CONVERSION OF GERMANY'S FIRST SEASONAL SOLAR THERMAL ENERGY STORAGE INTO AN INNOVATIVE MULTIFUNCTIONAL STORAGE

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Abstract

In 1996 the first large-scale seasonal solar thermal energy storage in Germany was built in Hamburg-Bramfeld. It was operated until 2009 in a central solar heating plant with seasonal storage storing solar thermal energy from the summer period to the heating season.

The owner of the storage, the E.ON Hanse Wärme GmbH, now decided to connect the storage to the district heating net of Hamburg-East and to convert it into an innovative multifunctional storage. This means that besides solar heat in future also surplus heat from a waste-fuelled cogeneration plant will be charged into the storage. With this connection a favourable combination of solar seasonal heat storage and waste heat from cogeneration will be demonstrated for the first time.

The partners in this project are Hamburg Gas Consult GmbH for the design of the overall system, WTM Engineers GmbH for the design of the storage reconstruction, the Technical University of Brunswick (IGS) for monitoring and Solites for scientific accompaniment and advice.

1. Introduction

The 1996 built seasonal thermal energy storage (STES) is a ground buried concrete tank with a water volume of 4 500 m³. For the last 13 years it was charged by 3 000 m² (2.1 MW) of solar collectors to deliver heat for space heating and domestic hot water preparation to residential buildings, see Fig. 1.

Fig. 1: Solar housing area in Hamburg-Bramfeld

Fig. 2 shows the service area of this central solar heating plant with seasonal storage (CSHPSS) in Hamburg-Bramfeld.

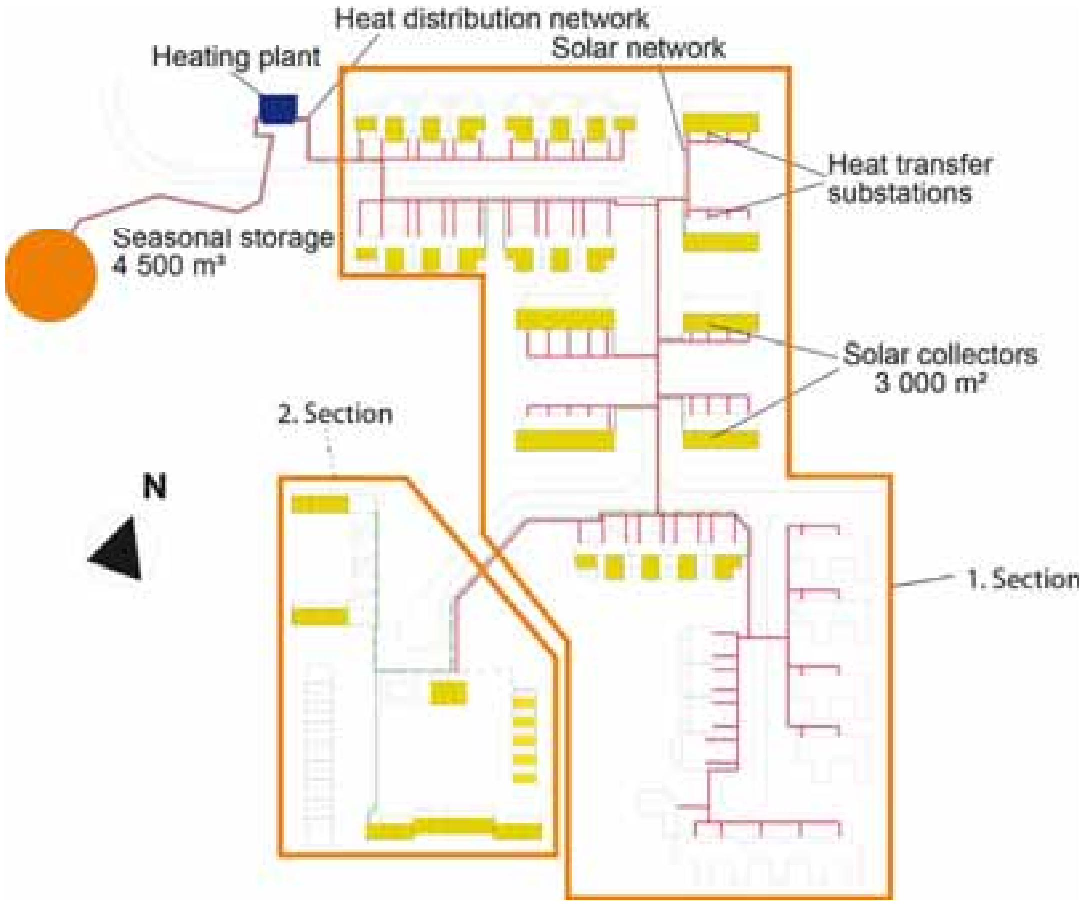

Fig. 2: Site plan of the CSHPSS in Hamburg-Bramfeld

The main characteristics of the plant are:

