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Practical Experiences on Operating a Combined Geothermal Power Plant in Alaşehir Field

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ABSTRACT

Geothermal power plant operating conditions and efficiency are heavily influenced by the quality of the produced geothermal fluid, which is directly affected by changes in geothermal well performance and reservoir dynamics. The Alaşehir geothermal field, one of the most active fields in Türkiye, is operated by various geothermal developers. This study highlights the challenges encountered during 10 years of operation at a combined double-flash and binary geothermal power plant, with a focus on resource and power plant management. Solutions implemented include enhanced resource management strategies and operational improvements such as ESP installations, gas lifting, acidizing, booster pumps, and equipment upgrades. Modifications and adaptations were applied to critical components such as pumps, fans, heat exchangers, turbines, and other equipment in both the flashing and binary systems to maintain efficient and reliable operations.

1. INTRODUCTION

Maintaining consistent flow rates and temperatures is essential for a reliable and feasible geothermal project. Changes in delivered flow characteristics can significantly impact the working efficiency of geothermal power plants (GPPs). For example, a flashing-type power plant requires a steady supply of steam, which is highly influenced by reservoir temperature. Additionally, the non-condensable gas content is critical for the overall gas rate and turbine inlet pressure. Therefore, operating a GPP efficiently highly depends on the resources. To illustrate, Jolie et al. (2021) emphasized geological controls such as the impact of heat flow, permeability, and fluid properties on geothermal power generation. Similarly, Aydin et al. (2020) evaluated the working capacity of GPPs in Turkiye, noting that the average working capacity is only 65%. This indicates that the plants are operating inefficiently due to overestimated resources and significant interference between wells. They proposed a unitized reservoir management solution to achieve more sustainable production from the same basins. Therefore, conducting a long-term estimation of resource capacity is critical before deciding on the capacity and type of GPP for a project.

To overcome resource-associated risks, various reservoir and production engineering applications are typically conducted, including stimulation (fracturing and acidizing), artificial lifting (downhole pumps and gas lifting), reservoir simulation, well testing, reservoir surveillance (pressure, temperature, and geochemical monitoring), and chemical treatments. However, geothermal reservoirs are highly heterogeneous and uncertain. Therefore, finding the optimal production and injection strategies is challenging without first encountering field-specific problems. GPP operators should have the capability to operate plants under diverse conditions and proactively develop solutions to adapt to varying resource conditions.

This study will first present the resource-associated problems encountered during 10 years of operation in the Alaşehir geothermal field, Turkiye. The solutions applied to manage these issues will then be provided. The impacts of changes in reservoir conditions on a combined GPP operations will also be discussed, along with the applied solutions.

2. CHALLENGES IN ALAŞEHIR GEOTHERMAL FIELD

The Alaşehir field is characterized as a medium- to high-temperature (150–250 °C) resource with highly permeable metamorphic rocks, consisting of marble, quartz, and schist. The installed GPP capacity is 321 MW as of 2025. The field has been operated by seven different operators under aggressive production conditions. Akin (2017) estimated the field's potential at 103 MW (minimum), 183 MW (most likely), and 335 MW (maximum) per hour for 30 years. This indicates that the installed power plant capacity is close to its theoretical maximum potential. Managing the resource and GPPs under such aggressive production conditions is highly challenging.

2.1 Resource Associated Challenges

More than 100 wells have been drilled in the Alaşehir field, serving 13 binary plants and one combined (flash-binary) plant. Aydin and Merey (2021) highlighted the proximity of licensed areas and reported a fluid extraction rate of 12,600 tons per hour from the field. Aydin et al. (2024) analyzed pressure transient tests of the Alaşehir geothermal reservoir, reporting a high permeability-thickness product, which results in the high production and injection capacity of the wells. The connectivity between the re-injection and production wells was revealed through monitoring geochemical data and conducting a comprehensive tracer test using naphthalene sulfonates (Aydin et al., 2018; Aydin and Akin, 2020).

