Los Azufres II

A New 100-MW Geothermal Power Project Starts Operations Near Morelia, Michoacán in Central Mexico

By Dr. Gerardo Hiriart – Comisión Federal de Electricidad, Mexico City, Mexico

The Comisión Federal de Electricidad (CFE) recently commissioned an important new geothermal power plant in Central Mexico—Los Azufres II. It consists of four independent 25-MW units, fueled by 14 production wells. Three deep wells are used for injection of brine back to the geothermal reservoir. Technical and economic features of the project are provided in this article.

The Beginning

Los Azufres owes its name to small and scarce deposits of native sulphur around some of the field's natural geothermal manifestations. The field lies at 2,800 m above sea level, surrounded by a pine forest in the State of Michoacán, 90 km east of Morelia (Fig. 1). Exploration studies at Los Azufres started in 1975, and the first exploration well was drilled in 1976. The first power units were commissioned in 1982, consisting of five 5-MW back-pressure turbines strategically located across the geothermal field.

In 1987, CFE installed a 50-MW condensing unit in the southern part of the field, known as the Tejamaniles Zone. Four additional 5-MW wellhead backpressure turbines were installed later. CFE also installed two 1.5-MW binary-cycle power plants to use rejected heat associated with separated fluid from some of the production wells. With almost 100 MW of generation capacity at Los Azufres, enough information was collected to review the behavior of its reservoir, and to develop a new model for prediction of the field's incremental capacity. Current installed geothermal power capacity at Los Azufres—including the four Los Azufres II units—is 188 MW (Table 1).

Backpressure Turbines

CFE has extensively used 5-MW wellhead backpressure turbines to test the evolution of the Los Azufres geothermal reservoir (gas content, enthalpy, geochemical characteristics, injec-

tion well behavior, scaling and corrosion). These units do not have condensers, cooling towers or gas-extraction equipment. Thus, they can be easily transported to another site in the field, or moved to a different field (like Los Azufres Unit 8, which was moved to the Los Humeros Geothermal Field). The units can even be transported to another country to test new wells, with expenses paid by monetary resources gained from power generation during the tests. CFE has done this in Costa Rica and Guatemala, and plans such testing soon in Bolivia.

Backpressure turbines are less efficient than condensing turbines. They demand 12 tons of steam per megawatt-hour (MWh), compared to around 8 tons per MWh required for condensing turbines. But when used for testing new wells they are very attractive in an economic sense, since each 5-MW unit can generate up to 40 gigawatts-hour (GWh) in one year. This equates to $1.5 million (US) in power sales, enough to pay for the equipment in two to three years.

Los Azufres II Development Strategy

According to CFE's evaluation of the Los Azufres geothermal reservoir, more than 100 megawatts could safely be installed, providing steam for more than 30 years. In a complex volcanic field like Los Azufres, however, production prediction for every new well is problematic, because their ultimate output might range from 0 to 100 tons of steam per hour (t/h).

CFE's strategy was to install 100 MW (net) divided into four identical power plants of 25 MW each (Fig. 2). Unit 13 of the project was installed in the Tejamaniles Zone next to the present 50-MW condensing unit. From this unit all others in the project are remotely controlled. CFE decided to locate units 14 and 15 in the Marítaro (north) Zone, and Unit 16 in the El Chino Zone, in the central part of the field.

Each new power plant shares its steam with one or more backpressure generating units. In this way, if steam output from a new well is less than predicted, supply for the new condensing power plant can be taken from the less-efficient back pressure turbine(s). The time has come at Los Azufres, however, to use only condensing power plants. Backpressure equipment should be moved to the periphery of the field or sold, as CFE recently did with Guatemala (Unit 1).

Size of the Los Azufres II Units

There were several reasons CFE chose 25 MW as its standard size for power units at geothermal developments in Mexico. For the Los Azufres II project, these include:

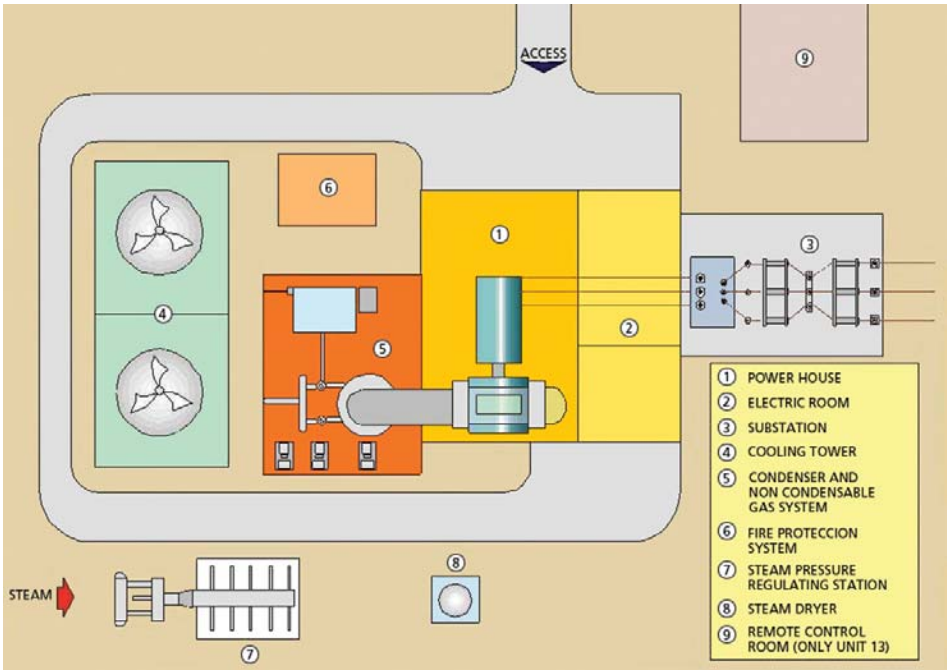
- Installation of a power plant without a concrete pedestal to place the turbine on top of the condenser reduces costs and construction time. Instead, the condenser is located alongside the turbine at almost the same level. Exhausted steam from the turbine is sent to the condenser through a very large stainless steel pipe. The largest plant that can be constructed under this scheme, without substantial exhaust loss, is approximately 28 MW.

