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The New Central Solar Heating Plants with Seasonal Storage in Germany

Dirk Mangold, Thomas Schmidt
Solites - Steinbeis Research Institute for Solar and Sustainable Thermal Energy Systems
Nobelstr. 15, 70569 Stuttgart, Germany, Tel: +49 711 673 2000 0, Fax: +49 711 673 2000 99,
info@solites.de, www.solites.de

Abstract

From 1995 to 2002 eight pilot plants for solar assisted district heating with seasonal thermal energy storage have been built in Germany in the context of the national R&D-programme Solarthermie-2000. The comprehensive monitoring data and experiences show that all investigated storage concepts are working without major technical problems (Mangold et. al., 2003). The subsequent R&D-programme Solarthermie2000plus, that is implemented by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), enables the realisation of new pilot plants. The new projects in Crailsheim and Munich are under construction at present and will start operation in autumn this year. Further pilot plants will follow in the next years to develop the seasonal heat storage technologies, the solar system and its comprehensive system integration step by step towards the applicability in the market.

Keywords: Central solar heating plant, seasonal storage, pilot plant, large system

1. Introduction

After some years of pause in building new pilot plants with seasonal heat storage, now the next generation of central solar heating plants with seasonal storage are presently in realisation in Germany with support from the national R&D-programme Solarthermie2000plus. Solites carries out the scientific technical supervision, basic R&D on storage concepts and, together with scientific partners, the scientific-technical accompaniment for the new plants. In the seasonal storage solar thermal energy is gathered during summer to provide a district or block heating net with solar energy also through the heating period in winter. The designed solar fractions of the new plants amount to 47 and 50 % of the total annual heat demand for space heating and domestic hot water preparation. Each plant comprises an advanced or new seasonal storage technology:

- In Munich a pit storage of 5700 m³ water volume is built of prefabricated concrete elements. The cylindrical wall and the frustum roof are going to be prestressed. The water and water vapour tightness is secured by an inner stainless steel liner.
- In Crailsheim a borehole thermal energy storage with a ground volume of 37,500 m³ will be built. The integration of the thermal insulation system into the storage takes care of the groundwater flow in the upper storage levels.
- In Eggenstein a storage built as an insulated pit is in the planning process. The storage will transfer the results of a three years research project carried out at the University of Stuttgart into practical application (Ochs, 2006). The storage is going to be built in 2007. Detailed information about this system will be published in due time.

2. The Munich Project

The project development for the solar assisted district heating system with seasonal thermal energy storage at the Ackermannbogen in Munich started in the year 2000. The construction of the residential area started in autumn 2005. The seasonal thermal energy storage is currently under construction just as the solar collector fields on top of three multifamily houses. The heat supply system is expected to start operation in autumn 2006.

Table 1 gives the main data of the system and the involved project partners. Owner of the system are the Munich City Utilities, the scientific accompaniment within Solarthermie2000plus is performed by ZAE Bayern., Solites takes care of the scientific-technical supervision and develops the detailed storage concept in close cooperation with the planner.

Table 1: Data of the solar assisted district heating system in Munich

Solar collector area	2,900 m²
Water volume seasonal thermal energy storage	5,700 m³
Service area	300 apartments
Total heat demand	2,300 MWh/a
Absorption heat pump	1.4 MW
Solar fraction	47 %[1]
Solar heat cost	0.24 €/kWha[2]

Recipient of subsidies	City of Munich
Owner	Munich City Utilities (SWM)
Planner system installations	Kulle and Hofstätter, Munich
Planner thermal energy storage	Lichtenfels eng. consultant, Keltern
System concept	ZAE Bayern, Garching
Scientific accompaniment	ZAE Bayern and Solites
Start of operation	autumn 2006

[1] TRNSYS-Simulations ZAE Bayern; [2] according to calculation guideline of Solarthermie2000plus (BMU, PTJ, 2006)

Figure 1 shows the concept of the heat supply system. The solar collectors charge heat into the heat storage when more solar heat is available than heat is demanded by the local heat distribution network. The main charging takes place during summer. During winter time the stored heat is used to supply the heat demand for space heating and domestic hot water preparation. To reach a high usability of the seasonal thermal energy storage (STES) an absorption heat pump is integrated into the system. The heat pump is driven by heat from a district heating network that also covers the remaining heat demand in the local heat distribution network. The supply flow to the local heat distribution network can be directly reheated by the district heating network to ensure the necessary supply temperature level. The return flow to the district heating network can be re-cooled by the return flow of the local heat distribution network to ensure a maximum return temperature of 50 °C to the district heating network that is required by the Munich City Utilities.

