Presented at "Short Course VI on Utilization of Low- and Medium-Enthalpy Geothermal Resources and Financial Aspects of Utilization", organized by UNU-GTP and LaGeo, in Santa Tecla, El Salvador, March 23-29, 2014.

UNITED NATIONS UNIVERSITY
GEOTHERMAL TRAINING PROGRAMME

LaGeo S.A. de C.V.

EXPERIENCE WITH LOW ENTHALPY GEOTHERMAL PROJECTS IN MEXICO

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ABSTRACT

In Mexico, Comision Federal de Electricidad (CFE) has identified several low enthalpy sites related with thermal water, at shallow depths. Some of those geothermal prospects are located far away from the electrical national grid. In some cases, the population solves their electricity needs by internal combustion engines with a very high operating cost, but there is the possibility of using those low enthalpy sites for rural electrification. By the other hand, there is a high potential of energy recovery from the brine or separated water in the back pressure and condensation units already installed in the four geothermal fields in operation in Mexico. CFE has developed some projects oriented to use both, the energy contained in the thermal waters with off-grid binary cycle power plants and also using the residual brine in the existing geothermal fields to increase the contribution to the distribution network. In this paper, the experiences acquired installing and operating four binary plants of 300 kW each is presented as well as the experience taken from two 1.5 MW air-cooled binary plants using the residual brine from Los Azufres wells.

1. INTRODUCTION

Mexico has numerous low temperature resources around the country. In many states it is possible to find thermal waters used for touristic purposes.

Most of those low temperature resources are related to the Mexican Volcanic Belt and to the tectonic activity in the Baja California Peninsula. Also, in some cases these resources are located in isolated places where it is possible to use them to produce electricity on a very low scale with binary cycle power plants. The acquisition of four binary power plants of 300 kW each, corresponds to a pilot project to test the binary cycle technology in remote sites taking advantage of the hot water as an energy source.

To take advantage of low temperature water it is necessary to drill shallow wells, with the advantage of lower cost compare with those in a depth resource The capacity of the power plants could be as low as around 100 to 300 kW. This is the size of energy units needed by these remote communities.

Also CFE identified possible energy recovery from the brine or separated water in back pressure and condensation units already installed making an improvement to increase the installed capacity and

make the most of the energy obtained from geothermal steam, this is the case of the 1.5 MW units at Los Azufres.

Binary cycle power plants are a proven technology worldwide to generate electricity from the geothermal brine or separated water. Most of the binary projects are related to low or moderate enthalpy. In Mexico, these plants were used temporarily as pilot projects in order to promote their application in subsequent projects (Figure 1) and also as a demonstration of their feasibility for rural electrification in remote areas away from distribution network. On the basis of experimental, the 300kW units were not part of the national electricity generation system and did not affect the program and development of this sector, differently from the 1.5 MW that were integrate to Los Azufres grid.

The characteristics of this type of projects are as follow.

- High Availability factor;
- High load factor;
- Non polluting units; and
- High reliability.

FIGURE 1: Binary cycle power plant locations as demonstrative projects in Mexico

2. GEOTHERMAL BINARY CYCLE PLANTS 300 KW

In the year 1998 CFE acquired four binary cycle power plants with capacity of 300 kW each to the company ORMAT, having the aim of exploring the generation on a small scale in rural or isolated areas where it is present thermal manifestations.

Seven sites were explored with thermal manifestations presenting attractive conditions for the installation of these pilot plants, performing perforations between 200m and 700 m deep. But the only one site that presents favourable conditions for the installation of these units was Maguarichic, Chihuahua.

Therefore, due to the budgetary and environmental constraints, it was decided to move three of the four units to the geothermal fields of Cerro Prieto, Las Tres Virgenes and Los Humeros in order to continue testing binary cycle power plants with geothermal brine *(*González, 2008).

The units were installed with the following objectives:

- Cerro Prieto: the unit was installed in order to experiment with the injection of scale inhibitors for the brine and see the results in the heat exchangers looking to tap a larger scale project using the residual energy. Finally were tested and injected several types of scale inhibitors without achieving considerably that reduces the inlay exchangers.

- Las Tres Virgenes: the unit was fed with geothermal brine produced by the LV-1 well supplying electric power to the pumping station for two years (2000-2002) the generation had to be suspended due to the production decline of mentioned well.

- Los Humeros: the unit was installed in the field in order to take advantage of the residual energy of the brine produced by the H-1 well and test a pond that would act as a cooling tower. Due to production decline in the production of brine from the mentioned well and the presence of leaks in the pond, lead to the suspension of the test.

