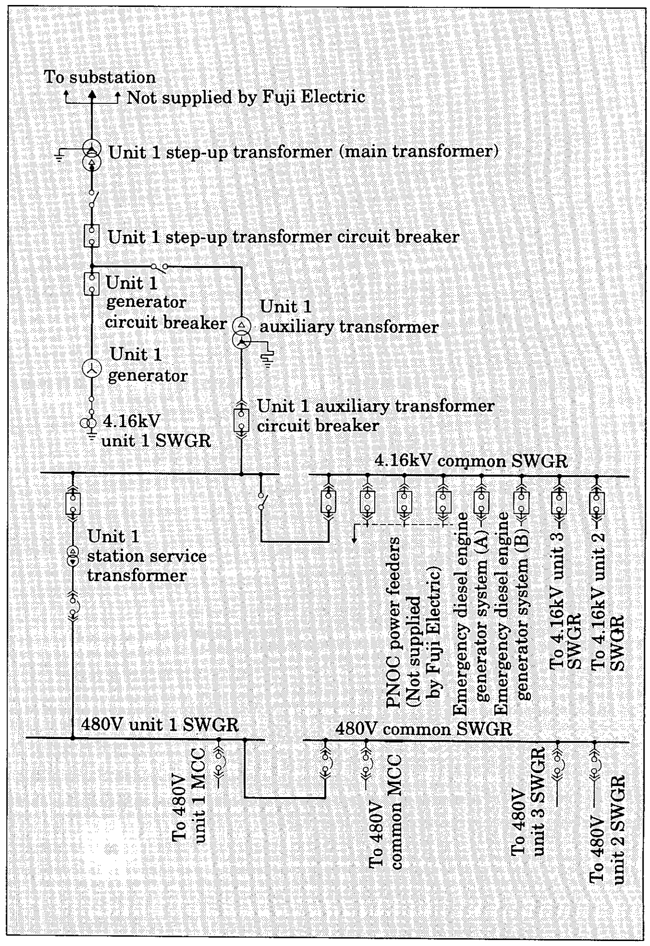
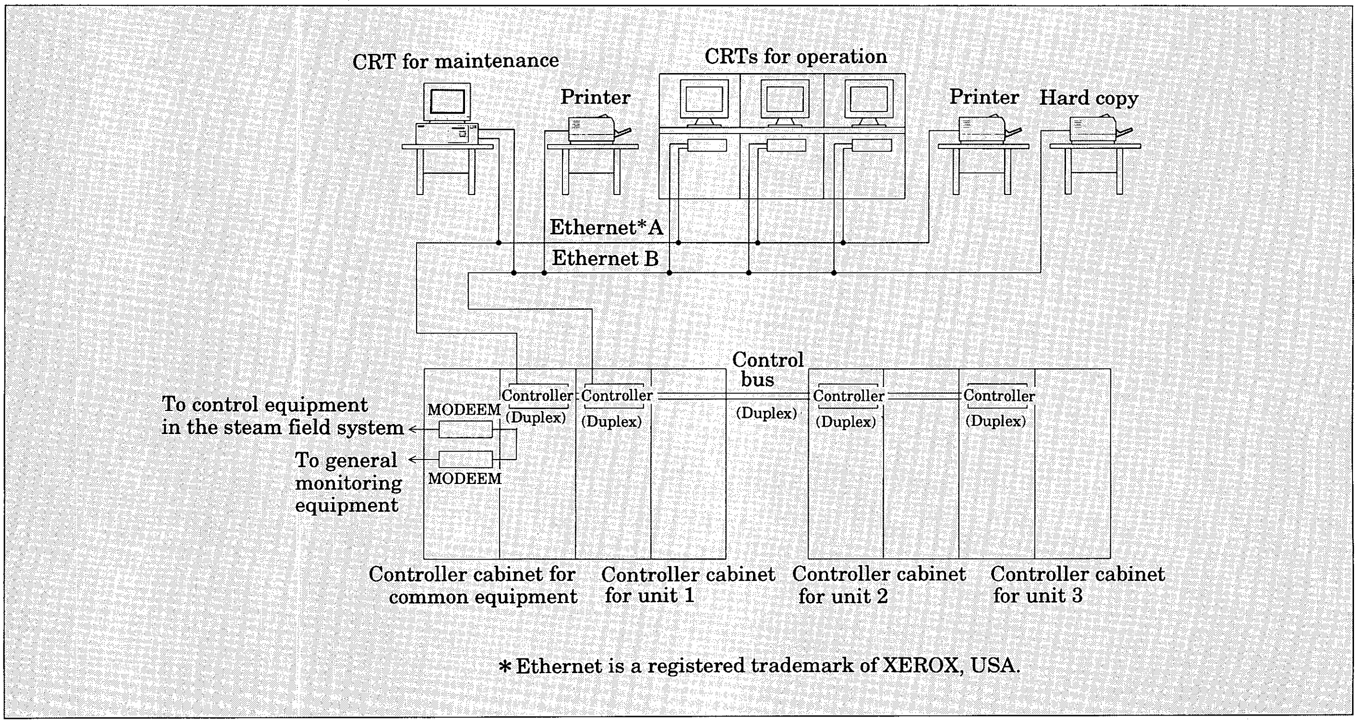


