Berlín Geothermal Power Plant

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1. Introduction

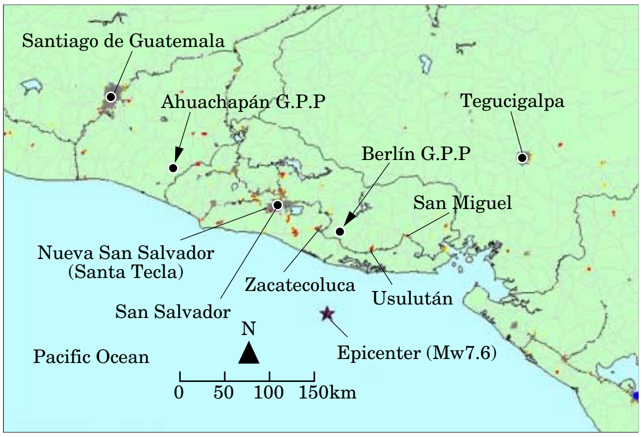
The Berlín Geothermal Power Plant is located in the province of Usulután, an eastern vicinity in the Republic of El Salvador, Central America. The plant area consists of 15km², is 107km away from the capital city of San Salvador (See Fig. 2), and is at an altitude of 645 meters above sea level. Geothermal resources at the Berlín area were originally explored in 1970's, but actual project development activities only began in the early 1990's. El Salvador has two existing geothermal complexes. One is Ahuachapán, located in the western vicinity of the country and consisting of three units with 95MW net capacity in total. The other is Berlín, where two 5MW wellhead units have been operational since 1992. This project is the second phase of development of Berlín Geothermal, following construction of the wellhead units. This is also the second project for Fuji Electric to provide equipment to El Salvador, more than 20 years after completion of the Ahuachapán Unit 3 (35MW, dual pressure unit) in 1980.

A turnkey contract was signed with the owner, Comisión Ejecutiva Hidroeléctrica del Río Lempa (CEL) in November 1996. After overcoming some natural obstructions, steam was successfully produced, and continuous power generation began in April 1999, The two units were officially put into commercial operation in November 1999.

After more than one year of continuous operation, the first major inspection was carried out in September and October 2000 for each unit respectively. During the inspection, no major problems were found in any of the plant systems and principal equipment.

Fig.1 Overview of Berlín Geothermal Power Plant, El Salvador

Fig.2 Map of El Salvador and location of Berlín



2. Summary of Contract Scope of Work

The basic contract scope includes the engineering, design, supply, procurement, construction and commissioning of 2 units of 28MW for the condensing power generation plant and its associated steam production system. This project involved the expansion of an existing geothermal plant with further future expansion possibilities, however since the new plant is located mostly in a remote field area, infrastructure related works were also included in the scope of work. To summarize, the following geographical area are in our scope of work:

(1) Power generation facility, consisting of 2 × 28.12MW units (Units 1 and 2)
(2) Grading/landscaping of area of future units
(3) 1.2km of access road from the junction of national road (Mercedez Umaña - Berlín Road) to the power plant
(4) Accumulation tank for condensate overflow from the cooling towers

(5) Steam separation system and fire water tank at Production wellpads TR-3, TR-4 and TR-5
(6) Cross-country cable ductworks between power plant, production wellpads and CEL's resource office at existing backpressure units
(7) Remote monitoring system of reinjection wellpads TR-1, TR-8 and TR-11
(8) 115kV switchyard equipment at Berlín and remote substations, 15 de Semtiembre S.S. and San Miguel S.S.

In conjunction with the engineering work, Fuji Electric supplied its own steam turbine and condenser units and procured all other equipment and material from various countries. The construction work was subcontracted to and carried out by local firms. For example, earthmoving and foundation works for the power plant, access road and accumulation tank (cold water condensate pond) were performed by Piassa, SA de CV, architectural and electromechanical works for the power plant were performed by Prinel SA de CV, and the steam production system was constructed by Monelca SA de CV.

