TWO-YEAR EXPERIENCE IN THE OPERATION OF AN AQUIFER THERMAL ENERGY STORE BASED ON SURPLUS HEAT ARISING FROM A GAS AND STEAM COGENERATION PLANT AT NEUBRANDENBURG / NE GERMANY

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1. INITIAL SITUATION ON THE SITE OF NEUBRANDENBURG

Major parts of the stock of buildings in Neubrandenburg are connected to a central district heat supply network with the below nominal parameters:

- heating capacity: 200 MW
- feeding flow temperature: 130 °C
- return flow temperature: 60 °C

The base load in this network is covered by a gas and steam cogeneration plant:

- power: 77 MW
- heat: 90 MW

In summer, the high efficiency potential of the cogeneration process cannot be utilised completely. Since the heat supplied in summer in Neubrandenburg is used mainly for sanitary hot water preparation, the heating demand set up is rather low (approx. 20 MW), thus being even below the amount of heat arising from power generation at minimum load (approx. 40 MW). The differential amount had to be released into the atmosphere via a re-cooling unit.

The Neubrandenburger Stadtwerke GmbH operates another, smaller district heat supply system along with the one described above.

- heating capacity: 12 MW
- feeding flow temperature: 80 °C
- return flow temperature: 45 °C

From 1987 to 1998, the network “Rostocker Straße” was supplied geothermally:

- productive horizons: Hettangian/ Upper Postera
- depth: 1,200 m – 1,300 m
- flowrate: 150 m3/h
- thermal water temperature: 53 °C – 55 °C
- mineralisation: 120 – 130 g/l

The direct heat exchange of the thermal water and the heating network achieved small volumes only. The installed hot water-driven absorption-type heat pump had to be added to the system quite often which reduced both the energetic and the economic efficiency. The small heat sales in summer put another load on the result.
2. CONCEPT

The described problems of both energy generation plants shall be solved by retrofitting the geothermal plant as an aquifer heat store.

- The excess heat arising from the cogeneration plant in summer which has been led by now to the cooling towers is supplied to the central district heat supply network and fed to the geothermal heating plant.
- In the geothermal heating plant, the surplus heat serves to increase the heat potential existing in the subsoil at large depth by approx. 25 K up to 80 °C
- In winter, the heat store is operated as by now the geothermal heating plant, but the thermal water temperature is 80°C – 65 °C when produced.

Based on the behaviour of the two district heat supply systems and the cogeneration plant as well as on the assumption of the following parameters of the heat storage loop

- maximum thermal water flowrate 100 m³/h
- heat charging temperature 80 °C

Thermodynamic calculations gave the result that an amount of 12,000 MWh of heat can be fed into the aquifer storage from April through September. 8,800 MWh shall be recovered in direct heat exchange in winter with an output ranging from 4.0 to 2.9 MW.

![Figure 1: Scheme of heat storage](image)

3. TECHNICAL WORK

After thorough inspections, two of the four wells of the geothermal heating plant were selected for re-installation as heat store wells. The “warm” well is based on the production well Gt N 1/86 which developed the Upper Postera horizon. In the course of the work, the initial concept of almost unchanged re-use had to be given up, however. Especially the bad condition of the wire-wrapped screen called for a completely new installation which included finally even a fiber glass-reinforced protective casing reaching down into the store section. In addition, a new well head was installed so that later the thermal water can be produced via the pump riser and injected through the
annular space. The injection well Gt N 4/86 of the geothermal plant which develops the Hettangian horizon will be used as the “cold” well. The well was drilled deeper to reach the Upper Postera horizon, the screen was installed, and the old perforation in the Hettangian was sealed by a 7” liner which was installed and cemented. Moreover, a glass fiber protective casing, a submersible pump and a new well head were installed. A scheme of the well construction is shown in Figure 2.

![Figure 2: Well construction](image)

Most of the existing pipe system is re-used in the surface loop. At several points, bypasses were installed to manage the reverse direction of the thermal water flow, in particular around the filter groups. In addition, a pressure-maintenance unit was added including a nitrogen loop to fill the annular space in the respective production well.

A modern automation unit provides reliable operation of the thermal water loop and regulates the integration of store into the overall heat supply system of the Neubrandenburger Stadtwerke GmbH. The aquifer store is monitored from the central control room of the cogeneration plant.

### 4. OPERATION

Figure 3 shows a simplified flow chart of the technical units. The two district heat supply networks which form the heat source and the heat sink of the store and the storage loop itself are shown, but – to make it clearer - without the peak-load units, the absorption-type heat pump and all secondary systems. The network “Rostocker Strasse” will be separated completely from the storage loop when heat is fed into the aquifer store, i.e., whenever surplus heat exists in the central district heat supply system exceeding the demand of the above network. A sub-section fulfills now the duty of an intermediate loop between the central district heat supply network and the storage loop. The store is charged exclusively with this surplus heat which is controlled by the differential pressure. The flowrate in the storage loop is determined by the desired injection temperature in the “warm” well.
When heat is discharged from the store, the return flow of the low temperature network “Rostocker Strasse” is led directly to the thermal water heat exchanger. Now, the thermal water flowrate is determined by the specified temperature at the outlet of the apparatus on the heating network side. The central district heat supply network or the existing peak-load boilers allow for additional heating.