- Maguarichic, Chihuahua: Pilot for rural electrification.

In this paper it is discussed particularly the Maguarichic project, due to the fact that it was the only off-grid binary cycle power plant used to community electrification and also was the one with the most extended operation.

2.1 Maguarichic project

The Maguarichic geothermal zone is located 11.5 km south westerly from Cuauhtemoc, Chihuahua. It is possible to reach the zone taking the highway Chihuahua-San Juanito and then driving by the secondary road San Juanito-Maguarichic. The zone is located in the Sierra Madre Occidental, in the area known as Sierra Tarahumara.

The geothermal manifestations in Maguarichic are constituted by superficial hot springs and some fumaroles which temperatures ranging from 60°C to 90°C. This zone is 5 miles away from Maguarichic Village. Maguarichic was at that time a small village of around 380 inhabitants.

Before the project that community was supplied with electrical power by a diesel generator that runs approximately 4 to 5 hours/day, mainly because of the fuel high cost. The rest of the time the community lacks of electrical energy supply.

2.1.1 General description of the project

In this zone, the project can be divided into three main parts:

- Drilling the production and injection wells;
- Manufacturing of generation power units; and
- Installation of the Generation unit.

2.1.2 Wells for water supply

The idea of electricity generation using low temperature water involves finding geothermal production of a maximum depth to 500 m, to reduce the well cost. Therefore, after geological, geochemical and geophysical surveys, CFE decided to drill a slim hole into the geothermal reservoir. Well PL-1 was drilled using a self-contained rig, finishing a 3.5" diameter hole to a depth of 49 m. The well produced water at 120°C. With this information and temperature and pressure logs, CFE decided to drill a second well, with a 9 5/8" casing to 35 m and slotted liner to 300 m. Well PL-2's target was to gain even higher temperature and more production. PL-2 well did not offer higher temperature than the measured in the PL-1 well, but produced 35 tons per hour (t/h) of hot water. With this positive result, CFE decided to install one of its small ORMAT geothermal power plants near the village of Maguarichic, at a total cost of approximately $1.3 million (US). Federal, state and municipal funds financed the project, and the community provided in kind services (Sánchez-Velasco et al., 2003).

The requirement of water to operate the pilot binary unit in full load ranges approximately from 70 to 100 tons/hour. Due to the pressure and temperature conditions of shallower well drilled to supply the mentioned flow rate, it was necessary to install down hole pumps of 8" diameter.

For this project two wells were drilled but only PL-2 well, were used to supply water to the pilot binary cycle power plant.

2.1.3 Power unit

As mentioned before, the units were binary cycle, with a capacity of 300 kW using geothermal water at temperatures from 120°C to 170°C. This unit were going to operate without connection to any electrical system, so they had to be able to follow load variations in an automatically way. They need to do that rapidly, to assure a high quality of electrical service for the Maguarichic community.

The units were conceived as a modular type. All its parts, like the preheater, evaporator, turbine generator, lubrication system and control system are located on a platform with approximate dimensions of 3m x 8m. The condenser and the organic fluid storage tank integrate, the second module installed above the powerhouse.

The turbo generator will operate with an organic fluid (isopentane) and has to be equipped with all necessary systems to operate in a continuous and safe way. Starting, operation and stopping mode had to be automatic.

To control load variation it was necessary to have a regulatory system integrated by:

A by-pass system totally automatic to divert the organic fluid to the condenser, before passing through the turbine, to assure the control of load variation.

- The preheater and evaporator of tube type, was built in a single piece;
- The cooling system was closed type with condenser cooled by air and water; and
- Units sent energy at 480 Volts to an elevating substation, where voltage had to be increased to 34.5 kV and to 23 kV.

2.1.4 Unit installation

Because these binary power units were designed in a modular configuration, their construction and installation required a minimum of time, a period of 2 months was taken for the construction in a factory and 1 month for installation.

Maguarichic unit was operating and supplying electric power to the community from 2001 to early 2008 (7 years) since was installed.

3. GEOTHERMAL BINARY CYCLE PLANTS 1.5 MW

Back in 1997, CFE due to an agreement between the Energy Ministers of Israel and Mexico, decided to buy two units of 1.5 MW each to gain experience using this technology, it was decided to install them in Los Azufres to exploit low enthalpy water wells.

After some problems at the initial start-up of the plans, a lot of experiences were obtained in 17 years of operation, showing that binary cycle power plants are technically and economically viable in Mexico.

Binary cycle plants in the Los Azufres geothermal field are known as unit 11 and unit 12.