3. Description of Each Plant Subsystems

3.1 Steam production system

In addition to existing production wellpads TR-2 and TR-9 which has been supplying steam to existing backpressure units (2 × 5MW), new production wells were drilled by CEL at wellpads TR-4 and TR-5. Our contract includes construction of 4 steam separators and associated piping systems at TR-4 and TR-5, which have a total of 8 production wells. The two phase fluid piping at the wellhead was designed to be routed through an underground channel so that future re-drilling or repairing of existing wells can be executed without removing large quantities of wellpad piping, and with minimum disturbance of production to that wellpad (See Fig. 3). The two-phase fluid is routed to separators (See Fig. 4) and separated steam is transported by 28-inch cross-country steam piping, one from the wellpad TR-5 to steam collector unit 1 located at the south boundary of the power plant at a distance of approximately 2.2km, and the other one from the wellpads TR-4, TR-2 and TR-9 to steam collector unit 2, at a maximum distance of approximately 1.7km. On the other hand, hot water from the separators is fed to reinjection wellpads TR-1, TR-8 and TR-11 also through miles of cross-country pipeline.

Located immediately downstream of each separator is a ball valve that protects the plant from water induction in case the separator should carry over hot water into the steam lines. At the power plant side, there are two steam collectors at the boundary, each equipped with pressure control valves, safety valve and rupture disc which connects downstream to a vent silencer.

The intent of this steam collector design is to maintain, to the extent possible, a constant steam flow in the cross-country pipeline, even if the steam flow to the turbine is interrupted due to tripping of the plant or load rejection.

3.2 Power generation plant systems

3.2.1 Steam turbine

The power plant has two identical steam turbine generator units each of which produce a total output of 28.12MW. The steam turbine has a single-flow top exhaust reaction type skid mounted design. It is also equipped with a blade washing system, allowing the injection of condensate water into the wheel chamber to remove deposits during load operation. The turbine is controlled by a triple-redundant microprocessor based Woodward Governor 509DCS, which has speed, load and inlet pressure control functions. It is also equipped with features that enable a quick response to runback and vacuum unloading situations. Main specifications of the turbine generator unit are summarized below.

(1) Steam turbine:

Fig.3 TR-5 wellhead

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Fig.4 TR-5 wellpad separators

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Type : single cylinder single flow, reaction condensing	
Rated output	: 28,120kW (condition A)
Maximum output	: 31,490kW (condition B)
Steam pressure	: 0.95MPa abs (condition A) 1.06MPa abs (condition B)
Steam flow	: 180t/h (condition A) 200t/h (condition B)
NCG in steam	: 0.4% in weight
Exhaust pressure	: 0.01MPa abs (3 inch Hg A)
Speed	: 3,600r/min
Number of stages	: 9 × 1
Length of last stage	: 581mm (22.9 inch)

(2) Generator:

Type : 3 phase synchronous, TEWAC	
Rated output	: 37,050kVA
Voltage	: 13.8kV
Power factor	: 0.85 lagging
Excitation	: brushless with PMG

3.2.2 Condenser and NCG removal system

The condenser is a low level direct contact type and its pressure is maintained at 0.01MPa abs by the non-condensable gas (NCG) removal system. The NCG removal system consists of two stages, two 100% capacity ejectors and two 100% capacity ejector cooling water pumps. The extracted NCG from the after-condenser and gland steam ejector condenser is led to the cooling tower.

3.2.3 Circulating water system

The circulating water system consists of two 60% capacity circulating water pumps which discharge condensate from the condenser hotwell to the cooling towers. The cooling towers have 3 cells per unit and are of the counter flow type with splash fill design.

3.2.4 Auxiliary, fire and potable water system

The plant's internal cooling water, the secondary cooling water, is fed to all of the internal subsystems, such as the turbine lube oil cooler, generator air cooler, compressed air system, air conditioning system, etc., and is cooled by the primary cooling water system through a plate type heat exchanger. While the source of water for the primary system is cooling tower water, potable water is used for the secondary cooling water system. Due to the local climate, with its clearly separated rainy and dry seasons, the city water supply from the foothills of Berlín area becomes critical during the dry season and may potentially be interrupted. To offset such risks, a 400 cubic meter capacity fire water tank was installed at a vacant space near production wellpad TR-3, whose elevation is 300m higher than that of the power plant. The power plant fire protection water and potable water are supplied from this tank through an underground pipeline.

3.3 115kV substation

The Berlín Power Station is connected to two transmission lines, one is routed to the 15 de Septiembre Substation and the other is routed to the San Miguel Substation. The Berlín Substation consists of two circuit breakers at the main transformer side, two circuit breakers at the line side, and one tie circuit breaker. Each circuit breaker, except the tie circuit breaker, has line and bypass disconnect switches.

