Geothermal turning up the heat at the Los Humeros geothermal field, Puebla, Mexico

Luis Jaime Martínez Toledo
Alstom Mexicana, SA de CV, Morelia, Mich., México.
Correo: luis-jaime.martinez@power.alstom.com

Abstract
Geothermal power is a highly reliable source of base load, renewable power. This is a feature that utilities, looking to increase their share of renewables in the energy mix while maintaining secure supply, will no doubt find attractive. Despite the relatively high installation costs for a direct-cycle geothermal power plant, the high capacity factor in operation results in a competitive levelized cost of electricity, even when taking into account the cost of drilling the wells and building the steam collection system. In May and December 2009, CFE awarded Alstom contracts to build two 25-MW power plants in the Los Humeros geothermal field, located in the state of Puebla, Mexico, 225 km southeast of Mexico City. When they begin operation, the two plants --known as Los Humeros II, Units 9 and 10-- will produce more than 400 GWh annually of reliable, clean electricity, enough to power 100,000 homes in the Puebla state. This paper presents the main features of the Units 9 and 10, currently under construction.

Keywords: Los Humeros, geothermal power plants, Units 9 and 10, turbine characteristics, condenser.

La geotermia aumenta el calor en el campo geotérmico de Los Humeros, Puebla, México

Resumen
La energía geotérmica es una fuente renovable altamente confiable de carga base. Esta es una característica que las compañía eléctricas, que buscan incrementar su cuota de energías renovables en su portafolios sin comprometer la seguridad del abastecimiento, sin duda encuentran atractiva. A pesar de los relativamente altos costos de instalación de una planta geotermoeléctrica de ciclo directo, su alto factor de planta en operación resulta en un costo nivelado de generación competitivo, aun tomando en cuenta los costos de perforación y de la construcción del sistema de vaporductos. En mayo y diciembre de 2009, CFE adjudicó contratos a Alstom para construir dos plantas de 25 MW de capacidad en el campo geotérmico de Los Humeros, ubicada en el estado de Puebla, México, 225 km al sureste de la Ciudad de México. Cuando empiecen a funcionar, las dos plantas --conocidas como Los Humeros II, unidades 9 y 10— producirán más de 400 GWh anuales de electricidad confiable y limpia, suficiente para abastecer a 100,000 hogares en el estado de Puebla. Este artículo presenta las principales características de las unidades 9 y 10, actualmente en construcción.

Palabras clave: Los Humeros, plantas geotermoeléctricas, unidades 9 y 10, características de la turbina y del condensador.

Introduction

Mexico-Geothermal power is a highly reliable source of baseload, renewable power. This is a feature that utilities, looking to increase their share of renewables in the energy mix while maintaining secure supply, will no doubt find attractive.

Despite the relatively high installation costs for a direct-cycle geothermal power plant such as Los Humeros, the high capacity factor in operation results in a levelized cost of electricity in the region of $58 to $93/MWh, even when taking into account the cost of drilling the wells and building the steam collection system. This makes geothermal comfortably one of the most cost-effective forms of generation available today.

Mexico's Comisión Federal de Electricidad (CFE) is one such utility that is taking advantage of its geothermal resources. In a market that stood at around 9.7 GW worldwide in 2007, Mexico is the fourth largest geothermal energy producer worldwide after the U.S., the Philippines and Indonesia.

CFE operates a total installed capacity of 58.2 GW, of which 964.5 MW is geothermal; a figure that is poised to increase still further.

In May and December 2009, CFE awarded Alstom contracts to build two 25 MW power plants in the geothermal field located in the Puebla state of Mexico, 225 km southeast of Mexico City.

When they begin operation, the two plants-known as Los Humeros II Units 9 and 10-will produce more than 400 GWh annually of reliable, clean electricity, enough to power 100,000 homes in Puebla state.

Under terms of the contract, Alstom will supply the complete engineering, procurement and construction (EPC) services for the power plants including the steam turbine, air cooled turbo-generator, turbine control and distributed control system.

Mexico Starts the Wave

Los Humeros II is Alstom's second project since its recent return to the geothermal market. With products and plants for both the 50 Hz and 60 Hz markets, Alstom has its sights set on being a global player. It is looking at projects in countries like Indonesia, The Philippines, Chile, Kenya and the U.S., as well as the rest of Europe and Africa.

