Geothermal and Solar Energy in Cerro Prieto

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ABSTRACT

In 2011, four of thirteen turbines at Cerro Prieto were shut down permanently (decommissioned) due to lack of steam, reducing the installed capacity from 720 MWe to 570 MWe. Since then, CFE is trying to increase energy generation by different means.

In 2012, a 5 MWe installed capacity power plant was installed (commissioned) in Cerro Prieto using four different technologies: polycrystalline panels with one and two axis tracking system, thin film panels with one axis tracking system and solar concentration panels with two axis tracking system. The solar radiation is 5.5 W/m^2 in Cerro Prieto, which is above the average of 5.0 W/m^2 in the rest of the country. The land was already part of the geothermal field. This project opened the door for a 10 MWe thermal solar plant to be commissioned in 2015 to evaporate the blow down residual water from the geothermal cooling towers and feed the steam to the Cerro Prieto pipeline grid that goes into the steam turbines in the power plants. A water treatment plant is going to be installed to remove mud and solids from the blow down before entering the thermo solar plant.

Organic Rankine Cycle in Cerro Prieto has been elusive because of the high scaling silica problem, but in 2015 a new well is going to be drilled to install a deep well pump to maintain high pressurized brine into a heat exchanger and avoid silica polymerization and precipitation.

1. CERRO PRIETO GEOTHERMAL FIELD

The Cerro Prieto Geothermal field owned by CFE (Comision Federal de Electricidad), located in the northern part of Mexico, 30 km south of the border with the USA (Fig. 1), in the Baja California zone, between meridians 115°12’ and 115°18’ longitude west and parallels 32°22’ and 32°26’ northern latitude, is located within the ring of fire. The field has an approximate area of 20 km^2 plus 18 km^2 associated with the evaporation pond.

Figure 1: Cerro Prieto Geothermal field located 30 km south of the USA border in Mexico.

The Cerro Prieto volcano, the field arrangement, wells distribution and the evaporation pond can be seen in Fig. 2.

Figure 2: Satellite view of the geothermal field showing the Cerro Prieto volcano (upper left) and the well arrangement area.

Cerro Prieto began its commercial operation in 1973 with a 75 MWe power plant in two 37.5 MWe condensing units, and later in 1976 another two 37.5 condensing units were added. All four plants were commissioned by Toshiba. This power plant was later named CPU and is located at the west of the field (Fig. 3); in 1985 a 30 MWe low pressure condensing unit was commissioned to achieve 180 MWe.

Figure 3: CPU satellite view.

In 1980, two additional 220 MWe twin power plants were commissioned also by Toshiba, named CPD (Fig. 4) and CPT (Fig. 5). Each of these power plants holds two single flashing units of 110 MWe; CPD is located at the south and CPT at the north of the field.

Figure 4: CPD Satellite view.

Figure 5: CPT satellite view.

In 2000, another 100 MWe power plant was commissioned by Mitsubishi at the east of the field, named CPC (fig. 6). This power plants works with four single flashing turbines of 25 MWe each. Since then the geothermal field worked with approximately 138 production wells and 13 cold injection wells.

Figure 6: CPC satellite view.

By the year 2002 there were still plans to build a fifth power plant of 100 MWe, but this never occurred due to the beginning of the depressurization of the reservoir.Since the year 2000 to 2011 Cerro Prieto operated with 13 turbines and 720MWe of installed capacity.Each year, six wells are mechanically repaired and almost nine new wells are drilled to try to maintain production. In 2012, well acidification (Fig. 7) began in Cerro Prieto.

Figure 7: Acidification in silica scaled well in Cerro Prieto.

By the year 2005 there was a myth that injecting greats amounts of brine could cool down the reservoir and thus no major injection program was working. By 2006, increasing levels of the evaporation pond lead to hot injection in additional dead wells. Two years later, the lack of steam and depressurization was obvious and an integral injection program was made. By the year 2012, there was an increasing lack of steam of about 4000 T/h a year to maintain electrical production of 570 MWe.

2. RESERVOIR PRESSURE

The Cerro Prieto geothermal field has a liquid dominated reservoir with sedimentary rock. The field worked for many years with three different types of pressure. The zone located in the west part of the field (CPU) was the first to be explored, and the reservoir was 1.5 km depth with pressures around 250 psig; this was later referred as medium pressure steam. The middle part of the field (CPD and CPT) is around 2.2 km deep and had pressures of 300 psig The wells located in this part are the most scaling ones. The eastern part of the field (CPC) has pressures of 450 psig, but wells with up to 1000 psig have been drilled. The later ones were short lived and depressurized in months.

