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REMOTE MONITORING AND CONTROL OF THE KAKKONDA GEOTHERMAL POWER PLANTS

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ABSTRACT

Geothermal power plants are generally sited in secluded and scattered mountainous areas where it is inconvenient for operation and maintenance personnel to reside. As there is less concern about safety in geothermal power plants due to their lower steam pressures and temperatures, and simpler plant systems and operation compared with fossil fuel thermal power plants, remote monitoring and control systems can be utilized.

At Unit No. 2 of Tohoku Electric Power Co., Inc.'s Kakkonda project there is a remote monitoring room in the town of Shizukuishi located 23 kilometers from the power station. Operation and maintenance personnel are usually in the remote monitoring room. Normal load operation and emergency shutdown can be carried out from the remote monitoring room. Start up and normal shut down operation must be carried out from the central control room of the power station. Maintenance personnel go to the power station for daily patrols and periodical testing. In case of abnormal plant conditions, the maintenance personnel immediately go to the power station for troubleshooting.

There are two independent communication lines between the power station and the remote monitoring room, which allow the remote monitoring and control of the unit. A remote monitoring console which has CRT's, recorders, alarm windows, control stations, and industrial television monitors is used for operation and monitoring from the remote monitoring room.

1. INTRODUCTION

Geothermal power plants, which utilize thermal energy of volcanoes , are often sited in secluded mountainous areas and it is very inconvenient or difficult for operation and maintenance personnel to reside near the plants. There is a need for remote monitoring and control from a remote monitoring room, which is more conveniently located , perhaps several tens of kilometers away from the geothermal plantsite. Until 1997 Japanese technical regulations for electrical facilities required that operation and maintenance personnel of a geothermal power plant reside at the site. However , remote monitoring and control was approved by exemption from the technical regulations , because there is less concern about safety compared with a fossil fuel thermal power plant for the following reasons.

a. Steam pressures and temperatures are relatively low and there is no threat of fire hazard caused by the steam.
b. Adopting an air-cooled generator, instead of hydrogen cooling, eliminates the possibility of hydrogen explosions.
c. Operation and maintenance of a geothermal power plant is easier than a fossil fuel thermal power plant, because it has no boiler and plant systems are much simpler than a fossil fuel thermal power plant.
d. A geothermal power plant is usually operated at full load and its operation and monitoring is simpler than a fossil fuel thermal power plant.

After deregulation in 1997, applying for the above exemption is not required on the condition that monitoring, control and protection system of a geothermal power plant satisfies some basic requirements. As a result, it has become easier to install a remote monitoring and control system at a geothermal power plant in Japan. Design concepts and technical features of a remote monitoring and control system at Tohoku Electric Power Co., Inc.'s Kakkonda geothermal power station unit No. 2 are presented.

2. OVERVIEW OF THE KAKKONDA GEOTHERMAL POWER STATION

The Kakkonda geothermal power station is located in Towada-Hachimantai national park in Iwate prefecture of Japan. It is located at an elevation of 720 to 740 meters above the sea level where up to 350cm of snow can accumulate in winter. The 50MW Unit No.1 was constructed in 1978 and the 30MW Unit No. 2 was constructed in 1996. Design features of Unit No. 2 are shown in Table 1. Unit No. 2 has a remote monitoring and control system. Unit No.1 has also been adopting remote monitoring and control since 1980. Its control system was replaced and upgraded in 1996 to have similar functions and features to Unit No. 2.

3. MONITORING, OPERATION, AND MAINTENANCE SYSTEMS AT UNIT NO.2 OF THE KAKKONDA GEOTHERMAL POWER STATION

In addition to a central control room in Unit No. 2, there is a remote monitoring room in the town of Shizukuishi located 23 kilometers from the Kakkonda power station. Fig. 1 shows the central control room of Unit No. 2 and Fig. 2 shows the remote monitoring room. An operator resides in the remote monitoring room 24 hours a day in three shifts, and performs operation and monitoring during normal load operation. The plant can be tripped from the remote monitoring room by the operator's action. Start up and normal shut down operations and emergency shut down operations are carried out from the central control room in the power station. Maintenance personnel reside in the remote monitoring room during normal working hours, and they go to

the power station for daily patrols and periodic testing of the power generation facilities. In case of abnormal plant condition such as an alarm, the maintenance personnel immediately go to the power station for troubleshooting upon receiving information on the abnormality from the operator. If they receive the information during night or on holidays, they also go to the power station as soon as possible. Table 2 shows a summary of monitoring, operation and maintenance systems at Unit No. 2.