Mexico is an important and growing market for power of all types, including renewables. In the past, CFE contracted Alstom for several geothermal plants including the building of four 25 MW units at the Los Azufres geothermal power plant in Michoacán state in 2000 and the supply of two 5 MW units to the Las Tres Vírgenes geothermal power plant in Baja California Sur in 1998.

The 50 MW from Los Humeros II units 9 and 10 will add to the existing 40 MW produced from eight, 5 MW plants installed at the Los Humeros field 10 years ago.

Los Humeros is one of four geothermal fields under exploitation in Mexico. It is located in the central-eastern portion of the country, within the Mexican Volcanic Belt, near the Gulf of Mexico. It is one of four geothermal fields, the other two being Cerro Prieto, in the state of Baja California, Los Azufres in Michoacan state and Las Tres Vírgenes in Baja California Sur state. The largest of these is Cerro Prieto with a capacity of 720 MW.

CFE is currently performing work to prove the further potential of the Los Humeros field. If there is sufficient reservoir potential, it is expected that they will extend the capacity in the area within the next five years. The new power plant is being built at a capital cost of close to $110 million.

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Types of Geothermal

Geothermal resources are concentrated near tectonic plate boundaries where the Earth's crust is thinner. Geothermal electricity is power generated using hot water and steam found in layers of impermeable rock near these tectonic boundaries. Using drilling technology developed by the oil industry or natural conduits such as geysers, geothermal plants can access this heated water and use it to power a steam turbine to generate electricity.

There are three main types of geothermal plants. The most common in operation today is a flash steam plant. This design pulls deep, high-pressure hot water into lower-pressure tanks and uses the resulting flashed steam to drive turbines. Flash steam plants require fluid temperatures of at least 150°C, often more, and are the type used at Los Humeros.

The second type is a dry steam plant, which is the simplest design since it directly uses geothermal steam of 150 C or more to turn turbines without the need for flashing equipment. These two are the oldest types of commercial geothermal power plants, and are sometimes called direct-cycle type since they expand the steam directly through the turbine.

The third type of geothermal power plant is called binary or indirect cycle power plants. Such plants are a more recent development and can accept fluid temperatures as low as 57°C. A secondary fluid that has a much lower boiling point than water passes the moderately hot geothermal water. This causes the secondary fluid to flash to vapor, driving the turbines.

Power Plant Design

Los Humeros II uses the geothermal steam extracted from wells drilled to a depth of 1,500 meters or more. CFE has overall responsibility for drilling these wells and installing the pipes that carry the steam of a specified pressure and mass-flow to the boundary of the power plant. From there, Alstom has full responsibility for supplying all equipment, building and plant commissioning. This responsibility does not end until final acceptance, which follows a one-year warranty period after issue of the provisional acceptance certificate (PAC).

Geothermal power plants have their own specific design and construction challenges when compared to conventional steam plant.

Steam is supplied at about 200 tons per hour (t/h) and at a pressure in the region of 8 bar. Typically, geothermal wells maintain a fairly constant steam flow and pressure with only long-term fluctuations, which means the plant is well suited to operating like a conventional base load plant. Just like an oil well, however, steam pressure and mass flow from the reservoir can reduce over time by around 10 to 25 percent causing a corresponding reduction in power output. To some degree this can be compensated for by drilling additional wells, re-injecting used geothermal fluids into the reservoir and implementing an effective regime of well maintenance, including scale removal. With these techniques, a properly managed and planned geothermal reservoir can expect to produce a steady output for the lifetime of the power plant.

With the volume of steam from the well remaining fairly constant, there are usually no special design considerations with regard to steam flow and turbine size. However, the amount of gas in the steam does present a challenge.

Geothermal steam can be aggressive. It contains around 3 percent gas, about 90 percent of which is carbon dioxide (CO_2), 2 to 3 percent hydrogen sulfide (H_2S), plus small amounts of ammonia, which is corrosive to the steam turbine and pipework. This means conventional steel cannot be used in parts of the plant that are exposed to steam. Therefore a large proportion of the steel used in the Los Humeros II plants, particularly for pipework and the condenser, is stainless steel.