- Start of operation: 1996 (the first pilot plant for large-scale seasonal thermal energy storage in Germany, built within "Solarthermie-2000")
- Owner: E.ON Hanse Wärme GmbH
- Service area: 124 Row houses
- Heated area: 14 800 m²
- Total heat demand: 1 610 MWh/a
- Solar collectors: 2 920 m² / 2 040 kW
- Storage volume: 4 500 m³ Concrete water tank
- Solar fraction: 49% (design)

2. Reasons for the reconstruction of the storage

The decision for the reconstruction of the STES was made mainly because of two reasons that are described more detailed in the following sections. The first one is the fact that the efficiency of the storage was much lower than originally expected during the last years of operation. The second is the plans of the owner for a connection of the storage to the Hamburg-East district heating (DH) network, which is also operated by E.ON Hanse Wärme GmbH.

2.1. Operational results of the storage

There are numerous publications available about operational results of this plant. At this point only a short summary can be given as a background for the following. For more detailed information see e.g. [1 - 3].

Overall it can be stated that the solar system in general was working well, but the efficiency of the storage and the whole solar system was much lower then expected at the time it was realised. Nevertheless, the plant was the first large-scale pilot installation of this kind in Germany and the experiences and results gave very valuable and important knowledge for the development of the technology and for the construction of following plants.

The mean efficiency of the seasonal storage during the last years of operation was 46 % compared to 89 % design value. This fact is mainly induced by thermal losses that are up to four times higher than designed. As the storage is a central part of the CSHPSS also the system efficiency and the solar fraction was lower then designed. The latter was at average in the order of 25 % during the last years of operation compared to 49 % design value.

The main reasons for the higher thermal losses of the storage are:

- A fluctuating and in the long run raised groundwater level in the wider area. By this the uninsulated bottom of the storage is temporarily exposed to moving groundwater.
- The return temperatures of the heat distribution network are higher than expected. By this the uninsulated bottom of the storage is also on higher temperatures than designed what results in higher thermal losses in the bottom region.
- At the design time no detailed information about the dependency of the thermal conductivity of insulation materials on temperature and humidity rate was available for high temperatures.
- A humidification of the insulation material. This was approved by taking samples at various places around the storage surface.
- The dismounting of the roof (see below) showed a damaged insulation in the roof caused by a leakage in the inner liner.

2.2. Connection to the Hamburg East district heating network

With the connection of the STES to the district heating network the E.ON Hanse Wärme GmbH aims to extend the utilization of the storage, to increase the share of cogeneration heat in the DH and by this to reduce CO_2 emissions and to improve the economic efficiency of the overall system. In future the STES will be used to store besides solar heat also surplus heat from a waste-fuelled cogeneration plant. This will only take place in time periods with no or only limited usage of the storage for a solar application, e.g. after discharging of the STES in winter and before charging of solar heat into the STES in spring. The monitoring data shows that this time period was in average about four month in the previous years. In peak hours stored cogeneration waste heat can be delivered to the DH net and hence there is no need for the operation of inefficient peak load boilers.

As a side effect the connection allows for a further solarisation of the DH area. This is described more in detail below.

3. Reconstruction concept for the storage

The original construction of the storage is not able to withstand the thermal stress that is caused by the high capacity rates of 7 to 10 MW during charging of the storage by the cogeneration plant and discharging in peak hours to the DH net.

A description of the original storage concept can be found in [4]. For the reconstruction two concepts were developed and tendered in parallel:

1. Insulation of the storage construction from inside

   To reduce the thermal stress to the existing concrete construction the structure has to be insulated from the inside. The insulation material on the other hand has to be protected from humidification by a suitable liner. Seven columns that carry the roof complicate the insulation and lining work.

   Due to a high groundwater level the tank can only be emptied during construction with a costly lowering of the groundwater table. Otherwise the whole structure would buoy up and be destroyed.

2. Installation of a second tank into the existing concrete casing

   In this concept the existing roof and the seven columns are removed and the storage is only partly emptied. Afterwards the bottom truncated cone is backfilled, see Fig. 3. By backfilling a buoying upwards of the structure can be avoided without a lowering of the groundwater table. Then a new steel tank is placed inside the existing concrete structure.

Both concepts were tendered and after availability of the offers an economic and risk assessment was conducted by E.ON Hanse Wärme GmbH. Based on this assessment it was decided to realise the second concept.