Strong connectivity between well pairs has both advantages and disadvantages. From the perspective of production wells, highly permeable wells have a large drainage area that interferes with other production wells, resulting in a decline in production performance over time. Therefore, a local pressure drop occurs as the result of high fluid extraction within the overall drainage area. For re-injection well pairs, injecting into the same fracture system will cause a local pressure increase, reducing injection capacity due to counteracting reservoir pressure. Lastly, in production-reinjection well pairs, high interference helps maintain reservoir pressure. However, the rapid circulation of injected cold and NCG-free brine in the reservoir can significantly reduce the reservoir temperature and NCG content of the wells.

Some critical changes in reservoir conditions have been reported in the literature. Aydin and Akin (2020) documented a pressure decline of 3 bar per year following the commissioning of new GPPs in the Alaşehir field. Aydin and Merey (2021) observed a significant reduction in the production performance of a well, from 450 tons per hour to 80 tons per hour, after changes in reservoir conditions. Aslan et al. (2022) used Interferometric Synthetic Aperture Radar (InSAR) to analyze the Alaşehir field and reported large-scale production and injection effects in the area. They found that production areas exhibited higher subsidence compared to reinjection areas. Aydin and Akin (2021) conducted a 3D numerical reservoir simulation of the Alaşehir field using TOUGH2. They noted that early temperature decline would occur in wells located less than 2 km away from the injection sites. Additionally, production wells in the central field experienced significant declines in temperature and NCG content. The NCG content in the Alaşehir field was reported to have decreased from 2–3% to 0.2–0.3% by weight (Akin et al., 2020; Aydin et al., 2020). The NCG decline has resulted in the shifting of the flashing depth of the wells from 600–800 m to 50–150 m (Aydin et al., 2024).

2.2 Challenges Experienced in the Combined Geothermal Power Plant

The studied GPP is a combined system consisting of a 33 MWe flashing system and a 12 MW Organic Rankine Cycle (ORC). The double-flash system includes a High Pressure (HP) and a Low Pressure (LP) separator, directing steam into the corresponding turbine stages. The waste steam from the HP turbine exit is utilized in the steam vaporizer of the binary plant. Additionally, the reinjection brine is utilized in the high-pressure brine vaporizer. The GPP has a wet type cooling tower (Figure 1).

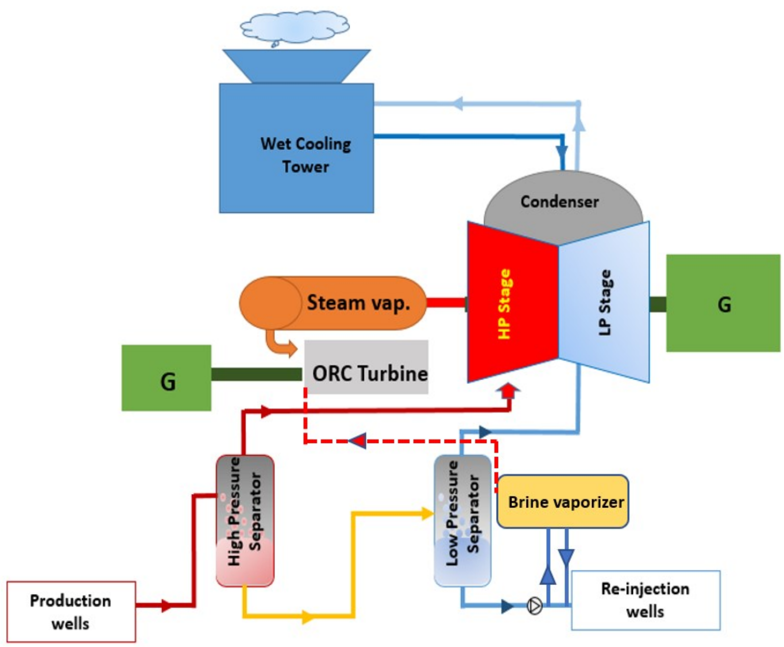

Figure 1: Flow Diagram of the Combined (Double Flash and Binary) Geothermal Power Plant