Table 1. Present Power Units at the Los Azufres Geothermal Field

Unit	Type	Capacity (MW)	Constructor
2	Backpressure	5.0	Mitsubishi
3	Backpressure	5.0	Mitsubishi
4	Backpressure	5.0	Mitsubishi
5	Backpressure	5.0	Mitsubishi
6	Backpressure	5.0	Toshiba
7	Condensing	50.0	GE
9	Backpressure	5.0	Ansaldo
10	Backpressure	5.0	Ansaldo
11	Binary cycle	1.5	Ormat
12	Binary Cycle	1.5	Ormat
13	Condensing	25.0	Alstom
14	Condensing	25.0	Alstom
15	Condensing	25.0	Alstom
16	Condensing	25.0	Alstom
		Total 188.0 MW	

Figure 1. Location of the Los Azufres Geothermal Field in Michoacán State, near Morelia.

Figure 2. Schematic design of 25-MW units at the Los Azufres II Project.



CFE

Well rig drills for fresh geothermal resources to fuel the Los Azufres II Project.

- The usual practice with geothermal turbines is to avoid stress-corrosion failures. This parameter limits a single-flow turbine to approximately 28 MW.
- With four units at the Los Azufres II project, unexpected failure or programmed maintenance at one of the power units shuts down only 25 percent of total generating capacity.
- The rough topography and soil characteristics at the Los Azufres Geothermal Field do not permit long pipe networks for the steam gathering system.
- The unit price of the four 25-MW units at Los Azufres, compared to only one with pedestal for the turbine, is only a few percent higher (learned by CFE at the Cerro Prieto IV project).

Technical Characteristics

In its international request for proposals (RFP), CFE specified desired characteristics of the four 25-MW power plants at the Los Azufres II project, defining steam quality, maximum available steam, climate conditions, maximum permitted noise level, and gas concentration at floor level (Fig. 2). Winning bids included delivery and installation of the following:

Turbine: Single flow, impulse (most), upper exhaust, 3,600 rpm, manufactured by Alstom.

Generator: Air cooled, synchronous, 3,600 rpm, 4,160 volts, manufactured by Alstom.

Condenser: Direct contact, stainless steel cladding, manufactured by Ecolaire.

Gas extraction: Hybrid, ejectors, and water ring vacuum pumps.

Steam pressure: Inlet 8.0 bar (absolute), exhaust 3.0" Hg, quality 99.99%.

Non-condensable gases: 1.5% in three units, 2.5% in the fourth.

Vacuum system: Manufactured by Nash Kinema.

Cooling tower: Counter-flow, four cells, PVC filling.

Power output: 27.5 MW gross, 25.0 MW net.

Steam consumption: at design average wet-bulb temperature (19 ℃): 7.8 tons/MWh.

Project Bidding Process

The Los Azufres II RFP was published under the above specifications, asking for a complete set of parts, one well-equipped repair shop, and a one-year warranty. Five proposals were received. Alstom Power (France) was the winner with the lowest offered price. Requested construction time in the contract was 24 months for the first unit, and 25, 26 and 27 months for the following units.

Financial Scheme

As a 100-percent government-owned company, CFE chose a financial arrangement called "Financed Public Work" (Obra Pública Financiada, OPF) for the Los Azufres II project. Under this scheme, Alstom financed the project during the construction period, taking all risks. After the turnkey project successfully passes acceptance tests, CFE will pay the price of the complete operation to the contractor and take on the risks of power plant operation and maintenance (O&M). CFE will acquire inexpensive loans for O&M, effectively negating further project risk.

An important consideration for the Los Azufres II project was the drilling of additional wells required by the new power plants. This part of the project, Phase B, was contracted under the same Financed Public Work scheme used for the power plants. Only five new wells were needed to augment excess steam from existing power units. After the wells were completed, CFE shouldered fi-

nal production risk. With high-quality work by the drilling company and the expertise of CFE engineers who know the field quite well, the expected amount of steam was secured.

Project Economics

For projects like Los Azufres II, in which the turnkey power plants cost less than $1,000 per installed net-MW, payback time was very attractive. If only the five new wells are considered in the balance of the investment, the cost of the project's power, including O&M, is below 3¢ (US) per kilowatt-hour (kWh). If all installations and expenses related to the 100-MW project are considered, the cost of power generated remains at a low 4¢ (US) per kWh.

Project Advantages

The Los Azufres Geothermal Field is located only 250 km from Mexico City (Fig. 2). The Los Azufres geothermal power plants contribute to the nation's total energy supply, and help raise and sustain the voltage and stability of the electric power grid. Since the geothermal field lies at 2,800 m above sea level, its power units do not consume cooling water that might otherwise be used for irrigation. In addition, the Los Azufres II power plant units do not emit combustion gases, which makes it possible for CFE to secure additional revenues in the future by selling carbon credits for the reduction of greenhouse gas emissions.

The Los Azufres geothermal reservoir, lying close to large urban areas like Toluca and Mexico City, has a large volume of thermal energy. The only clean and economic way to use that energy for generating electricity is through the expertise of CFE technical personnel, and with the invaluable assistance of colleagues we have met during many years of working closely with the Geothermal Resources Council. ■