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Altheim geothermal plant for electricity production by ORC-turbogenerator

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ABSTRACT

The paper describes the plan **of** the town of Altheim in Upper Austria to produce electricity by an Organic-Rankine-Cycle-Turbogenerator in the field of utilisation of low temperature thermal water. **The** aim of the project is to improve the technical and economic situation of the existing geothermal plant.

KEYWORDS

Organic Rankine Cycle, turbogenerator, low enthalpy

1. Introduction

Geographically Altheim is located in tbe Austrian federal state Upper Austria; about 15 km to the German border and about 60 km to Salzburg. The area of Altheim covers about 22 square kilometres, about 5000 people live there.

Geologically Altheim is located in the Molasse Basin. The Upper Austrian part is the area between the Flysch Zone of the Alps in the south and the old Bohemian Massif in the north.

The deepest units in the underground of **the** basin are the crystalline primary rocks - mainly granite - and the above lying rocks of the Mesozoic - mainly of the Jurassic system and the Cretaceous system. **The** carbonates of the Malm period belong to **the** uppermost layers of the Jurassic system which show a good permeability along crevasses and commissures (in part through solution).

The borehole Altheim "Thermal 1" was drilled in 1989 to a depth of about 2.400 m. The artesian flow rate was 11 **l/s, the** head temperature 98 °C. At the end of 1989 the production bad **sunk** dramatically. The reason was a clogging by a mixture consisting of stone-material and bentonite, but it was not possible to drill through this material. Therefore a "window" was cut in the 9 5/8" casing at a depth **of** about 1.800 m. From this window a deviation hole was drilled to a depth of about 2.300 m. After a period of 3 months water was found

again with at improved yield 18 l/s by artesian flow. After stimulating the borehole by hydrochloric acid the artesian flow rate increased to 46 l/s and the head temperature increased to 104 °C. Considering these parameters the borehole "Altheim la" is one of the most powerful geothermal wells in Central Europe in non-volcanic areas. The capacity is more than 22 MW_{th}. The renewal rate in the Upper Austrian part of the Molasse basin is estimated to 250 l/s, which would allow to install a capacity of about 100 MW_{th}.

The thermal water is of the sodium-bicarbonate-chloride-type with an enhanced content of sulphur. The mineralisation is very low, reaching only 1,3 gram per litre.

2. Present utilisation

At present the geothermal resource is only used for district heating and for domestic hot water. Some 2.000 people (40 % of all people in Altheim) are supplied by geothermal energy, the installed capacity amounts more than 10 megawatt. In 1998 about 23.000 MWh were produced; the needed thermal water amounts about 510.000 m^3 or average 16 l/s *(peak* 35 l/s). Table 1 shows the environmental consequences of the geothermal plant.

The expenses for the production well, the network, the heat exchangers and the other equipment were about 8,140.000 EURO. The financial support by the government was about 2,108.000 EURO (non repayable); about 4,542.000 EURO are loans, the rest of about 1,490.000 EURO are contributions by the customers. At the time being the interests are low - less than 4 %.

The network has a length of about 14,5 km. The inlet temperature is between 90 and 80 "C, the outlet temperature is about 55 to 60 "C.

The operator of the district heating is the Municipality of Altheim.

Tabie I: *Environmentai impacts of the geothermalpiant*

Reduction of greenhouse gases by using geothermal energy (comparison 1989 and present)			
Gas	1989	Present	Reduction
CO_2	11,150.000 kg	3,094.000 kg	72 %
NO_2	8.000 kg	2.600 kg	67 %
SO_2	32.200 kg	11.200 kg	65 %
CO	411.000 kg	173.000 kg	58 %
Energy savings			
Fossil fuels		2.500 t/year	

3. Future utilisation

At the start of the project in the year 1989 the people responsible assumed it would not be necessary to reinject the used thermalwater due to the small size of the project In companson the mstalled power reached 2,5 MW_{th}, and today more than 10 MW_{th} In fact however it was known that reinjection is state-of-the-art So the expenses for the second well were not included in the pnce for the heat (by doing that the project would have failed because of the higher price)

By looking for possibilities how to finance the reinjection well the idea was born to generate electncity This seemed and still seems to be the best way because a further greater expansion of the district heatmg network was and is not possible Therefore, the Municipality of Altheim jointly with the German Company Terrawat asked the Italian company Turboden to investigate the feasibility Turboden presented two different solutions (Tables 2 and 3)

Table 2 Solution 1

Geothermal water inlet temperature	104 °C
Geothermal water flow	28.6 kg/s
Geothermal water outlet temperature	80 °C
Geothermal water pressure at module inlet	2 bar g
Geothermal water pressure at module outlet	1 bar g
Fouling coefficient (water side) in the heat exchangers	5700 W/m2K
Cooling water flow	100 kg/s
Cooling water temperature (mean value)	10 °C
Cooling water outlet temperature (about)	15.2 °C
Dimensions	2,5 x 12 x H2,5 m
Noise level at 50 m	<= 70 dbA
Binary unit net electric output	240 kW *

* Net value of all bmary plant auxiliaries supplied (working fluid feed pump, lubrication system etc)

These solutions are based on the present artesian water flow which is 46 l/s The aquifer has a very good productivity In 1989 a test by airlift produced a rate of more than 70 l/s Due to the poor stability of the surface equipment it was not feasible to increase the flow rate Considenng a flow rate of about 100 l/s a power output of about 750 kW can be obtained

Table 3: *Solution 2*

Geothermal water inlet temperature	106 °C
Geothermal water flow	81,7 kg/s
Geothermal water outlet temperature	78,6 °C
Utilised thermal power	9.410 W
Water pressure loss across evaporator	<= 1 bar
Water pressure loss across condenser	<= 1 bar
Fouling coefficient (water side) in the heat exchangers	11.400 W/m2/K
Cooling water flow	270 kg/s
Cooling water temperature (mean value)	10 °C
Cooling water outlet temperature (about)	17,6 °C
Dimensions	2,5 x 12 x H2,5 m
Noise level at 50 m	<= 70 dbA
Binary unit net electric output	750 kW *

* Net value of all binary plant auxiliaries supplied (working fluid feed pump, lubrication system etc.).

