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Update On European Geothermal Binary Units Delivered By Turboden

Joseph Bonafin

Turboden, via Cernaia 10, 25124 Brescia, Italy

info@turboden.it

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ABSTRACT

Turboden is a leader in the Organic Rankine Cycle Technology (ORC) technology and business. The company was established in 1980, so has almost 4 decades of experience behind it. Currently there are already 380 Turboden ORC plants in operation or under construction in 42 countries worldwide, utilizing turbines designed in-house.

Turboden has seven geothermal binary plants in operation, and two under construction. The plants are located in Germany, France, Austria and Croatia, supplying base-load power and heat for the local communities.

In the last few years, Turboden has successfully implemented 4 geothermal plants in the Molasse basin (Bavaria, south of Munich). One 5 MW geothermal power plant (in Sauerlach), two 5.6 MW plants in the same region (in Dürrnhaar and Kirchstockach), and a 4.1 MW cogen geothermal plant in the city of Traunreut, designed to deliver also up to 12 MW thermal power to the local heating grid [1].

In August 2017, Turboden won a European tender for a 3.4 MWel plant to be realized in Holzkirchen. This order establishes the Turboden's leadership in the German ORC geothermal market.

Turboden's successful experience continues in France, for the Soultz-sous-Forêts plant in operation. Currently Turboden is in the construction phase for another geothermal plant in the Upper Rhyne Valley.

In Croatia, Turboden has constructed one of the largest single ORC turbines for the 17.5 MW Velika Ciglena project which has been in operation since December 2018.

The technical features and the operational data of these plants will be described in detail, focusing on both the performance figures and availability of the ORC unit and on the overall availability of the projects (including downhole geothermal pumps and balance of plant).

1. OVERVIEW OF TURBODEN'S PRESENCE IN EUROPE

Turboden has a growing presence in the European geothermal market, and this has been increasing very by year, buoyed by solid and dependable performances of its existing plants in operation.

Germany, more specifically the Molasse basin, has been an area of focus for Turboden and its efforts have been rewarded with four geothermal plants operating with high availability. Another one, in Holzkirchen, is currently under construction and will add to the reference list of Turboden once it is commissioned.

Moving away from Germany, other developments include a 17.5 MW plant built in Croatia for the production of electricity. The Velika Ciglena plant hosts one of the biggest turbines ever built for a binary plant. Another plant worth of mentioning is the Soultz-sous-Forêts plant, located in France, in operation since 2016 with continuous operation and good performance figures.

We look at each of these plants in more detail below.

2. SAUERLACH

Sauerlach geothermal plant has been in operation since the beginning of 2013. It is one of the three geothermal plants operated by the local utility provider StadtWerke München, built by Turboden. Sauerlach plant has a gross power of 5 MW with a water temperature of 140°C. It uses a custom turbo-generator to maximize efficiency, minimize noise emissions and provide maximum usage of the available limited space. The plant is a unique example of architectural integration of a power plant with a building, with a turbogenerator indoor (two turbines coupled to the same double-shaft generator), and a dissipation system (air cooled condensers) placed on the roof. This flexibility in lay out design that Turboden brought to this project is one of the unique features of this plant. Along with the production of electricity, the plant is capable of island mode operation to feed the local municipality with highly available heat. This allows the operation of the unit in the absence of a local utility grid.

The Sauerlach ORC power plant won the Geothermal Energy Prize of Bavaria mainly due to the outstanding operational data in 2017. During this period the plant reached an overall availability (including balance of plant and ESP pump) of 98%. When reviewed by itself, the ORC availability was a very high 99.5% [2], which reiterates the high dependability and reliability of Turboden's ORC units.



Figure 1: Sauerlach geothermal plant

3. KIRCHSTOCKACH AND DÜRRNHAAR

Kirchstockach and Dürrnhaar plants have followed Sauerlach in Turboden's expansion in the Molasse Basin of Bavaria. They are electric power-only plants with an identical gross power output of 5.6 MW from the generator terminals. Both plants are in operation since 2012 and operated by StadtWerke München since the takeover in 2016. Due to the proximity of the plants to the city of Munich, stringent noise limits are required to allow the units to be located at the current site. Fortunately, with the help of detailed noise reduction engineering efforts, these strict requirements have been successfully achieved and the plant is operating acceptably since the commissioning of the units. Another distinctive feature is that the organic working fluid used in this plant is HFC-245fa, a non-flammable liquid, and this helped to minimize the environmental risk in this area, so that there is no detrimental effect to a forest nearby. Both plants have double-pressure level cycles with a geothermal water temperature of 138°C.

A detailed analysis of availability and performance of the ORC conducted in collaboration with the owner shows the following average performance figures in the period 2015-2017.

Dürrnhaar: Average ORC availability 98.2%; total availability of plant (including ESP pump and balance of plant): 83%.

Kirchstockach: Average ORC availability 9811%; total availability of plant (including ESP pump and balance of plant): 90.1%.

Both plants have exceeded the guaranteed performance for operation by far during the above mentioned 3 year period, despite real world operating conditions (scaling at evaporator inlet, and fouling on air condensers. Turboden implemented the needed O & M activities including removal of the fouling on the air condeners which contributed to the high availability numbers. [2].