After experiencing temperature and NCG declines, the power plant has been operating under off-design conditions. The NCG production rate decreased from its design value of 67 tons per hour to 5 tons per hour, leading to a significant decline in the HP steam rate. However, the LP steam rate remained relatively close to design conditions. To compensate missing HP steam, more fluid had to be withdrawn from the reservoir. This necessitated higher reinjection capacity. However, reinjection pumps have already working at their maximum capacity

Another critical issue related to the NCG decline arose in the NCG removal system, which utilizes an ejector-vacuum pump setup. The ejectors use 4–6 tons per hour of HP steam as the working fluid. The decrease in HP steam pressure reduced the performance of the ejectors, while the significant drop in NCG rate caused the vacuum pump to become oversized for the current NCG rate. As a result, the vacuum pump operated outside its optimal range, leading to inefficient performance.

Aggressive production from geothermal wells has led to the mobilization of unconsolidated sands and schists from the reservoir. These solid particles accumulated in the separators and traveled with the geothermal fluid, causing abrasion of the impellers in the reinjection pumps. Additionally, the particles accumulated in the brine vaporizer, leading to flocculation.

Due to the temperature decline and increased fluid extraction, the load on the cooling tower and the need for cooling capacity have increased.

3. APPLIED SOLUTIONS TO MANAGE THE CHALLENGES

A series of solutions have been applied to address the changes in reservoir conditions and mitigate their impacts on GPP operations.

3.1 Solutions for Resource Management

First, a comprehensive tracer test was conducted to understand the preferential flow paths in the reservoir and determine the mean fluid travel time of the injected brine. The results revealed that wells targeting the main faults were accepting more than 90% of the injected brine and experiencing temperature decline, while other wells suffered from pressure drops. Based on these observations, a new production strategy has been implemented in the field as a part of field development.

To compensate for the missing production, seven makeup wells have been drilled in regions with low injection interference. The new production wells have been adapted to the changing reservoir conditions. The casing design of the new wells has been optimized to accommodate large ESPs capable of delivering high flow rates (Figure 2). As a result, the average enthalpy of the produced fluid has been maintained with minimal decline. Besides, the production capacity of the wells with low performance have been increased with artificial lifting methods: ESPs and Nitrogen (N_2) lifting. Nitrogen lifting has been found as an alternative to ESPs in Alaşehir field. Continuous N_2 lifting has been successfully implemented in one of the wells, increasing the flow rate from 270 to 320 tons per hour.

The main failures of ESPs are associated with electrical components, namely the motor and power cable (Aydin and Merey, 2021). However, ESP vendors have improved the components, increasing the run life from 6 months to more than 1 year at dynamic flowing temperatures ranging from 160 °C to 200 °C.