4. FUNCTIONS OF THE REMOTE MONITORING AND CONTROL SYSTEM

There are two independent communication lines between the power station and the remote monitoring room, which allow the remote monitoring and control of the unit.

4.1 Monitoring From the Remote Monitoring Room

Major plant data are displayed on CRT's of a data processing computer and recorders on a remote monitoring console. The status of electrical breakers and pumps are displayed on the CRT's and indicating lamps on the remote monitoring console. Power generating facilities and surrounding areas are monitored by an industrial television (ITV) system.

4.2 Alarm Annunciation in the Remote Monitoring Room

All individual plant alarms are transmitted to the data processing computer and are displayed on the CRT's alarm list display. Grouped alarms are indicated on alarm windows on the remote monitoring console.

4.3 Operation From the Remote Monitoring Room

Manipulating load and reactive power control set points during normal load operation and emergency shut down operation is done from the remote monitoring console. Table 3 shows operation items in the remote monitoring room.

5. CONFIGURATION AND FEATURES OF THE MONITORING AND CONTROL SYSTEM

The configuration of the monitoring and control system of Unit No. 2 is shown in Fig. 3. The features of the system are as follows.

5.1 Control and Monitoring Equipment in the Power Station

Control Panel in the Central Control Room

Control switches and stations, alarm windows, indicators, recorders, and ITV monitors, which are necessary for all operations including start up, normal load and shut down, are installed in this panel.

Automatic Voltage Regulator System

The automatic voltage regulator (AVR) consists of digital controllers and has generator voltage control function.

Turbine Control System

The turbine control system is a digital electro-hydraulic control system (D-EHC). The major part of the system consists of dual redundant digital controllers. The turbine control system has the following major control functions.
- Acceleration control
- Line speed matching control
- Load control
- Inlet steam pressure control

In addition, this system has a supervisory sequence control function for automatic start up and shut down of the plant. Automatic start up and shut down is conducted in such a manner that the supervisory sequence control generates start and/or stop commands to the various components and lower level group sequences. The scope of start up automation is from the circulating and cooling water system start to the target load. The scope of shut down automation is from normal load operation to turbine trip and placing the turbine on the turning gear. Fig. 4 shows the outline of the automatic start up and shutdown.

Local Control System

The local control system consists of single-loop digital controllers corresponding to the following four control loops.
- Turbine gland steam pressure control
- Turbine bearing feed oil temperature control
- Condenser hotwell level control
- Generator cooling air temperature control

Air operated control valves are usually utilized in such local control of thermal power plants, however, electrical motor operated control valves are utilized at Unit No. 2 to reduce construction costs by eliminating an air compressor station.

Auxiliaries Relay Cabinet

Relay circuits in this cabinet implement the following discrete control and protective functions.
-Protective interlock logic
-Auxiliaries interlock logic
-Group sequences of the circulating and cooling water system start/stop, condenser air evacuation system start/stop
-Control of the number of operating cooling tower fans

Considering the remote monitoring and operation of the plant, the protective interlock function is reinforced. For example, automatic trips are implemented upon detection of fire or excessive seismic shocks.

Industrial Television (ITV) Control Cabinet

Four sets of television cameras are installed in the power plant. One for monitoring the turbine generator building floor, one for monitoring the central control room, and two for outside monitoring. Motion pictures are transmitted from the power plant to the remote monitoring room by way of optical fiber cable.

5.2 Control and Monitoring Equipment in the Remote Monitoring Room

Remote Monitoring Console

Devices necessary for remote operation and monitoring during normal load operation are installed on the remote-monitoring console. They include control stations for load control and reactive power control, grouped alarm indicators, CRT's of the data processing computer, ITV monitors, and emergency shut down push buttons.