The construction work started in January 2010 and is expected to be finished in October 2010. Fig. 4 shows some pictures from the storage construction: on the upper left side the original construction from 1996 can be seen. The upper right side shows the beginning of the reconstruction work after removal of the roof. The picture on the lower left side gives a top view on the new roof construction of the inner stele tank and the on the lower right side the welding of the side walls can be seen. The roof was first prepared on top of the tank bottom. The side walls are realised in a winding method. That means a steel band is fed continuously into a welding machine. During welding the roof and the existing wall section is rotated and lifted to the top until the final size of the tank is reached.

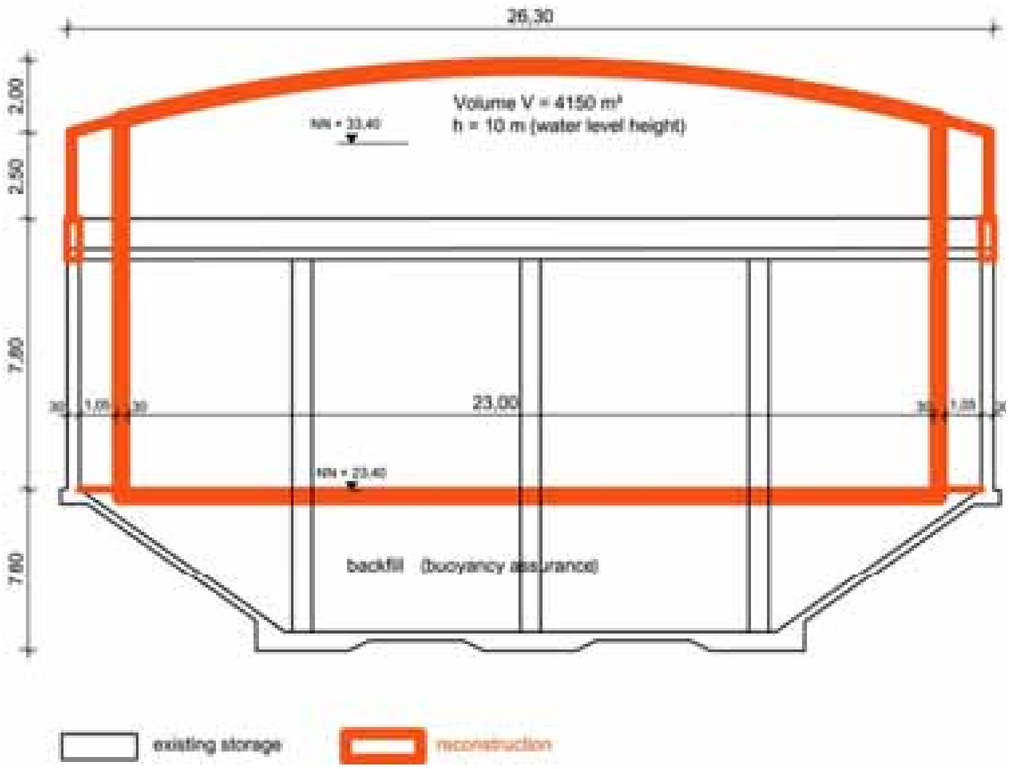

Fig. 3: Reconstruction concept for the storage (source: HGC – Hamburg Gas Consult GmbH)

Fig. 4: STES in Hamburg during construction in 1996 (left) and reconstruction in 2010 (upper right and bottom)

4. Integration of large-scale solar thermal plants into the Hamburg-East district heating network

In the course of the planning for the connection of the STES to the Hamburg-East district heating network the E.ON Hanse Wärme GmbH developed a feed-in model for the future integration of large-scale solar thermal plants into the DH network. In a first phase the integration of up to 20 000 m² (14 MW) of solar collectors is foreseen, to be doubled later in a second phase. The solar plants can be realised everywhere within the service area of the whole Hamburg-East DH network. The main addressees for this feed-in model are big housing companies that own large housing areas in Hamburg.

The main idea behind is to offer a service for storage and transportation of solar heat, allowing for the realisation of simple and cheap solar systems without storage facilities and complex hydraulics and controls. The solar heat can be fed into the DH network directly at any time and taken back at a later time (up to eight month later) or even at another place within the whole DH service area. Besides the reduced investment cost for the solar plants this gives the housing companies the possibility for allocating the renewable heat from the solar systems to the primary energy demand of other buildings in the area. In this way it is possible to benefit from favourable incentive programs.

For the service the E.ON Hanse Wärme GmbH plans to charge a service fee of 2,1 – 2,5 Ct./kWh. For this fee the owner of the solar plant gets heat storage and transportation to any other location within the DH network without any thermal losses.

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