Fig.5 Turbine and generator

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Fig.6 Turbine sectional view

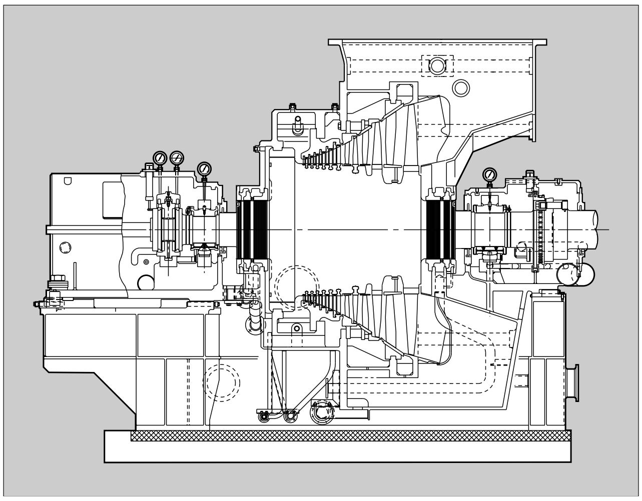

Fig.7 Spray jet condenser

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Redundant protection from transmission line failure is provided by conventional protection relays and a teleprotection system.

All operational conditions and status of the generator's main circuit and substation are also transmitted via the remote terminal unit to a national dispatch center in San Salvador.

Fig.8 Berlín Substation

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3.4 DCS and plant operation/control system

All plant operational conditions including those of the production and reinjection wellpads are monitored by DCS. The DCS itself is a fully double redundant configuration, but in addition to DCS, a PLC-based auxiliary service panel is also provided as a backup in order to realize bumpless transfer of all critical control functions. In other words, operation can be continued without tripping of the plant even if the entire DCS system fails. Pressure control of the steam/water separator and level control of the water tank at production wellpads can be controlled by either the plant's DCS, or by the backup PLC located at each wellpad, which also has the function of providing bumpless transfer whenever DCS control fails. The DCS system also consists of six operating stations: three in the control room, one in the superintendent's room, one in the operation chief's office (both of these rooms are located in the administration building in the power plant), and one in CEL's resource office (located at the 2 × 5MW pilot plant approximately 1km away from the power station).