The pressure of the new wells, once drilled, start to decline and after 3 to 5 years are declared dead and they have to be mechanically repaired. As the drills moved away from the Cerro Prieto Volcano, the wells became deeper because better enthalpies were found around the 3 km depth. This continuous growth of the field to the east provoked an abandonment of the west part of the field, leaving depressurized wells with good enthalpy that cannot flow by themselves anymore, becoming unexploited non artesian wells.

In 2012, Cerro Prieto acquired new grounds to the eastern part, limiting now a populated town that will limit further growth of the field. These new grounds have even greater enthalpy in the reservoir.

3. ARTESIAN WELLS

Since the beginning of the exploitation of the reservoir, all the drilled production wells have been artesian, there has not been need of additional equipment to extract the brine until now. The continuous exploitation and depressurization of the reservoir has rendered the west part of the reservoir useless.

4. DEPRESSURIZATION

Due to the exploitation of the geothermal field, the reservoir began to depressurize and in the year 2011 two 37.5 MWe turbines of CPU were decommissioned because of the lack of steam. Later in 2012 another two 37.5 MWe turbines of CPU were decommissioned leaving only the low pressure 30 MWe turbine, leaving the Cerro Prieto geothermal field with nine working condensate units and 570MWe.

These events lead to the search of new methods to protect the reservoir and prolong the life cycle of the geothermal field. The lack of steam production became obvious by 2004, when high enthalpy wells in the east part of the field suddenly become acidic, corroding the casing and even the steam pipelines. In 2015, hot brine is going to be injected near this zone to try to minimize low pH's. The production declination ranges around 4000 Ton/h a year, to maintain production more wells are needed, which provokes further depressurization.

5. EVAPORATION POND

In 1985, a pond (Fig. 8) was built by a fertilizer private company named Fertimex to produce ammonia nitrogen, but it never worked for that use because the high costs it implied for the company. Instead it was used by CFE as an evaporation pond allowing silica to deposit in the bottom of the pond, part of the water evaporates and another part is sent to a crystallizer where the water is cold pumped into injection wells. The use of these wells was never to recharge the reservoir but to get rid of the excess water. The pond worked like this until the year 2011, when the pond became very difficult to operate due to its dimensions, the risk of border rupture due to seismic activities in the area, and the silica deposits.

Figure 8: Evaporation Pond of 18km^2 with a maze arrangement.

In the year 2006 a small fish was found in the pond, which has a pH above 8. This fish was believed to be extinct and to this date is unknown how it entered the pond, survived and proliferated. Pollution agencies in the country are enforcing CFE to preserve the fish and its habitat.

6. POND AREA DECREASE

In 2011, a new project began, as an agreement with the federal authorities, for decreasing the pond area to reduce the visual impact and pollution of the area. This will be achieved by using the some of the blow down of the cooling towers for internal services and potable water, by installing a 20 L/s water treatment plant and drastically increasing the hot brine injection. The fish in the pond and the pollution agencies doesn't allow to completely remove the pond, but at the same time are encouraging to improve the visual impact and the land by installing wetlands and reforest the drying zones of the pond.

7. FIVE MWE SOLAR PHOTOVOLTAIC PILOT POWER PLANT

Due to the steam declination and low steam production prediction and with average radiations of 5.5 W/m^2 the Cerro Prieto area was ideal for installing a solar power plant to increase energy production. Nevertheless there were no solar power plants installed in the country by 2011, nor the experience to operate one. CFE invested in an experimental photovoltaic field with four different technologies.

The grounds at the north of Cerro Prieto were chosen because the land was already part of CFE and had the necessary grounds. This zone was a bank of plant material because there is no usable enthalpy in this part of the field. In 2012, a 5 MWe solar pilot power plant was commissioned by Iberdrola. This was considered a pilot power plant to test four different types of photovoltaic technology: polycrystalline panels with one and two axis tracking system, thin film panels with one axis tracking system and solar concentration panels with two axis tracking system.

The power plant is built on 16 hectares inside the geothermal field (fig. 9).