Fig.2 DCS configuration



which has a shortage of electric power. Geothermal power generation does not require any fuel, therefore, its operating costs are low. The customer required the off-line time to be as short as possible in order to increase the operational factor of the plant.

Therefore, in designing the electrical system for this plant, we took into consideration the plant's ability to restart quickly in case it is stopped by either an accident or maintenance. In this design, a common bus bar of 3 units supplies the power source for the steam field system, which is typical of geothermal power generation. Even if 1 unit blacks out due to an accident, a power source for the well head system will be secured by a supply of power from the other unit.

Figure 1 shows a single line diagram of this plant.

(1) Shortening the startup time in a power grid failure

In case of a failure in the power grid, the step-up transformer CB (circuit breaker) must be opened so that in-plant operation will start. After the problem is resolved, the step-up transformer CB will be synchronized with and connected to the power grid. As a result, the time required to restart the plant is shortened.

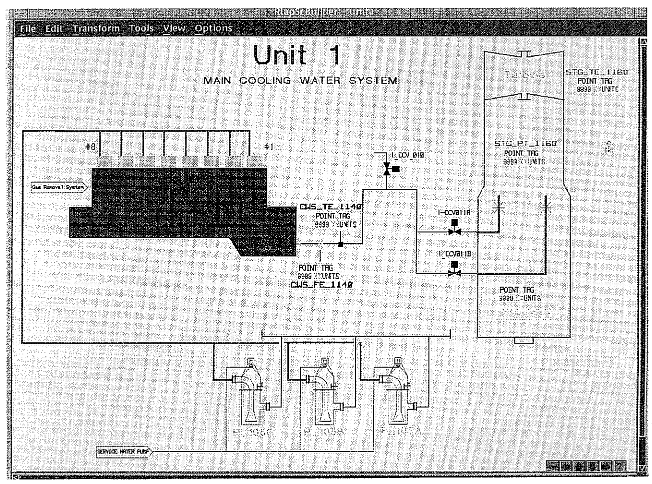
(2) No load and no excitation operation

If a fault such as an auxiliary transformer failure occurs, the generator CB must be opened so that the generator can be operated with no load and no excitation. The turbine has already restarted after the problem was resolved. The generator CB must be closed so the generator will be connected to the power grid. Then, the time necessary to restart the plant will be shortened.

(3) Ensuring a power source for a common bus bar

In the case of an auxiliary transformer fault, the auxiliary transformer CB must be opened. In this system, however, a power source for the important auxiliary equipment (including a source for the well head system) is secured by changing the destination of the power source supply from the common bus bar to another unit.