Data Processing Computer System

The data processing computer system consists of a UNIX workstation based small-sized computer with peripheral devices of two CRT's, two printers, and a video copier. It receives approximately 60 analog and 200 binary plant data inputs, which are transmitted from the power station by a remote data transmission system. It provides functions such as plant status monitoring, performance calculations, and data logging. The major software functions are as follows.
- Graphical display of plant status
- Trending of plant data
- Alarm list display
- Performance calculations
- Cumulative calculations of running time of pumps
- Data processing and outputting daily operation reports

As the data processing computer system is installed in the remote monitoring room, it does not need anti-corrosion protection against hydrogen sulfide, which is common at geothermal power plants.

5.3 Remote Data Transmission System

Configuration of Data Transmission System

As shown in Fig. 3, master and slave stations are installed in the remote monitoring room and the power station respectively. Each station exchanges signals with control and monitoring systems and transmits the signals between the stations. There are two independent data transmission lines. One is an optical fiber line and the other is a power cable and communication cable carrier line. The optical fiber line is utilized as a back up system.

Technical Specifications of Data Transmission

Specifications of the data transmission are as follows.
- Cyclic data transmission
- Frequency modulation
- Data transmission speed : 600 bps
- Data transmission performance from the power station to the remote monitoring room is 200 binary signals every 3 seconds and 10 analog signals every 3 seconds for rapidly changing signals such as pressure or vibration. For slowly changing signals such as temperature or pH there are 50 analog signals every 15 seconds.
- Data transmission performance from the remote monitoring room to the power station consists of 10 binary signals every second for operation commands such as an emergency shut down. There are 2 analog signals every second for operation commands for load control settings.

6. FURTHER IMPROVEMENTS TO THE REMOTE MONITORING AND CONTROL SYSTEM

Remote monitoring and control is intended to achieve increased efficiency of operation and maintenance while maintaining reliability and safety of plant operations. The followings are major possibilities for further system improvements.

6.1 Reduction of Work Load of Operation and Maintenance Staffs in the Remote Monitoring Room

Duties of operation and maintenance personnel in the remote monitoring room are explained in section 3. To achieve more efficient operation and maintenance of the plant, incorporating the following items will be required.
-Remote operation of start up and normal shut down
-Reduced periodic patrols
-Preventive maintenance

To realize these improvements, the following expansions of the remote monitoring and control system are necessary.
-Extend the scope of automation to provide for easier operation.
-Reinforce the protective interlock.
-Reinforce the monitoring and alarm functions.
-Improve data transmission performance to accommodate the increased amount of data and real-time performance.
-Introduce a diagnostic data processing function to detect abnormal conditions in early stages.
-Introduce advanced equipment-monitoring systems utilizing television cameras, infrared sensors, acoustic sensors, and other sensors together with signal processing functions, which enable detailed monitoring, and diagnosis of equipment.

6.2 Optimization of Operation and Monitoring of the Overall Geothermal Power Plant

A steam supplier company and Tohoku Electric Power Co., Inc. jointly developed the Kakkonda geothermal power project. Operation and monitoring of the steamfield and its associated gathering system is currently performed separately from the power generation facility. A future project is optimization of the operation and monitoring of the overall geothermal power plant by cooperation with the steam supplier company. Integration of control and monitoring systems of steam production facilities and power generation facilities will accomplish this.

7. CONCLUSIONS

Design concepts and technical features of the remote monitoring and control system of Kakkonda geothermal power station Unit No. 2 have been presented. Similar systems are in operation at Kakkonda Unit No. 1 and two other geothermal power plants of Tohoku Electric Power Co., Inc. These remote monitoring and control systems successfully contribute to reliable and safe operation of the plants and increased efficiency of operation and maintenance.