Commissioning and trial run of the aquifer store began in March 2004 after completion of an extensive program of production, injection and, to a less extent, circulation tests. Charging was started with an injection temperature of approx. 70 °C, increasing it up to approx. 78 °C in autumn, and observing continuously the thermal water behaviour, in particular with regard to the formation of solids. Finally, 10,000 MWh of heat could be stored in the aquifer by the end of October 2004.
The commissioning of the store towards heat discharging took approx. three months. Mainly the adjustment of the automatic control engineering processes among the individual heat producers was difficult at the beginning. The first regular phase of discharging started in mid-January 2005 and ended after the feeding of approx. 3,000 MWh of heat into the district heat supply system “Rostocker Strasse” already in March 2005, since then surplus heat arised again from the cogeneration plant.

Since February 2005, the aquifer thermal energy store has been operated in fact without any technical problems, controlled only by the surplus heat / heat demand situation and interrupted by a power plant inspection in June 2005. Meanwhile, a first complete annual cycle can be presented. The three figures below show the essential energetic parameters.

Figure 4: Temperatures at the heads of the cold and warm wells of the aquifer store

Figure 5: Thermal output while charging and discharging the store
Beside the smooth operation with parameters in the charging phase (80 °C, 100 m³/h and, thus, up to 4.0 MW) which are meanwhile in conformity with the design, Figures 4 and 5 highlight the following:

- The period which is available for the discharging of heat from the store is shorter than planned originally. Namely in the recent years less heat from the district heat supply network was sold due to energy saving measures.
- At outdoor temperatures slightly above 2 °C, the limit of the heat supply capacity of the cogeneration plant is achieved, resulting in numerous and in terms of time unpredictable changes of arising surplus heat from the cogeneration plant and demand for additional heating capacity. The mainly in the starting and stopping processes very inert aquifer thermal energy store cannot balance these variations. For this reason, a simple mode of operation was determined. Above a mean daily temperature of 5 °C predictable for three days, the store is principally operated in the charging regime, and below 2 °C in the discharging regime. In the mean time it remains out of operation, even if a few hours of short-time operation would be possible.
- In the heating period, the return flow temperatures in the district heat supply system are temporarily clearly above the maximum temperature of 45 °C according to the design. Principally, this is to be understood within the context of the function of the house service sub-station when preparing sanitary hot water (cf. Figure 10 which makes clear the effect of sanitary hot water production by night). The heat capacity which can be taken from the aquifer store is reduced by up to 40 % temporarily. However, significant improvement can well be expected here after modifications in the sub-stations.
- The present economic frame conditions allow for the generation of more power in summer with corresponding amounts of surplus heat than it was the case when the concept was developed.

The above aspects lead to the picture presented in Figure 6. Compared to the initial concept, the charging of a major amount of heat in summer is opposed by a minor amount of heat discharged in winter. The coefficient of heat recovery is now approx. 42 %. Although this complies with the initial expectation for the first year of operation, it is not due to major storage losses in the aquifer at the beginning, but to external aspects, basically.

![Figure 6](image-url)
In the following, the two principle modes of store operation shall be described in more detail within the context of the respectively characteristic frame conditions.

Figure 7: Heat surplusses and their use on 5th and 6th November 2005

On 5 and 6 November 2005, i.e., typical days in the transitional period, surplusses amounting to 4.0 – 5.0 MW can be fed into the network “Rostocker Strasse”/ heat store. The store takes up the difference, respectively, between this surplus and the direct use of the heat in the heating network.

On these days, the heating medium was available with a temperature of approx. 95 °C. Via an intermediate loop, it heats up the thermal brine produced from the cold well of the aquifer thermal energy store from approx. 45 °C to approx. 80 °C. At this temperature level, the water is injected then into the warm well. The other advantage beside the storage effect is that the primary network is cooled down to a very low temperature level, thus influencing positively the efficiency of power generation in the plant.

Figure 9: Coverage of the demand in the district heat supply network “Rostocker Strasse” on 23th and 24th January 2006

23 and 24 January 2006 were cold days with outdoor temperatures clearly below 0°C. The cogeneration plant was operated at maximum capacity. In addition, boilers fed considerable amounts of heat into the centralised district heat supply system from which also the peak load of the district heat supply network „Rostocker Strasse“ is covered. Insofar, on these days the heat store could be operated at maximum capacity, as in this way it restrained exclusively the inefficient peak load boilers.

On warmer winter days with only low-level operation of the peak-load boilers, of course, the extent of the heat store operation is measured by the reduction of this boiler operation. In any case, the discharging of the heat store must not reduce the direct use of the surplus heat arising from the cogeneration plant.

Figure 10: Temperatures in the district heating system and in the heat store on 23 and 24 January 2006
5. CONCLUSION

Efforts aiming at minimisation of the primary energy use by combination of different processes of energy transformation are hindered often by the seasonal diverging of energy offer and energy demand. The development of efficient and economically reasonable techniques of long-term heat storage, such as ATES, may contribute significantly to the solution of this problem.

The aquifer heat store which was commissioned in Neubrandenburg in 2004 will help in the next years to further develop the know-how in the field of underground thermal energy storage at a high temperature level. Therefore, the operation will be accompanied by an adequate monitoring programme.

During the first year, the store to a high extent came up to the expectations tied up with its technical operation. There were not to be stated any considerable technical problems which could be assigned to the operation of the store. The water chemistry was manageable, i.e. above all, precipitations of solids were not observed.

Actually, cuts still have to be made regarding the energetic efficiency of the store operation, however, this is not caused by the store itself, but it is due to the characteristics of the connected heat producers and consumers. In particular a still too low potential of the heat sink in winter or the still too high return flow temperatures in the heating networks hinder the sufficient discharging of the store.

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