Fig.3 The plant's CRT screen of the DCS



3. Example of an Instrumentation and Control System for Geothermal Power Plants

3.1 Distributed Control System (DCS)

(1) Adoption of the DCS

The traditional bench-board type of control and monitoring panel was used for the Palimpinon Power Plant in the Philippines, which began operation in

1983.

For the Nasuji Site for the Palimpinon II Power Plant, which began operation in 1994, a data logger was adopted and monitoring by CRT became possible. For the Malitbog Geothermal Power Plant, scheduled to begin operation in 1996, the DCS is adopted. CRT monitoring and CRT operation will be possible.

The present trend is the use of CRTs in geothermal power plants. The DCS used in the Malitbog Geothermal Power Plant is a redundant calculating system.

The DCS is composed of the following equipment:

(a) CRTs for operation: 3 sets
(b) CRT for maintenance: 1 set
(c) Printers: 2 sets
(d) Hard copy: 1 set
(e) Duplex control equipment: 4 sets
(f) Transmission equipment with other systems (modem): 2 sets

Figure 2 shows the DCS configuration, and Fig. 3 shows an example of the plant's CRT screen.

(2) Data transmission

Underground geothermal steam is used for geothermal power generation. The wells surround the plant, and there are control and monitoring devices for the steam field system which manages the wells. The surrounding mountains are dotted with small geothermal power plants with a capacity of one unit. Devices for general monitoring of these plants have been set up.

Each type of data, such as plant generating power, is transmitted to the control equipment in the steam field system and to the general monitoring equipment in the central substation. The information contained in the DCS is directly transmitted via a modem (RS-485).

(3) Backup function

In cases where CRT operation by the DCS is adopted for a thermal power plant with a normal boiler, the plant's breaker switches are tripped when a failure in both systems of the duplicated DCS occurs. On the other hand, because in the case of geothermal power plants,

(a) there is few auxiliary equipment,
(b) there is no complicated control loop, and
(c) a higher plant operating factor is desirable,

this system is designed so that plant operations can continue in the event both systems of the DCS fail. Namely, it is designed so that backup operation of the main or auxiliary equipment is possible from the on-site control panel or the central operating room. The plant will not cease operation even when both systems of the DCS fail.

3.2 Steam flow detector

The pressure of geothermal steam is low. It is therefore necessary to hold the pressure loss caused by the main steam flow detector to a minimum. A venturi tube type of flowmeter has been used in the past. However, the total length of a venturi tube with a large diameter can be as long as 7 to 8 m. As a result, restrictions on installation space increase and costs are high.

Fig.4 Annubar-type flowmeter

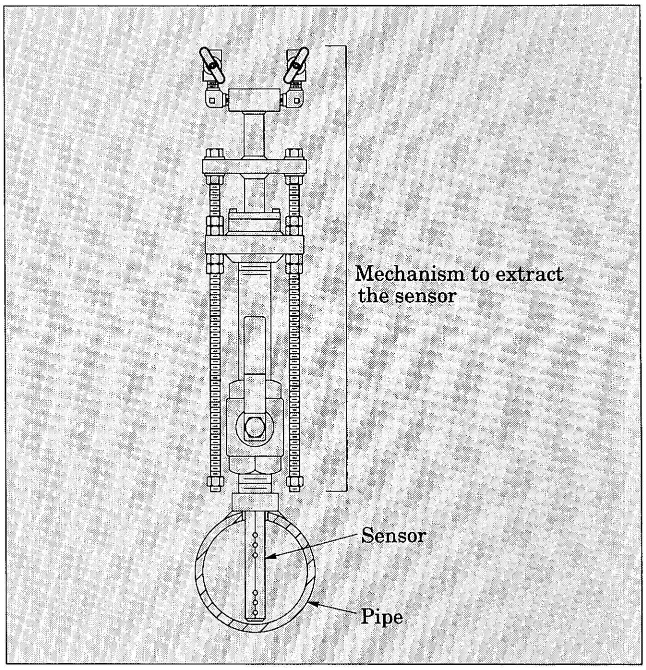
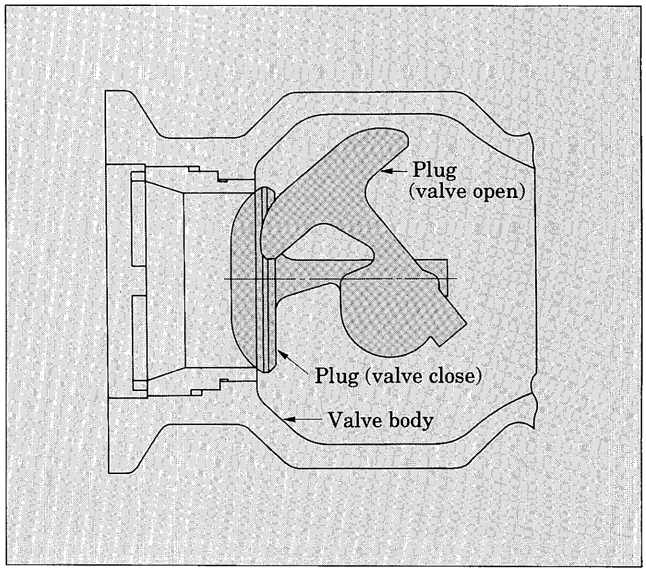