The development of the storage concept considered the four main concepts that are in use in Germany so far (hot-water, gravel/water, borehole (BTES) and aquifer (ATES) thermal energy storage, see Mangold et. al., 2004). ATES and BTES require special underground conditions that are not available at the site. In the progress of the project development it was found out, that the requirements regarding temperature stratification and capacity rate for charging and discharging can not be satisfied by a gravel/water thermal energy storage. For this reason a hot-water thermal energy storage was considered to be the best concept for Munich.

The specific investment cost of this new storage construction is expected to be significantly lower compared to those of the seasonal hot-water heat storages in the projects Friedrichshafen (12,000 m³), Hamburg (4,500 m³) and Hannover (2,750 m³), although it will have an improved heat insulation and a stratification device.

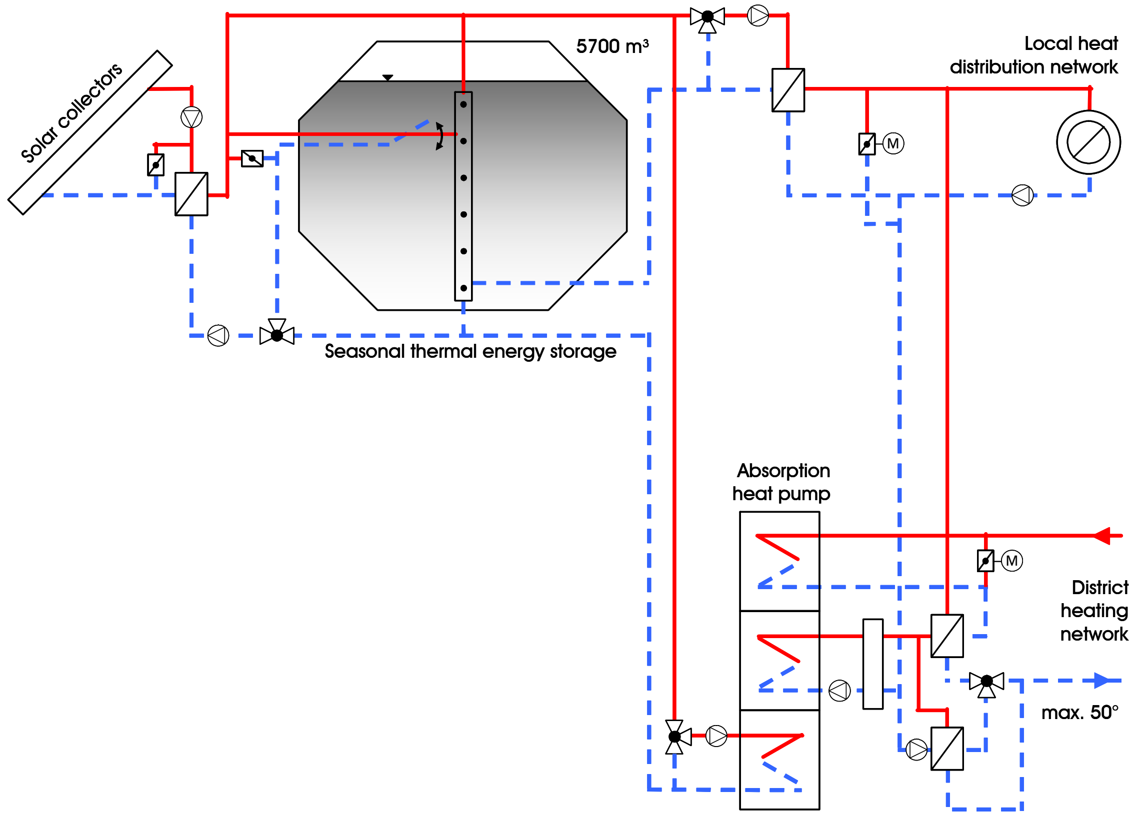

Figure 1: System concept of the solar assisted district heating system in Munich

3. The Crailsheim Project

In Crailsheim, situated roughly between Stuttgart and Nuremberg, a former military area is transferred into a district with a residential area in the north and an industrial area in the south. The two areas are separated by a noise protection wall. Some of former military barracks buildings are modernised, heat insulated and equipped with solar collectors on the south roofs. The new buildings area, named Hirtenwiesen 2, will be covered mainly with small-sized buildings (single family, row and twin houses). A school and a gymnasium have already been built and equipped with solar collectors (700 m²). Hirtenwiesen 2 will be realized in two phases. Within the next years the 1st phase will be built, somewhere in a closer future the 2nd phase will be completed.