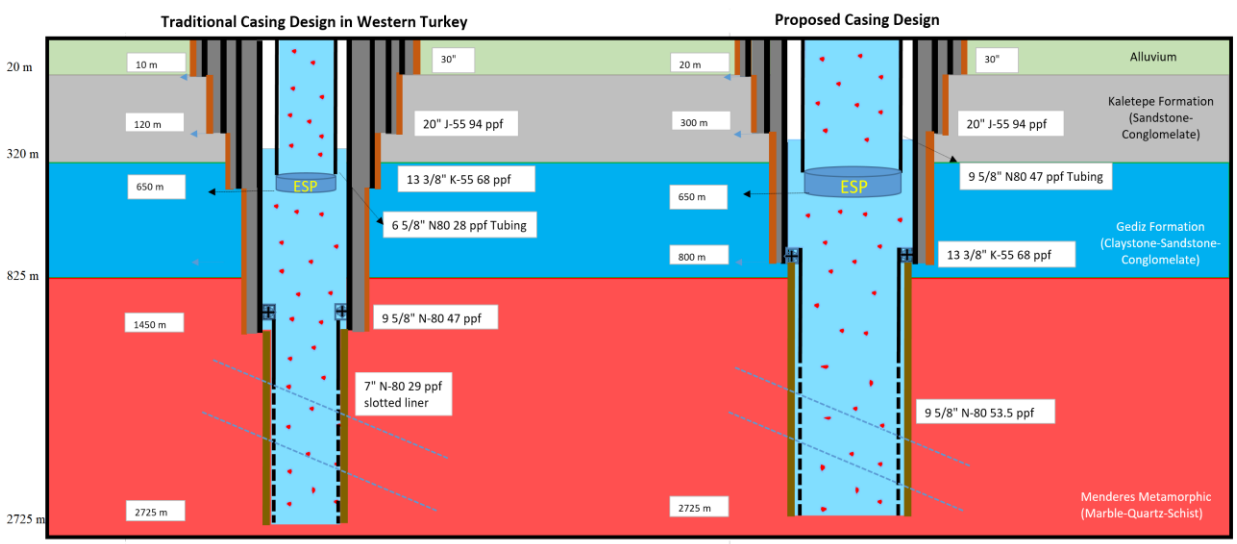

Figure 2: Traditional casing design (left) and the proposed casing design (right) for Alaşehir field (Aydin and Merey, 2021)

To improve the capacity of a low-permeability well, GasGun stimulation was applied in conjunction with high-rate matrix acidizing using HCl acid (Aydin et al., 2024). The production performance of the well increased fivefold.

3.2 Solutions for GPP Management

A higher flow rate was needed to compensate for the loss of HP steam caused by the decline in NCG content and reservoir temperature. Increased production also required a higher injection rate. To address the issue of exceeding the capacity of the existing re-injection system, new re-injection pumps were added in parallel to the existing setup.

The sharp decline in NCG levels caused the NCG removal system to operate inefficiently. Issues with vacuum in the condenser led to a decrease in turbine performance. The vacuum pump was underloaded due to being oversized for the new NCG rate. To address this issue, a new vacuum pump with a relatively lower capacity was installed to replace the existing pump (Figure 3). The new vacuum pump consumes 150 kW less energy while providing better performance compared to the oversized one.

To address the increased workload of the cooling tower, an additional cell was added, increasing the total number of cells from 7 to 8 (Figure 4). Additionally, the cooling tower fans were replaced with newly designed models, consuming 20 kW less energy compared to the previous ones (Figure 3).

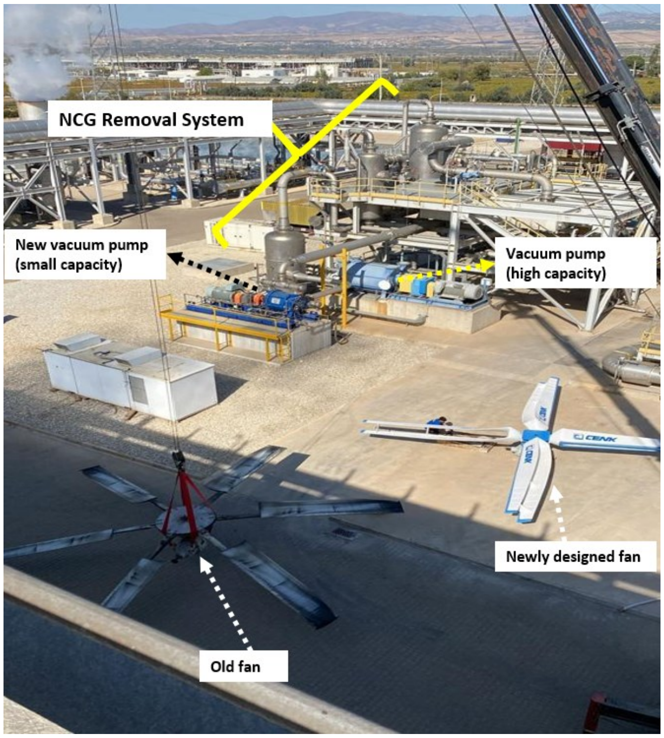

Figure 3: Vacuum pumps and cooling tower fans utilized to enhance the efficiency of the plant.