Fig.5 Cam-flex type control valve



In the Malitbog Geothermal Power Plant, an annubar type of flowmeter is used. With this type of flowmeter, a pipe is inserted into the fluid, detecting the pressure difference between the upper and lower reaches of the pipe as well as measuring the quantity of flow. Minimum pressure damage, reduced installation space and low costs have been realized.

Specifications of the flowmeter include:

(a) Type: DHF
(b) Fluid: geothermal steam
(c) Design pressure: 9.8 MPa/9.8MPa
(d) Design temperature: 184℃/184℃
(e) Design flow: 508t/h/20.5t/h

(f) Pipe size: 40 inches/8 inches {1,016mm/203.2mm}
(g) Quantity: 1 each per unit

Figure 4 shows the outline of the annubar-type flowmeter.

3.3 Control valve

(1) Water level control valve for the steam scrubber

A steam scrubber (scrubbing device) is installed in the main steam line of the Malitbog Geothermal Power Plant. This scrubber has a control valve for the drain water-level. This scrubber drain contains many impurities, which become scale, stick to objects like plugs inside the valve, and damage the sheet part when the valve is opened and closed. Therefore, we have adopted a cam-flex type control valve, in which the plug part moves eccentrically, reducing damage to the sheet part.

Specifications for this valve include:

(a) Type: 35000
(b) Fluid: condensed water
(c) Design pressure: 10.5MPa/10.4MPa
(d) Design temperature: 180℃/180℃
(e) Design flow: 139t/h/28.5t/h
(f) Valve size: 6 inches/2 inches {152.4 mm/50.8 mm}
(g) Quantity: 1 valve per unit

Figure 5 shows the internal structure.

(2) Water level control valve for the condenser

Generally, in geothermal power plants, when a direct contact type of condenser is used, the quantity of condensed water must be and the water level control condenser used must be large in size.

These are the specifications for the water level control valve in the condenser:

(a) Type: 7600
(b) Fluid: condensed water + circulating water
(c) Design pressure: 2.2MPa
(d) Design temperature: 46℃
(e) Design flow: 11,061t/h
(f) Valve size: 42 inches {1,066.8 mm}
(g) Quantity: 3 valves per unit

4. Conclusion

Because their unit capacity is relatively small and they are built in isolated mountain regions, unmanned Geothermal Power Plants are a necessity. This system is gradually being adopted in Japan.

In order to maintain unmanned Geothermal Power Plants and operate them safely and efficiently, it is necessary to improve:

(a) remote monitoring functions with the use of a robot to monitor the site;
(b) preventive maintenance functions with the use of equipment diagnostic devices; and
(c) remote controlling functions, such as automatic changeover to auxiliary equipment.

We at Fuji Electric will make a supreme effort in planning and design to achieve these objectives.