REFERENCES

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Table 1. Description of Kakkonda geothermal power station unit No. 2

Commercial operation	March,1996
Power output capacity	30 MW
Steam condition	Turbine inlet steam pressure : 343 kPa Turbine inlet steam temperature : 147.5 °C
Steam turbine	Type: Single casing single flow straight condensing, impulse turbine Rated output : 30 MW Rated speed : 3,000 rpm
Generator	Type: AC synchronous generator Rating output : 33,400 kVA Excitation: Brushless excitation system Cooling: Air cooling

Fig. 1 Central control room of Kakkonda geothermal power station unit No. 2

Fig. 2 Remote monitoring room of Kakkonda geothermal power plant

Table 2 System of monitoring, operation and maintenance

Activities		System
Monitoring		Plant status is monitored by the CRT's, recorders, indicating lamps, and ITV monitors in the remote monitoring room.
Reporting		When an alarm is initiated, the operator reports this to maintenance personnel.
Operation	Startup and normal shutdown	Carried out from the central control room in the power station.
	Normal load operation	Megawatt and megavar setting can be done from the remote monitoring room.
	Emergency shut down	In case of abnormal conditions, the plant will be automatically tripped by protective interlock logic. The plant can be tripped from the remote monitoring room by the operator's action.
Maintenance	Periodical patrol and testing	Maintenance personnel go to the power station for daily patrols and periodic testing.
	Troublesho-oting against failures and alarms	Maintenance personnel go to the power station for troubleshooting.

Table 3. Operation items in the remote monitoring room

Operation items
(1) Generator load control setting
(2) Generator reactive power control setting
(3) Selection of load control mode (MW control / Pressure control)
(4) Load limiter position raise / lower
(5) Closing test of main stop valve
(6) Emergency shutdown of the plant
(7) Emergency stop of oil pumps
(8) Start of dry chemical extinguishing system
(9) High voltage circuit breaker and disconnecting switch open / close
(10) High voltage grounding switch open / close
(11) Selection of in service / out of service of reclosing device
(12) Generator circuit breaker opening

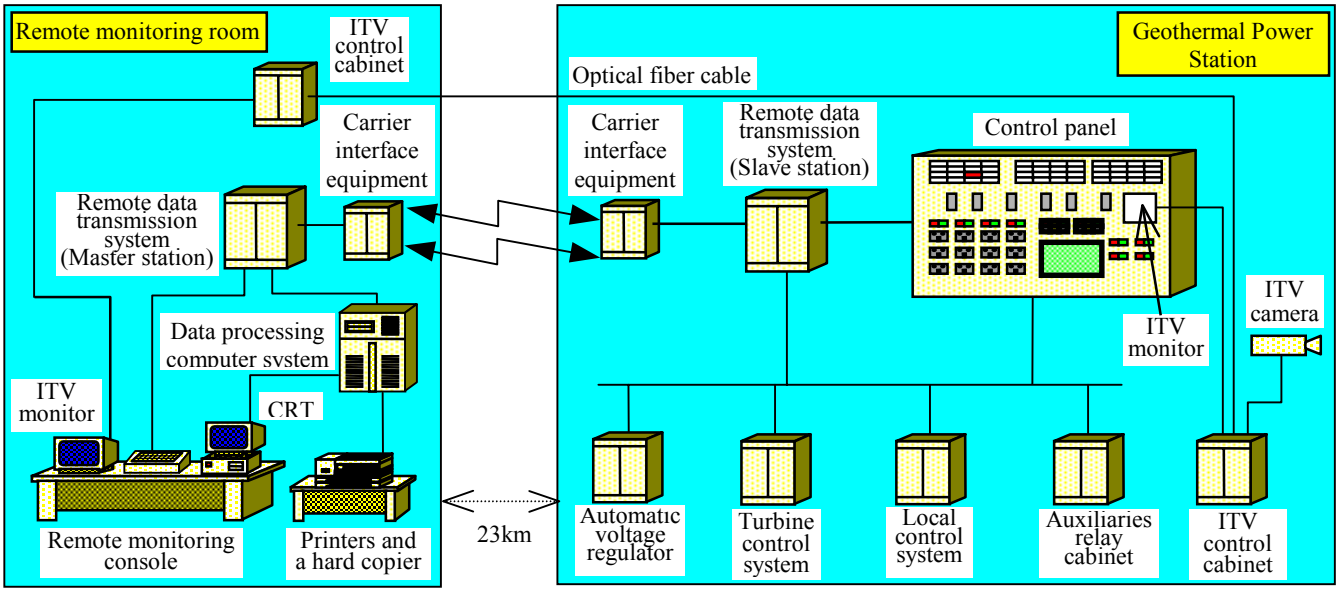

Fig. 3 Monitoring and control system of Kakkonda geothermal power station unit No.2