A Solar power plant and rooftop panels with annual 6.5 GW electricity generation capacity have been incorporated to the Alaşehir power plant to account for partial auxiliary consumption, enhancing net power output of the geothermal plant (Figure 4).

Reinjection pumps exposed to abrasive solid particles underwent maintenance to refurbish the impellers, shaft, and main bearings. Mineral precipitation in the lines, reported mostly as magnesium silicate (Tezel, 2018), was also mobilized after thermal cracking, causing clogging in the shell-and-tube sections of the brine vaporizer. Periodic mechanical and chemical cleaning operations are conducted to address this issue (Figure 5).

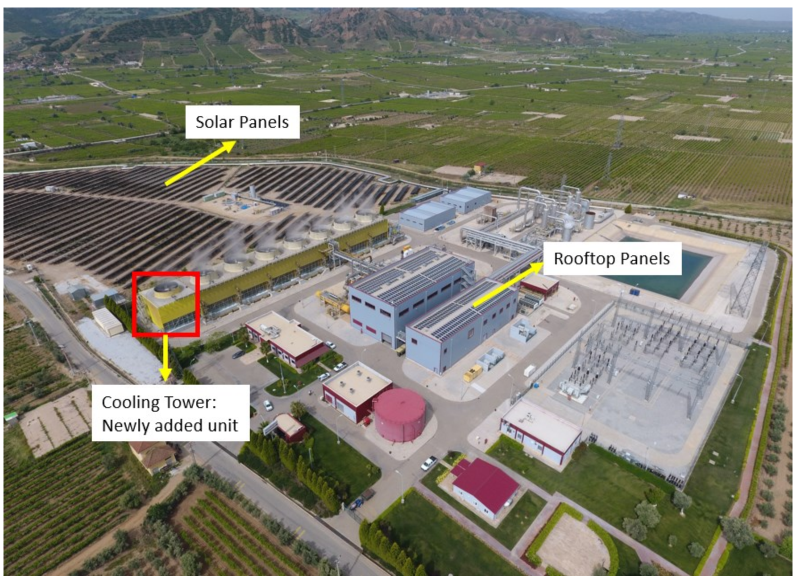

Figure 4: Alaşehir geothermal power plant: Newly added cooling tower unit and solar panels

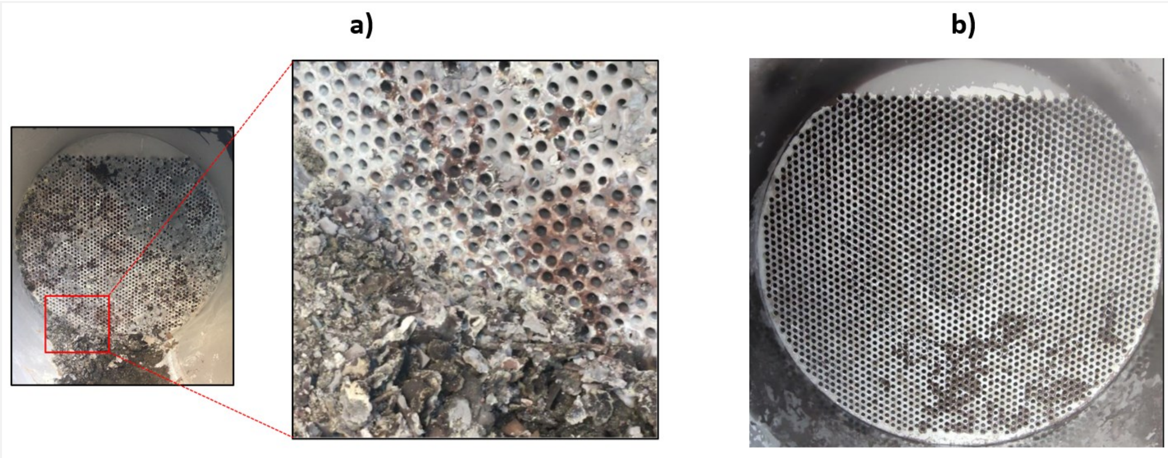

Figure 5: High pressure brine vaporizer: a) Clogging of brine vaporizer b) After mechanical and chemical cleaning