Fig.9 Power generation plant layout

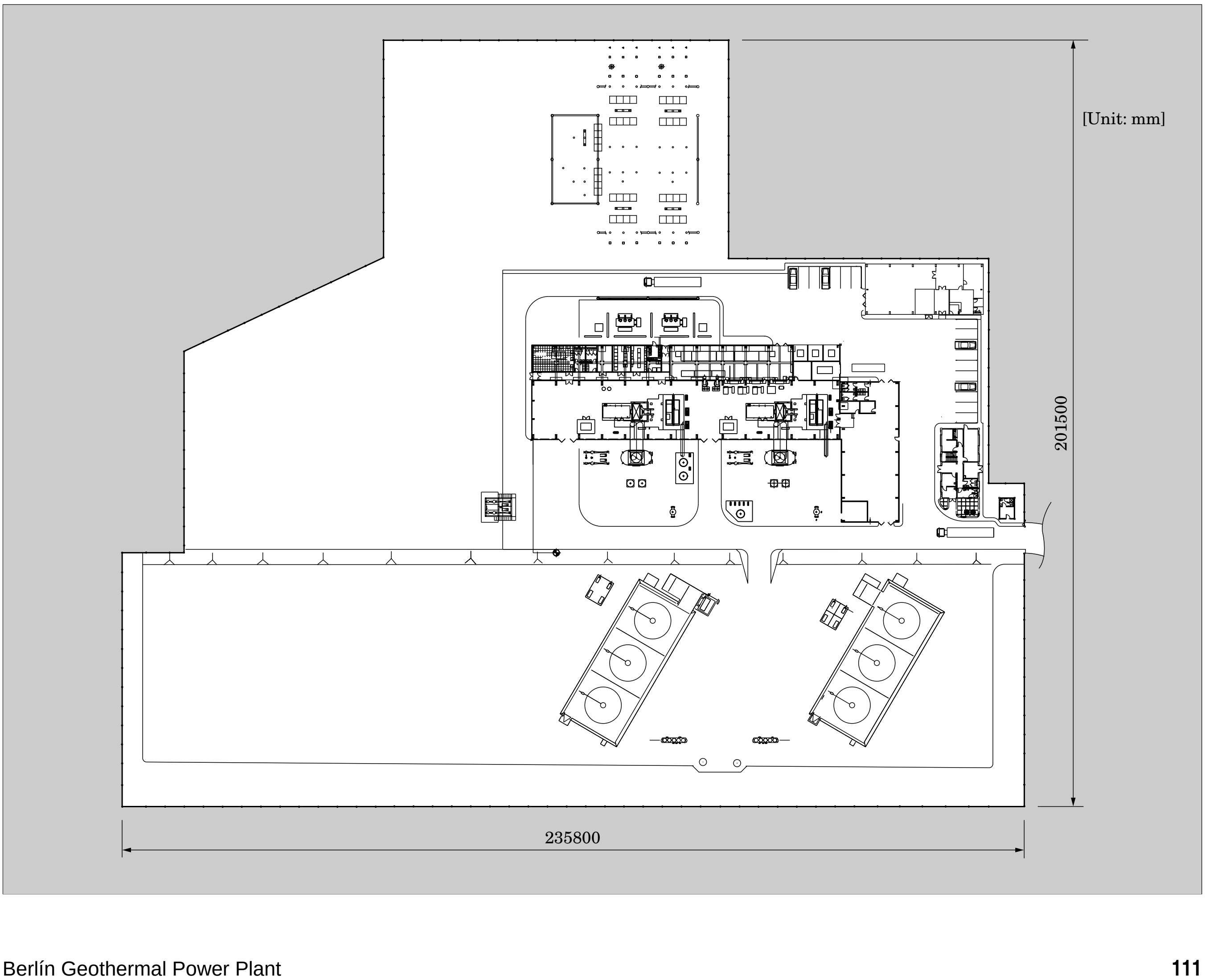

Fig.10 Plant control room

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Fig.11 Reinjection wellpad

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3.5 Reinjection system

All hot water from the 4 wellpad separators is led to reinjection wellpads through a cross-country water pipeline and is continuously reinjected. To confirm secure operation of the production wellpads, the flow and pressure of the reinjection line at each reinjection wellhead are continuously monitored. Because of the remoteness of the reinjection wellpad area, the monitoring panels at reinjection wellpads are powered by solar panels and all data is transmitted to the DCS in the plant control room via a radio frequency system. On the other hand, monitored data at production wellpads is transmitted to the plant's DCS via hard-wired lines.

4. Construction and Commissioning

The construction work was subcontracted to local firms. Other contractors were also working throughout the Berlin geothermal area, such as cross-country piping installation contractors, transmission line construction contractors, O&M personnel camp facility building contractors, etc. All of the interfaces and potential conflicts between the parties were well coordinated by CEL field personnel.

During execution of the construction work, we had to overcome several natural difficulties.

First was the rainy season in 1997. Civil works such as ground breaking work in the power plant area and the access road were started in early 1997, the year remembered for the "El Niño phenomenon". Although the rainy season in El Salvador normally ends in October or November, the rainy season in 1997 was extremely severe and long, lasting until the beginning of the following year.

Second was the discovery of an enormous underground layer of solid rock in the power plant area, whose volume was approximately 21,000m^3 just in location of the plant building and equipment foundation area. During the excavation work, a tremendous amount of dynamite was used to blast this solid rock layer.

Third was the assault of Hurricane "Mitch" in November 1998. This hurricane killed hundreds of people nationwide in El Salvador, and plant construction work was forced to slowdown due to water/electricity outages, the non-availability of transportation for worker commuting, etc. Physical damage to the construction site was minimal, however.

All of these difficulties were overcome minimum impact on the schedule, due to the coordination and determined effort by CEL and local subcontractors.

The schedule also had to be coordinated with drilling activities. The new production wells at TR-4 was drilled in mid-1998, and wells at TR-5 were drilled from late 1998 to early 1999. Accordingly, the construction work at wellpad TR-4 was started after the completion of drilling and flow testing in late 1998. When the Unit-1 commissioning test was completed in May 1999, TR-5 construction had not yet started. Therefore, Unit-1 was halted and the steam from TR-4 was then diverted to Unit-2 for commissioning. TR-5 construction work finally started in July 1999 and TR-5 began producing steam in November 1999, when the two units became operational.

5. Conclusion

Geothermal power generation is one of the most proven, reliable and environmentally safe alternative energy sources. Fuji Electric continues to contribute its efforts in providing efficient and reliable geothermal power plants throughout the world. In the course of constructing the Berlín Geothermal Plant, we received tremendous and professional support from the owner, CEL, and from geothermal division company GESAL (Geotérmica Salvadoreña S.A. de C.V.) personnel, to whom we sincerely indebted. Fuji Electric looks forward to opportunities for participation in the next phase of the Berlín geothermal project or in other geothermal projects in El Salvador.

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