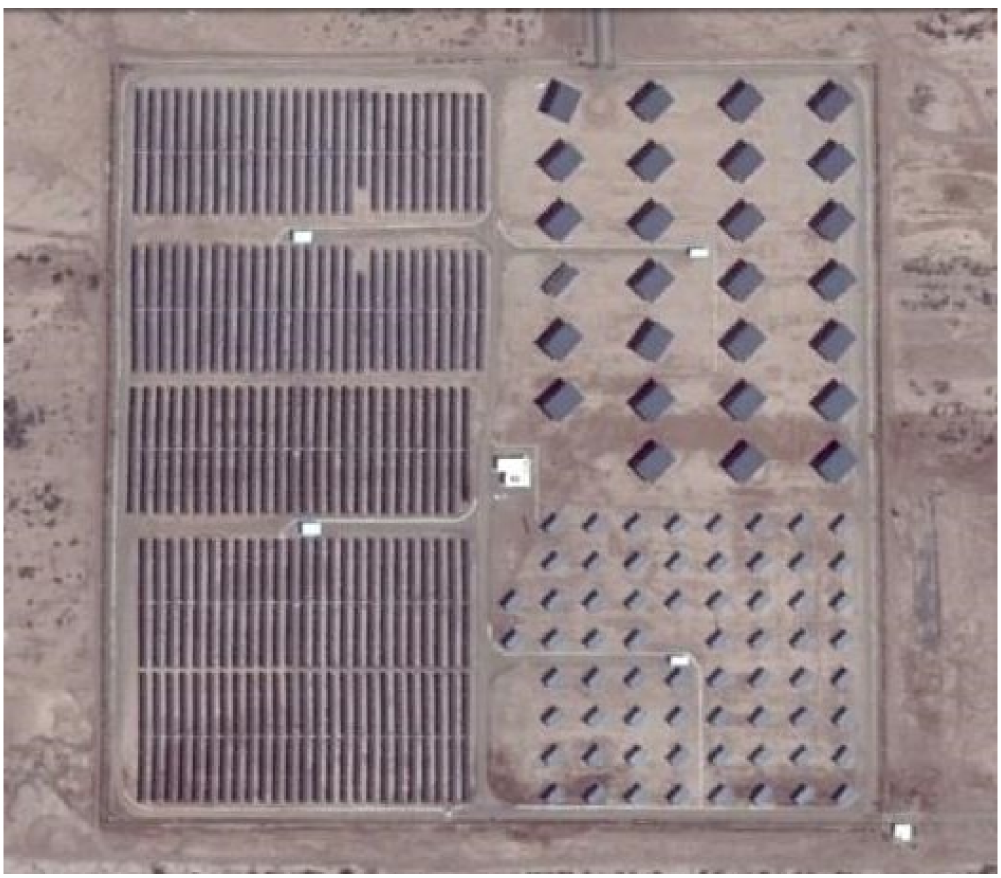

Figure 9: 5MWe Photovoltaic Power Plant Satellite View.

When the test period ends the best technology will be installed in a 30 MWe power plant at the west of the pilot power plant to increase electricity generation of Cerro Prieto in 2016.

8. TEN MWE THERMO SOLAR POWER PLANT

Due to the results obtained in the pilot solar power plant, a new power plant of 10 MWe thermal solar power plant is planned to be built next year to increase electricity production in Cerro Prieto. This power plant will take the water from the blow down of the cooling tower of CPC, treat it to remove solids, and then evaporate it to use this steam to feed the high pressure steam pipeline to obtain an equivalent of 10 MWe in the CPC power plant. The turbines in CPC have a specific consumption of 8.5 Ton/h of high pressure steam.

9. NON ARTESIAN WELLS

The zone located to the west of the geothermal field was the first to become depressurized early around the year 2000, production of the wells began to decrease and the density of wells began to reduce. This was a medium pressure zone, and now it only has five operating wells from the 80 that were drilled since 1967.

Due to the low pressure in the zone wells doesn’t flow by themselves anymore, so it is planned to install a 1017 gpm deep well pump with a variable frequency drive (VFD) to extract part of this fluid. A test of the reservoir and the equipment available in the market by sending the produce brine to a steam separator to feed the 30 MWe unit in CPU and then began binary fluid test in a heat exchanger to install an Organic Rankine Cycle power plant. If the pump and the reservoir behave accordingly, new non artesian wells are going to be drilled in the west part of the field to extract the brine. These wells are shorter in depth but larger in diameter to fix the pump and axle into the casing pipe.

10. ORGANIC RANKINE CYCLE POWER PLANT

Several tests to install an Organic Rankine Cycle (ORC) have been tried over the years in the Cerro Prieto field, but none have been successful due to the high scaling silica the wells produce. If the deep well pump succeeds in extracting the brine without provoking silica scaling, a new Organic Rankine Cycle power plant could be installed giving new life to Cerro Prieto and allow exploiting again this zone of the reservoir abandoned for more than ten years. The wells in this part of the field are expected to have temperatures around 180-200 C.

11. CONCLUSIONS

The Cerro Prieto geothermal field has suffered depressurization due to the reservoir exploitation, and this has caused the abandonment of the west part of the field and corrosion problems in the east part. Two major solar projects will test the available technology in the field to increase electricity production: one photovoltaic and one thermal. A project for testing a deep well pump and the reservoir to produce hot pressure brine will deliver a solution for the silica scaling problem and will open the door for installing Organic Ranking Cycle to use the shallow part of the reservoir in the west of the field. Hot brine injection will reduce acid zones in the east of the field and will provoke a hydraulic reservoir recharge that will prolong the life of the reservoir.