4. CONCLUSION

The Alaşehir field is one of the most actively producing fields, operated by various operators under aggressive production conditions. This study has presented the challenges experienced and the solutions applied. The following important outcomes can be drawn from this study:

- Geothermal resources should be evaluated and analyzed for the long term, taking into account the activities of neighboring operators.
- Forecasting a resource's production capacity and reservoir characteristics is critical in determining the appropriate capacity and type of power plant technology.
- GPPs are dynamic systems that require adaptation to changing resource conditions.
- Combined geothermal plants are unique and necessitate redundant equipment for each critical component.
- Numerous revisions have been made in resource and plant management to address challenges, including improvements to ESPs, nitrogen lifting, fans, pumps, and the addition of a solar plant.

REFERENCES

Akin, S. 2017. Geothermal Resource Assessment of Alaşehir Geothermal Field. 42nd Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, February 13-15, 2017.

Akin, S., Aydin, H., & Akin, T. (2020). CO2 Decline in Alaşehir (Turkey) Geothermal Reservoir. In Proceedings World Geothermal Congress 2020+1, Reykjavik, Iceland, April- October 2021 (p. 1).

Aslan, G., Aydin, H., & Cakir, Z. (2022). Wide-area ground deformation monitoring in geothermal fields in western Turkey. Turkish Journal of Earth Sciences, 31(3), 247-259.

Aydin, H., & Akin, S. (2020). Numerical reservoir simulation of Alaşehir geothermal field. Proceedings of the 45th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California.

Aydin, H., & Akin, S. (2020, November). Analysis of a comprehensive tracer test in alaşehir geothermal field. In Turkey IV. Scientific and Technical Petroleum Congress Chamber of Petroleum Engineers (pp. 8-20).

Aydın, H., & Merey, Ş. (2021). Changing casing-design of new geothermal wells in western Anatolia for adapting to the changes in reservoir conditions. PROCEEDINGS, 46th Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, February 15-17, 2021.

Aydin, H., & Merey, S. (2021). Design of Electrical Submersible Pump system in geothermal wells: A case study from West Anatolia, Turkey. Energy, 230, 120891.

Aydin, H., Akin, S., & Kumsal, B. (2020). Mathematical Modeling of Geothermal CO2 Production. In Proceedings World Geothermal Congress 2020+1, Reykjavik, Iceland, April- October 2021 (p. 1).

Aydin, H., Akin, S., & Tezel, S. (2018). Practical experiences about reservoir monitoring in Alaşehir Geothermal Field. In 43rd Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California.

Aydin, H., Akin, S., Senturk, E., & Energy, Z. (2020). Evaluation of production capacity of geothermal power plants in Turkey. GRC Transactions, 40, 163-174.

Aydin, H., Junesompitsiri, C., Hunkar, F., Schmidt, J. D., Schmidt, R., & Schmidt, A. (2024). Boosting the Performance of Geothermal Wells Using Progressively-Burning Propellant and High-Rate Acidizing. In SPE Western Regional Meeting (p. D021S010R004). SPE.

Aydin, H., Merey, S., & Akin, S. (2024, February). Pressure Transient Analysis of Alaşehir Geothermal Reservoir. In 49th Workshop on Geothermal Reservoir Engineering, Stanford, California, USA (pp. 12-14).

Aydin, H., Tezel, S. I., & Erol, S. (2025). Optimizing inhibitor injection in geothermal wells with electrical submersible pump. Geothermics, 127, 103238.

Jolie, E., Scott, S., Faulds, J., Chambefort, I., Axelsson, G., Gutiérrez-Negrín, L. C., ... & Zemedkun, M. T. (2021). Geological controls on geothermal resources for power generation. Nature Reviews Earth & Environment, 2(5), 324-339.

Tezel, S. (2018). *Alaşehir-Piyadeler (Manisa) jeotermal alanının hidrojeolojisi ve jeokimyası* (Master's thesis, Dokuz Eylul Universitesi (Turkey)).