The main part of the solar collector area will be built on the south side of the noise protection wall. Between the residential area and the noise protection wall a borehole thermal energy storage will be located that will be operated as a STES.

Table 2: Data of the 1st phase of the solar assisted district heating system in Crailsheim

Solar collector area	7,300 m^2
Buffer storages (water tanks)	100 m^3 480 m^3
Seasonal thermal energy storage (BTES)	37,500 m^3 ground volume
Service area	260 houses, school and gymnasium
Total heat demand	4,100 MWh
Heat pump	530 kW
Solar fraction	50 %[1]
Solar heat cost	0.19 €/kWha[2]

Recipient of subsidies / Owner	Crailsheim City Utilities
Planner system installations	HGC GmbH, Hamburg
Planner hot-water heat storages	Lichtenfels eng. consultant, Keltern
Planner BTES	EWS GmbH, Lichtenau
System concept	ITW, University of Stuttgart and Solites
Scientific accompaniment	ITW, University of Stuttgart and Solites
Technical developments	Solites and planners
Start of operation	autumn 2006

[1] TRNSYS-Simulations ITW; [2] according to calculation guideline of Solarthermie2000plus (BMU, PTJ, 2006)

Table 2 shows the main data of the system and Figure 2 the system concept. The realisation of the whole central solar heating plant started in 2004 with a first, diurnal part. This consists of the solar collectors on the retrofitted buildings, the school and the gymnasium and a 100 m^3 buffer tank that is located close to the school. The solar energy from this part can mostly be used directly to supply the heat demand from the local heat distribution network Hirtenwiesen 2.

The solar collectors on the noise protection wall together with the BTES and a second water tank with 480 m^3 present the seasonal part of the system that is under construction. The water tank of the seasonal part was added because of the high capacity rate of the solar collectors during summer. This high capacity rate can not be charged directly into the BTES during daytime but has to be distributed over a longer time period by reasons of cost effectiveness of the storage system.

Heat from the seasonal part can be transferred to the diurnal part by a 300 m district heating pipeline either directly or via a heat pump. The heat pump allows a higher usability of the temperature difference of the seasonal heat storage and thus a higher storage capacity. In addition it reduces the temperature level in the storage and therefore results in lower storage heat losses. Furthermore the efficiency of the whole solar system becomes much more robust against high return temperatures from the heat distribution network.

An extensive investigation of the ground showed good prerequisites for a BTES. To design the solar system, a feasibility study for the whole heat supply system was performed by ITW, University of Stuttgart with advice from Solites and showed the best economy (lowest solar heat cost) for the system concept displayed in Figure 2. According to the simulations the BTES will be heated up to 65 °C at the end of September, the lowest temperatures at the end of the heating period will be 20 °C. Maximum temperatures during charging will be above 90 °C. The storage faces up possible ground water flow in the upper part and will be built of a new piping material for the ducts. It is yet not decided if PEX or PE-HT will be used.