The aggressive nature of the steam also has to be taken into account in the turbine design. Unlike the existing 5 MW backpressure units, the new steam turbines will be condensing units. These feature a seven-stage turbine where the first five stages are of impulse design with the two last stages using specialized three-dimensional blade forms that present aerodynamically optimized surface contours for increased efficiency prior to the exhaust.

Certain parts of the turbine have to be protected from corrosion that can be caused by H_2S and other fluids, such as sodium chloride, in the gas-steam mixture. Mitigation measures are also applied to prevent potential erosion which can occur due to microscopic water droplets in the steam. For example, the rotor seals are coated and the last stage blades are induction hardened.

Los Humeros II has a hybrid gas extraction system consisting of ejectors and vacuum pumps to remove geothermal gases and prevent them from building up inside the condenser and reducing performance. The condenser is a direct contact condenser, specially designed for geothermal applications. The top exhaust from the turbine has a crossover going into the top of the unit. Unlike conventional plants, the condenser is almost entirely made from stainless steel. The condenser, supplied by SPX-Yuba from the United States, uses technology licensed from the U.S. government that was co-developed by Alstom in the late 1990s. Cooling is provided by standard wooden and fiberglass counter-flow cooling towers with PVC packing.

The other challenge is that no two geothermal sites are the same. In a conventional plant it is straightforward to control the size of the boiler, allowing the size of the turbine to be accurately determined.

A geothermal plant has to be designed according to the amount of steam that is available from the reservoir. Turbine designs, therefore, have to be flexible to cover a large potential range of steam pressures and mass flows. While this is not a great technical challenge, it does present issues for the supply chain and logistics, especially where a standard product might otherwise reduce cost and lead-time.

Local Content

In accordance with CFE's request to have as much local manufacturing content as possible, a significant portion of the components is procured from local sub-suppliers. Approximately 50 percent of all the components and materials for the steam turbine, valves and auxiliaries were sourced from a Mexican supply chain. In addition, the cooling towers, transformers and switchyard were also all sourced from local companies.

Notably, the turbine is being manufactured at Alstom's local manufacturing facility in Morelia, Michoacán state. The key components manufactured or machined in the Morelia factory include: LP ITB rotor blades 1 to 15; LP rotor; LP outer casing; gland casings front and rear; LP ITB stator blades rows 1 to 7; diaphragms LP 1 to 7; pedestals front and rear (and covers); journal bearings; LP module assembly; full steam turbine assembly; and regulation valve assembly.

It is the first time that some of this work has been undertaken in Morelia, representing a transfer of technology from Birr, Switzerland and Elblag, Poland. Valve assembly, which is almost now complete, took place in the Mexico factory as well as machining of the last two stages of the rotor.

On Schedule

So far manufacturing is progressing smoothly along with plant construction. At the end of 2010, Unit 9 was more than 90 percent complete. Cold commissioning was set to start by Jun 15, 2011. Hot commissioning was set to begin of Sept 11th with final completion scheduled for October 2011.

As of this writing, the cooling towers are finished, silencers, vacuum pumps and the condenser have been installed and the generator is in place. The turbine arrived on site in mid-December 2010. By then the switchyard was finished. The transformer was expected to reach the site by February 2011.

Contracts for the two units were signed seven months apart and unit 10 is more than 65 percent complete, with all main civil works already finished. The generator will arrive during the first week of February 2011 and delivery of the turbine is expected by the end of March 2011. Cold commissioning is scheduled for August 2011. This will last 6 to 8 weeks so that hot commissioning can start in October 2011.

With Mother Nature providing the steam, there is no boiler to be commissioned so the entire commissioning process will be shorter than for a conventional steam plant or combined cycle unit. Achieving PAC will require three months and both units are expected to be ready for operation by the end of 2011.

During operation, Alstom's Controsteam V3 turbine controller will control each steam turbine. Both units will be placed in a single powerhouse and the entire power plant will be controlled using Alstom's ALSPA Series 6 distributed control system.

Operating any plant is important and with geothermal plants the potential exists for the aggressive geothermal steam to affect the operational life of the turbine and plant. Alstom believes, however, that with the correct service and maintenance approach geothermal power plants can last more than a lifetime. Alstom's geothermal project in Wairakei, New Zealand is cited as a good a case in point since this was commissioned in 1958 as one of the first commercial plants of its kind anywhere in the world. It is still operating more than 50 years later.