ESPs in Geothermal Applications: an Operational and Commercial Success Case Study in Turkey

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ABSTRACT

While other neighboring geothermal energy plants are located around sea level and enjoy artesian production with moderate flow and surface pressures to supply their power plants, the Limgaz Organic Rankine Cycle (ORC) power plant in Turkey is situated at an elevated location around 1312ft (400m) above the sea level. Therefore, the static fluid level in the wells was at approximately 300 meters below the wellhead. The expected brine temperature was around 300°F (150°C) from the production wells.

In 2014, two wells were simultaneously tested using electrical submersible pumps (ESP). At this time, the operator was also able to determine interaction between their wells allowing the calculation of operational and financial feasibility of their future power plant. The study resulted in investment and successful completion of a 13.8 MW ORC geothermal power plant in 2018.

This particular application is an important reference for the role that downhole pumping units play in the low enthalpy geothermal systems, as the production for the ORC is 100% dependent on 5 ESPs. This case study highlights the combined technology packages employed to accommodate different well characteristics and flow conditions of each well and the brine production overall.

1. Introduction

Significant development has been made since 2010 in the growth and development of the Turkish geothermal market. Uses of the abundant geothermal resource include district heating applications, agriculture used, greenhouse heating, tourism, and with the aid of feed-in tariffs, electricity generation. To make the most of the resource, some power plants have incorporated heat-consuming factories that produce liquefied carbon dioxide and dry ice.

The growth rate of the power generation sector has been tremendous; in 2010, only 100 MWe of capacity was available compared to over 1,300 MWe as of March 2019, putting Turkey as the fourth largest producer of geothermal electricity globally. Current market projections estimate generating capacity to increase to 2,000 MWe by 2020; an almost 50% increase according to the Turkish Geothermal Power Plant Investors Association. However, a common problem that is encountered as operators continually draw resource from the same reservoir is pressure decline. To mitigate the production losses in areas of pressure decline, as well as open up new opportunities, operators are looking to use ESPs for production.

2. Limgaz Buharkent Geothermal Power Plant

Located within Aydin Provence in the Aegean region of Turkey, the Limgaz ORC geothermal power plant began operation in autumn 2018. It is situated at approximately 400 meters above sea level and utilizes a resource of approximately 300°F (150°C) on average from 5 production wells. Within the region, other power generating facilities are at or near sea level with most benefiting from artesian production. However, the higher elevation of Limgaz results in a static fluid level at a depth of 984ft (300m). Therefore an artificial production method to supply fluid to the ORC heat exchangers is required. Due to challenging well conditions and temperatures, it was decided the most effective way of achieving adequate production was with ESPs. BHGE was selected as a supplier due to its proven record with the CENtigrade™ high temperature ESP.

2.1 Technology Package

The power plant at Limgaz is 100% supplied with fluid produced by ESPs. Highly rugged geothermal pumps were installed in each of the facilities 5 production wells capable of delivering flowrates ranging from 885 GPM (56 l/s) to 1541 GPM (97 l/s) each. In total, nearly 5800 GPM (366 l/s) of fluid is produced and supplied to the ORC. The parasitic load of the ESPs represent approximately 20% of the total power production. As part of the solution provided by BHGE, medium voltage motor controller and high temperature sensors monitoring downhole conditions were also included in the pump installation.

Well	Production Rate		Fluid Temperature	
	GPM	l/s	°F	°C
KBD1	1541	97	314.6	157
KB2	1100	69	293	145
KB5	885	56	302	150
KB6	960	61	312.8	156
KB8	1320	83	291.2	144

Figure 1: Well flow rate and temperature from Limgaz

2.1.1 BHGE CENtigrade™ ESP

To service the global geothermal market, BHGE has developed a line of submersible pump systems that can produce fluid rates of up to 4,600GPM (291 l/s). Depending on the well diameter, a pump may be housed for when smaller flow rates are required or use a bolted bowl design. Bolted bowl pump designs are made with a higher strength metallurgy, which negates the otherwise necessary pump housing that is needed to hold the pump stages together. By not needing the housing, the cross sectional surface area of the pump is able to be larger, allowing for greater production. Material configurations and specialized coatings have also been developed to ensure high reliability and performance in the presence of scaling or corrosive well fluid. In most cases, small stainless steel injection lines can be installed and set to discharge chemical inhibitor below the ESP to help maintain a benign production fluid.

Figure 2: A bolted bowl pump, top/right (~3200GPM, 200 l/s) compared to a smaller housed pump, bottom/left (~1600GPM, 100 l/s)

The downhole motors offered have a maximum nameplate rating 2800 horsepower (2087 kW) and various configurations that can produce in up to a bottom hole temperature of 482°F (250°C). Motors have to be de-rated to operate in high bottom hole temperatures. The diameters of these motors extend up to 8.80in (224mm) for when a high production rate is required and are paired with specially modified seals/protectors to improve reliability and reduce NPT for geothermal applications.