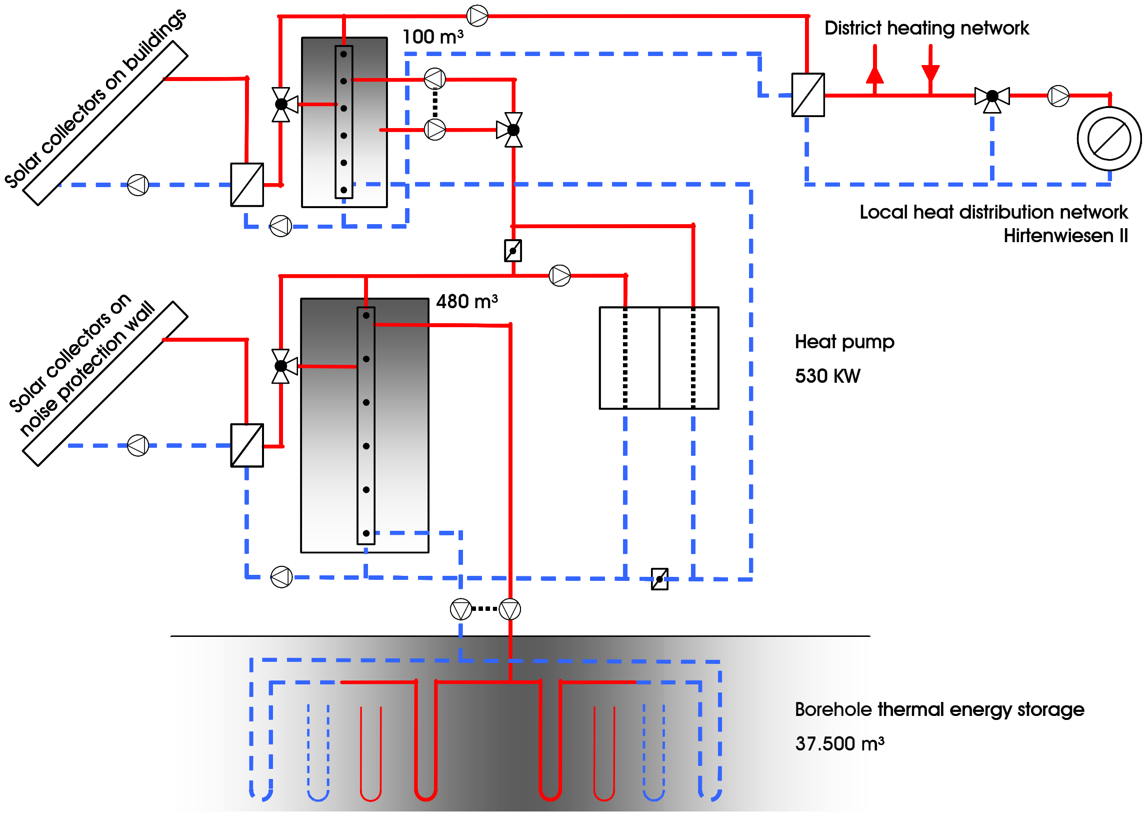

Figure 2: System concept of the solar assisted district heating system in Crailsheim

4. Status Quo of System Technology and Perspective

The first German central solar heating plant with seasonal storage started operation in 1996. The main R&D-tasks for the first generation plants were essentially technological: the technology for large, roof integrated collector areas had to be developed, the first system design methods had to be applied and the fulfil of storing heat seasonally had to be proved.

With the following pilot plants the second generation technology could be realised over the year 2000. Some of the main results were the achievement of a state of the art for large roof integrated collector areas, that all four of the seasonal storage technologies are in operation in at least one pilot plant - and that all these four technologies could be verified!

In the third generation plants that are under construction in 2006 the solar thermal developments are only part of the total R&D work. Besides the reduction of storage building costs by technological innovations the main R&D-topics are:

- Comprehensive, integral technical project development:
  The scientific technical accompaniment of the new pilot plants starts years before the first building activities to enable the incorporation of the prerequisites for high solar fraction and low solar heat cost. E.g. in Munich the maximum allowed average return temperature of the local heat distribution network is 30 °C. To enable this encouraging aim a comprehensive catalogue of requirements for building services engineering was set up as an integral part of the contract of sale for the building site.

- Reduction of solar heat cost by multi usage:
  The profitability of units of the solar system can be improved if the single unit offers additional features that can favourably used by the conventional heating system. E.g. in Crailsheim the solar buffer storages (100 m³ and 480 m³) are simultaneously used as pressure maintenance device of the local heat distribution network.
- Innovation impulses for the conventional heating system:
  The need of low supply temperatures to the collector areas to achieve high efficiency requires well adapted heat supply systems on low or very low temperature levels. E.g. the catalogue of requirements for building services engineering that is used in Munich led to a new room heating system that cool the return flow of the radiators via a subsequently connected floor heating system.

Solar heat cost for the new plants are calculated to 24 Euro-Cent/kWh for Munich and 19 Euro-Cent/kWh for Crailsheim (without VAT and subsidies). Started in 1996 with solar heat cost being four times the cost for conventional heat from fossil fuels, the technology for central solar heating plants with seasonal heat storage is today on the way from three times to a double of the conventional heat cost – without considering the recently strong raised fossil fuel prices. And at the same time the current pilot plants save about 50 % of CO_2-emissions of an entire residential area!

5. References

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6. Acknowledgements

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