3.1 General description of the project

Two 1.5 MW ORMAT Energy Converter (OEC) units were installed in two separate locations in Los Azufres Geothermal Field, at an altitude of 9,500 ft (2,900 m above sea level).

The goals for the installation of this power plant were the use of otherwise wasted geothermal brine. In this zone, the project can be divided into two main parts:

- Manufacturing of generation power units
- Generation unit installation.

3.1.1 Power units

Generally, the production of the geothermal wells at Los Azufres consists of liquid and a mix of steam and gas. This two phase flow is led from the wellhead to a flash separator which separates the liquid (brine) from the saturated steam and the non-condensable gases (NCG). The steam flows from the separator to the existing steam turbine.

The brine flows from the separator to the OEC vaporizer where it heats and evaporates the organic fluid and from the vaporizer to the preheater. The exhausted brine was discharged from the outlet of the preheater through a discharge line directed to a silencer.

The brine has an inlet temperature of 347°F (175°C) and a flow of 517 gpm (141,000 kg/hr) for each of the two locations.

The organic working fluid (isopentane) is fed from the vaporizer to the turbines. After expanding in the turbine, it flowed to the air-cooled condenser and from there via a feed pump back to the preheater.

Each binary module generates 1.5 MW gross, 0.25 MW is used for condenser cooling fans and pentane pump.

To generate 1.5 MW is required 155 t/h of hot water at 175 °C which is cooled to 110 ° C in the heat exchanger.

3.1.2 Unit Installation

The binary cycle power plants were supplied by ORMAT but owned by CFE. All power plant engineering and construction, including installation, well pumping and electrical connections were locally designed and executed by CFE and other Mexican companies.

The first unit was installed next to the back pressure unit 10 of 5MW, to take advantage of the separated water from this unit (160 t/h) while the steam was used in it. The electrical energy from the binary cycle went to the same transformer of the 5 MW unit.

The second unit was installed in the AZ-22 well to get 120 t/h combined with 30 t/h more which produces well AZ-55, the purpose of this binary cycle plant was to test as an independent unit with its own substation.

Those units were commissioned in 1992 and were uninstalling in 2009 (17 years) due to several problems, one of them was that the binary cycle power plant was connected to the system of steam duct of a 50MW condensing unit, when the binary cycle stopped for any problems losses of pressure in the separator and the steam of the principal steam line was discharged by the water line of this highly affected the generation of the condensing unit *(*Gerencia de Proyectos Geotermoeléctricos, 2009*)*.

By the other hand, recurring problems arose with the seal of the turbine unit binary cycle and it was not possible to get support from the manufacturer for repair so the units had to be out of operation for long periods increasing operating costs thereof, which exceeded the benefits to generate electric power with those units (Gerencia de Proyectos Geotermoeléctricos, 2009).

4. NEW PROJECT

Derived from the results of the units at Los Azufres and taking into account the large residual brine separated from the steam of the production wells at Las Tres Virgenes geothermal field, a 1.7 MW binary cycle project is intended to be installing. As mentioned the project is located in Las Tres Virgenes geothermal field, located in the northern part of Baja California Sur State, 32 km northwest of the town of Santa Rosalia, at an elevation of about 720 meters above sea level (Figure 2).

Binary cycle project aims to take advantage of the energy of the separated brine produced by four geothermal wells dedicated to provide steam to the condensing units in operation at this geothermal field, The aim of this project is to contribute to the demand for electricity in the Santa Rosalia system, increasing the share of clean electrical energy and reducing the environmental impact of the energy sector.

The specific objectives are:

- Installing a binary cycle power plant of 1.7 MW net capacity, to increase the installed capacity at Las Tres Virgenes geothermal field; and
- Leverage the residual energy contained in the waste water (brine).

With this project, the system will have a net increase in the capacity of 1.7 MW, without requiring new wells, which represents a technical and economical way of improving the energy efficiency in this isolated system of Mexico.