Figure 2: Kirchstockach geothermal plant



Figure 3: Dürrnhaar geothermal plant

4. TRAUNREUT

Located in Traunreut, a town in southeastern Bavaria which is located on a deep geothermal reservoir, the Traunreut power plant has been in operation since 2016. GKT (Geothermische Kraftwerkgesellschaft Traunreut GmbH) is operating the plant which produces about 4 MW electric power by using geothermal water at 118 °C and it is coupled with the district heating system of Traunreut.

The plant is able to deliver a peak load of 12 MW thermal power. HFC-134a is the organic working fluid of choice for the operation, while the plant is optimized for highly efficient electricity production at a very low sound level (< 92 dBa PWL).

5. SOULTZ-SOUS-FORÊTS

The well-known Soultz-sous-Forêts geothermal site, located in Northern Alsace (France) is home to a Turboden ORC unit of 1.7 MWe. The reservoir is a deep fractured granite, thus the type and quality of the brine has high salinity (about 100 g/l of TDS). An enhanced geothermal system has been developed by GEIE to produce geothermal water at 160 °C. Thus, Turboden provided an innovative air-cooled ORC plant to exploit the heat from the geothermal brine and reinject into the source with a temperature of 75 °C. Turboden has the capability to analyse and determine the most suitable working fluid for each geothermal resource and select that fluid to maximize performance, while taking into account the required environmental impact requirements. And in this case, the working fluid selected for the single-pressure level process was isobutane, which has proven to be a good choice, as it has provided excellent performance results.

A detailed analysis of availability conducted in collaboration with the Owner has shown the following availability figures in the period 2017-2018:

Average ORC availability: 99.9%

Overall plant availability (including line shaft pump and balance of plant): 91.2% [2].



Figure 4: Soultz-sous-Forêts geothermal plant

6. HOLZKIRCHEN

The town of Holzkirchen is located in the south of Munich, on the Molasse basin. Turboden is constructing a 3.4 MW to be delivered to its customer, Geothermie Holzkirchen GmbH, in 2019. The aim of the customer is to provide the local grid with electric energy and server the households connected to the district heating network with clean thermal energy.

A double-pressure level system is being adopted by Turboden, which utilizes isobutane as the working fluid. The combined heat and power plant will have a geothermal water temperature of 152°C at the inlet and 50 °C at the outlet. This is possible due to the low salinity of the geothermal water. The plant is currently under commissioning, with start-up expected very soon.



Figure 5: Holzkirchen geothermal plant

7. VELIKA CIGLENA

In Croatia, Turboden designed and constructed one of the largest single ORC turbines, for the 17.5 MW Velika Ciglena project.

The innovation here for this particular ORC is the adoption of the 5 stage large axial ORC turbine for this geothermal application, a first of its kind for this application. The Velika Ciglena project uses steam and hot water at 170 °C to produce electricity to the local power grid. The region of Velika Ciglena is situated in Bjelovar subdepression, the north east of Croatia. The Turboden ORC plant converts the heat harnessed from two geothermal wells into base-load renewable electricity. The ORC process is based on a single turbine, with isobutane as working fluid. The cooling is accomplished by air cooled condensers. As of today, the Velika Ciglena is the largest single turbine installed in a geothermal ORC power plant in Europe.

The plant was commissioned in December 2018 and it is in base load operation since that time. In a further review of this paper information regarding the overall plant's availability will be provided.



Figure 6: Velika Ciglena geothermal plant

8. AFYON

Afyon Jeotermal Turizm ve Ticaret A.Ş (AFJET); was established in 1994 with the purpose of installing district heating facilities exploiting geothermal water resources and providing greenhouses with the return water. The company is a municipal enterprise, and owns 24 geothermal wells to date and provides heating for 23,900 homes.

In addition to electricity production, AFJET also provides heating for homes in the area and water for the greenhouses.

A custom made Turboden ORC solution was designed to address the customer's need and the plant was put into operation in 2017. The unit produces 3 MWe. The geothermal brine is exploited at a temperature of 110°C and a flow rate of 150 kg/s while cooling towers are employed to cool down the condenser of the ORC.



Figure 7: Afyon geothermal plant

9. VENDENHEIM

Turboden has been awarded a new project in the Upper Rhyne Valley in France by Fonroche Geothermie. The projected power output will be 11 MWe exploiting the liquid brine at 200°C from a single deep well in Vendenheim (close to Strasbourg). The project is still under construction with the estimated start-up date is by the end of 2019.

10. CONCLUSION

Based on the experience and field data from Turboden's geothermal ORC installations in Europe, the following key conclusions can be reached.

First, Turboden's ORC units have very high reliability and availability, achieving in the 99% range provided the heat input is stable and meets the designed conditions.

Secondly, Turboden is growing the market and becoming a leader in Europe for ORC geothermal, particularly in Germany. (Now the company is spreading their products to other parts of the world including Asia, Africa, North, Central and South America).

Finally, Turboden is very flexible and capable in customizing designs to meet the local requirements in terms of space available, maximizing turbine efficiency, meeting stringent noise constraints, using different fluids for different locations and resources to optimize the environmental impact, and a large variation in size from about 1 MW to about 20 MW for a single turbine.

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