Pump OD		Flow		Pump Type
in.	cm	GPM	l/s	
6.75	17.1	166-1400	10-88	Housed
8.62	21.9	360-840	23-53	Bolted Bowl
8.75	22.2	400-975	25-62	Housed
9.00	22.9	1350-2600	85-164	Bolted Bowl
10.00	25.4	583-1458	37-92	Bolted Bowl
10.25	26.0	650-1600	41-101	Housed
10.38	26.4	1458-4608	92-291	Bolted Bowl

Figure 3: Pump outer diameter (OD), flow range and types offered by BHGE

2.1.2 Zenith™ downhole sensors

As part of the downhole equipment package utilized at Limgaz, a high temperature Zenith™ sensor was installed at the base of the motor. These sensors communicate via micro-voltaic pulse through the power cable, which eliminates the risk of plugging in a capillary tube line that would be needed for data transmission otherwise. This provided the operator with real time data and the ability to monitor the pump intake and discharge pressures, fluid temperature, motor temperature and system vibration. Having the sensors to monitor the downhole parameters provides the ability to identify impeding issues in production and adjust the equipment operation accordingly; for example, the detection of abnormal vibration or increase in motor temperature within the ESP allows a proactive response that can prevent further damage or failure. Sensor data can be monitored 24/7 by BHGE ProductionLink™ engineers and also provides the operator the ability to monitor the reservoir in real-time.

2.1.3 Medium voltage drives

Due to the importance of power supply quality for motors greater than 800HP in challenging in-flow conditions, a medium voltage variable speed drive (VSD) solution was used as the surface controller. In addition to sinusoidal wave filter at output, a low harmonic power signal was supplied to the ESPs. As the return on investment (ROI) and future profit depends on the marginal gain between power generation and consumption during production from a geothermal source, savings at the surface equipment is as important as the efficiency of downhole equipment. In this respect, the use of medium voltage into the drive that outputs directly to the ESP eliminates additional transformer requirements and capital expenses. While this helps to decrease overall power consumption between 4% and 6% among 5 ESPs, it also provides quality power supply for an increased run-life of the system and reduces risk of electrically-induced system failures.

2.2 Financial returns

The operator leased the elevated field for their future geothermal energy plant plans due to established good production rates at bordering licensed fields by other operators, as well as the findings of their literature and geophysical research. Their drilling campaign for 8 wells ended up with non-artesian flow regimes at all wells. Production tests with other artificial lift methods was not successful. Overall expenditure and investment the operator had made along with unsatisfactory fluid production results nearly concluded the project unsuccessfully. However, well testing with ESPs were able to provide positive marginal benefits and ROI.

Among these ROI calculations, CAPEX and OPEX for Lines Shaft Pumps (LSPs) and ESPs were also put into account. A higher complete system efficiency was revealed with ESPs versus LSPs due to more efficient stage design:

- There was less power consumption for the equivalent head
- Fewer mechanical parts with no-additional lubrication requirement in high temperature environment
- Less risk with regards to thermal expansion of the system components
- A greater capability to handle gas and vapor with flexibility
- Ability to set the pump intake deeper and in a smaller casing/liner hanger ID of 9-5/8in (244mm)

ROI was estimated as 2-1/2 months to cover the capital investment ESP equipment for this project which supplied 100% of the fluid for the facility. With operational expenditures such as the power consumption, installation, pulling and possible early troubleshooting expenses are also factored into the calculation, ROI was estimated as 3 to 3-1/2 months. Future project development in this region which includes increased knowledge of the reservoir and in-flow performance as well as with increased operational skills and experience, the expected ROI is estimated to be less than 3 months in total.

During the first year of operation, 3 of the 5 installed ESPs experienced a system failure and were replaced. After an analysis of the incidents were completed, preventive measures were taken with start & stop procedure, control mode settings in the VSD and upgrades of seal section to increase reliability further in challenging geothermal applications.

3. Conclusion

The 13.8MWe Limgaz ORC power plant in Turkey is an excellent case study in how ESPs play a pivotal role in the feasibility and operations of geothermal projects globally. The BHGE CENtigrade line of high temperature and robust submersible pumps coupled with advanced sensors, service ability and surface equipment were provided as a turn-key production solution for each of the 5 wells at Limgaz. With high overall system efficiency, the ROI for the operator was estimated to be at 3 to 3-1/2 months. In total, the combination of ESPs are currently supplying over 5800 GPM (366 l/s) to the turbine for the project with no artisanal resource.

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