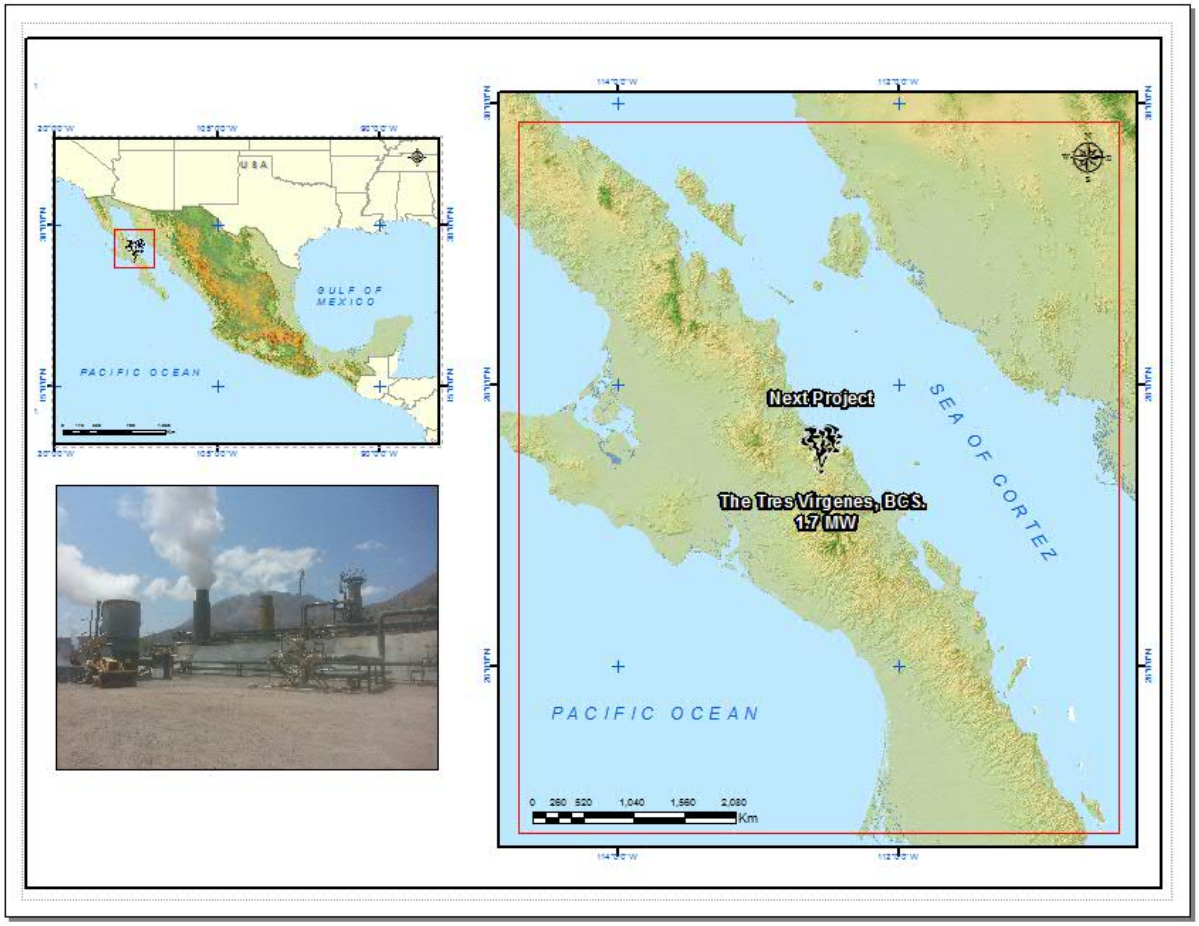

FIGURE2: Localization of the 1.7 MW binary cycle project at Las Tres Virgenes

4. CONCLUSIONS

There are in Mexico several zones with superficial temperatures between 26°C and 90°C in which small binary cycle power plants can be installed, to supply electricity for small and isolated communities. In many of those geothermal zones, the CFE has done geological and geochemical pre-feasibility studies. Results show that it is possible to find low temperature resources at shallow depths (maximum of 500m).

The first projects of this type were conducted by CFE in an isolated zone at the Northern State of Chihuahua: Maguarichic with an impact in the community increasing the productivity and lifestyle of this people.

A large amount of geothermal energy is available from low and moderate enthalpy geothermal sources in Mexico, Central and South America as well as many parts of the world.

The feasibility of binary cycles power plants using the residual brine in the existing geothermal fields to increase the contribution to the distribution network

Increase the electrical capacity of geothermal fields, without requiring new wells, which represents a technical and economical way of improving the energy efficiency.

Interest is high in the use of these proven binary cycle power plants to provide electrical generation in applications in Mexico for a variety of goals, including enhancing central power plants as well as providing power to remote areas.

Among non-fossil alternative energy sources as separated water or geothermal brine provide one of the most attractive means of generating electricity.

The experience accumulated over the past years shows that the binary system has now been developed into a well proven technology. The binary plants units have accumulated operating hours in actual field operation, thus demonstrating the reliability, availability and inherent long life of binary geothermal power systems in Mexico.

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