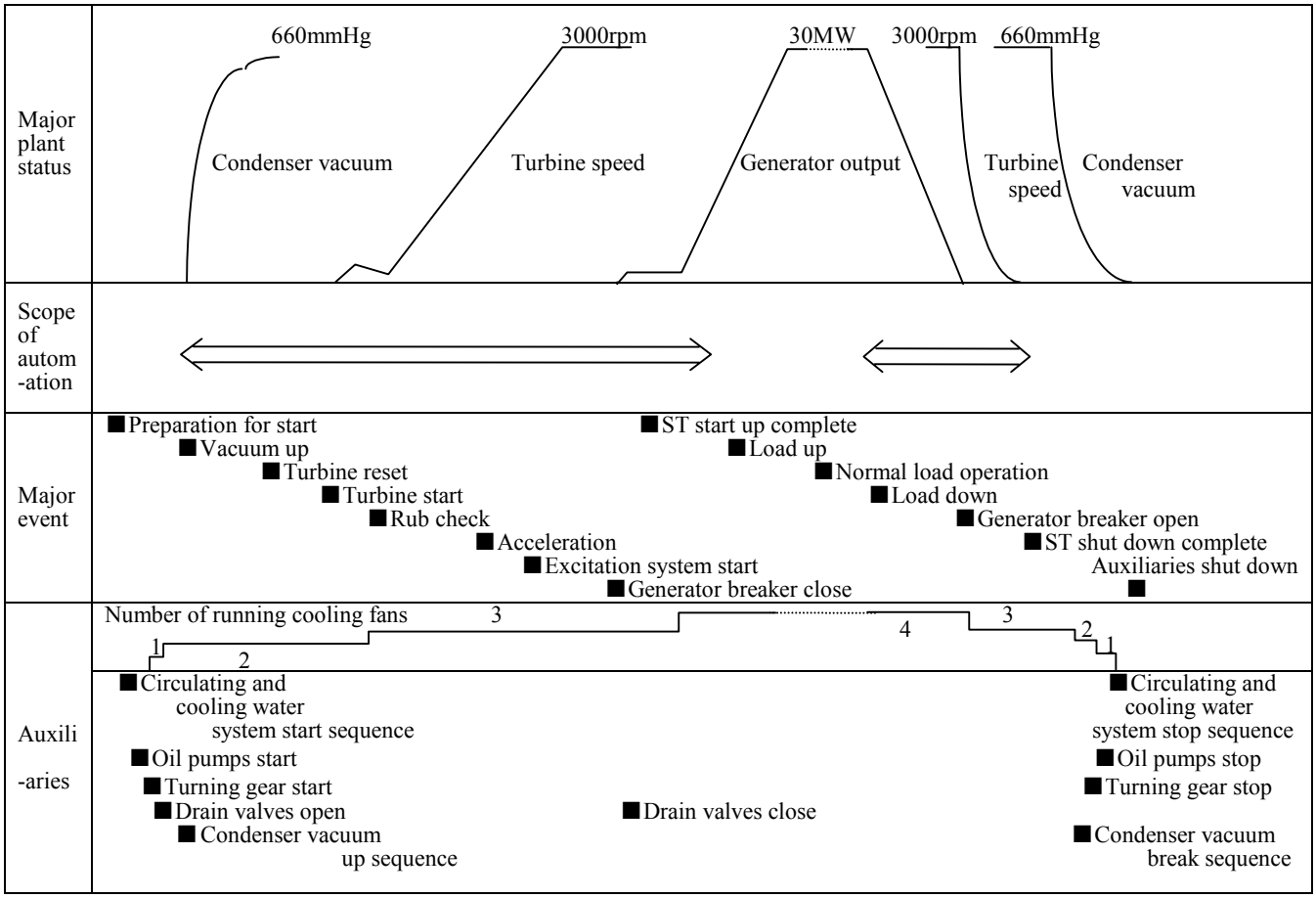

Fig.4 Automation of start up and shut down