The turbogeneratorwill be installed within a dense constructed area (close to both wells). Therefore it is not possible to envisage an air-cooled system. The cooling water will be taken fiom the same river in which the used hotwater was discharged. The river is at a distance of about 200 m fiom the planned installation of the turbogenerator.

Working fluid

The working fluid is a new refrigerant of the hydrofluorocarbon class (HFC) that is now fast replacing the ozone-depleting CFC 22. This fluid is safe also fiom the toxicological point of view and not flammable. It will enable a safe plant both for people working in the industry, and, more in general, for the environment itself. During the thermodynamic design phase of the ORC machine, the use of a new, less pressurised working fluid (still very safe from an environmental and toxicological point of view and non ozone depleting) will be evaluated.

Financing

Table 4 presents the different costs of the operation. With such a cost, it was impossible to realize the project. The only a chance was to obtain a sufficient financial support, and this was offered by the European Union's programme THERMIE (4th Framework) THERMIE

is a vital part of the European Union's strategy for meeting the energy challenges which we face today:

- To reduce lasting and reliable energy services at affordable cost and conditions.
- To reduce energy consumption.
- To reduce the environmental impact of the production and use of energy, in particular CO_2 emissions.
- To strengthen the technological basis of industry.

THERMIE operates around two principal axes:

- sharing cost for projects implementing innovative energy technologies.
- other measures to define energy RTD (research/technological development) strategies and to promote and disseminate energy technologies.

THERMIE's is looking to the folowing objectives:

- To improve energy efficiency, in both demand and supply sectors.
- To promote a wider utilisation of renewable energy sources.
- In the field of renewable energy sources the THERMIE program covers also the sector of geothermal energy.
- European Community fmancial support may he granted for shared cost projects. Projects eligible are those designed to advance or implement innovative techniques, processes or products, for which the research and development stage has, for the most part, been completed. This type of project is designed to prove the technical viability and the economic advantages of new technologies by applying them on a sufficiently large scale for the first time.
- According to the technical Annex 3.7 "GEOTHERMAL ENERGY" of the THERMIE-programme support will be allocated to demonstration projects aiming at improving the energy efficiency and cost-effectiveness of geothermal plants in the following configurations (selection):

  - exploitation of geothermal fields where resources are proven or well documented, in order to reduce mining risks;

  -production of electricity.

To be accepted, a project must meet several conditions (for instance).

- It must use, with a view to their implementation and propagation, innovative techniques, processes or products.
- It must offer technically and economically viable prospects of subsequent commercial exploitation of the relevant technology.
- It must be difficult to finance because of major technical and economic risks. Commercial investment projects cannot be supported.

Investment cost	**EURO**
Reinjection well with connection pipe to the production well	2,632.847 €
Turbogenerator, cooling, pumps, wellhead, pipes etc.	1,175.912 €
Design, monitoring, dissemination, evaluation	701.858 €
Total	4,510.617 €
Annual cost	
Repayment	386.698 €
Other expenses	152.090 €
Total	538.788 €
Production cost/MWh	**140,90 €**

Financial Contributions

Corresponding to the European Commissions „Call for proposals" from September 1995 the Municipality of Altheim and the companies Turboden (Brescia/Italy), Geotherma (Le Blanc Mesnil/France) and Terrawat (Markt Schwaben/Germany), submitted a proposal for electricity production by ORC-turbogenerator.

This proposal was favourably evaluated by the European Commission (among 13 projects, ranked as „to be supported"), and the Commission decided to give a contribution up to about 1,565.000 EURO, which is 34.70 % of the eligible cost.

The Government of Austria also gives a contribution up to ahout 640.000 EURO.

These contributions show the following consequences of the costs:

Investment cost	2,300.415 €
Annual cost	349.861 €
Production cost per MWh	91,50 €

4. Benefits

It is unimportant if it is summer or winter, if the sun is shining or not, if it is windy or calm. The air keeps clean, there are no negative effects on the landscape.

As the used thermal water is given back to the underground geothermal energy production works like a rechargeable battery. Moreover users can say: "We are literally sitting on our own energy source". Beside the reduction **of** CO_2 emissions the yearly savings of oil amount ahout 1.500 tons.

5. Status of the project:

The reinjection well was performed as a deviated one (by the Austrian company Stoffner TransGlobeEnergy) and was completed successfully at the depth of 3.078 m. The aquifer was tapped at the vertical depth of 2.150 m. The horizontal distance between the production well and the reinjection well reaches about 1,7 km. The pumping tests show a flow rate of some 70 Vs and a head temperature of 93 "C. As the drawdown was only about 70 m, it will not he a problem to extract about 100 l/s. The first part of the reinjection tests is finished with 30 l/s and a temperature of ahout 55 °C, and no reinjection pump is necessary. The ORC-Turhogenerator is ordered and under construction. The on-site-test of the machine and the start of the electricity production will be in June 2000.

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