Solar Thermal System to support the district heating network in Wels

By Rolf Meißner

Summary

On 12 May 2011 the largest evacuated tube collector to date, with an area of 3,400 m^2 and an output of around 2 MW, came into operation on the roof of the exhibition hall in Wels, Austria. The collector feeds energy directly into a domestic heating network. Due to this solar thermal system, in summer the energy providers can at times reduce their use of gas by 50%. The same water is used in both the solar thermal system and the heating network. The collector field extends over almost 10,000 m^2 of the roof, while all the machinery needed for its operation and transfer of heat to the heating network is housed in a boiler room of around only 50 m^2. The expanded water from the solar thermal installation runs directly into the heating network, which is the sole reservoir for the solar energy.

picture 1: 3388 m² CPC-ETC (Evacuated Tube Collector) gross collector area for a Domestic Heating Network (DHN)

Aims of the Solar Thermal System conception

The operators of the district heating network in Wels were looking to support their gas heat generator with a system which produced no CO_2. Wels is the location of Austria's most important environmental fair, and therefore the exhibition hall roof ought to be used as a display of the most up-to-date methods of obtaining solar thermal energy. It was also high time to install a pilot solar district heating network in Upper Austria, an area active in the field of solar technology, as such technology has long been investigated in places such as Carinthia and Scandinavia.

The planner's viewpoint

The district heating network was not to be changed in any way – the solar thermal installation had to be completely subordinate to the existing arrangement. Originally, the brief only comprised a solar installation with requirements on the feed temperatures, expected energy returns and use of the maximum available area for the collectors. However, it became necessary for the company awarded the work to rise to an additional and formidable challenge, as they became responsible for the complete hydraulic, electric and IT planning for the heat transfer to the district heating network, the development and supply of the switchboard technology, the hardware and software for the SPS control, the monitoring equipment, the communication with the district heating network control centre and the internet interface.

In every circumstance, the system has to be self-protected: for instance, during power cuts; if the district heating network is shut off without announcement for maintenance work; or if components such as the pumps fail.

According to the wishes of the client, the assembly and construction supervision was carried out by his own subsidiary firm. As solar thermal systems, which use water and no anti-freeze fluid, were not a widespread technology at this time, the supplier also had a large role in the planning of the installation of the system.

At the start, both the client and the contractor wanted the roof area to be put to considerably better use. However, objections from the structural engineers, the necessity of leaving

walkways for the clearing of snow, and over-generouse measurements of the roof dimensions reduced the collector area originally planned by around 20%.
The ongoing trade-fairs were not to be disturbed by the construction. Therefore much of the work could only be done between exhibitions, and during the fairs every visible and audible hint of construction work had to be a large extent removed, which led to a relatively long construction time.

Challenges and solutions

1.) *The space for the on-site machinery such as pumps, valves and the expansion apparatus is limited to a single room of around 50 m².* This meant that a heat storage tank or an automatic pressure control system was out of the question. The district heating network itself is the best store of solar heat. The expansion of the water of the solar thermal system takes place mainly in the network. Only within a small range, 3 closed expansion vessels with a volumes of 500 litres each come into action. As the solar thermal system uses water, all the pipe cross-sections and fittings can be chosen to be slightly smaller than would be necessary for a mixture including anti-freeze.

picture 2: Thermal Solar System in Wels, the collector field covers a roof area of about 10,000 m², all heat exchangers, pumps, valves and vessels are arranged in an heating room less than 50 m².

2.) *In winter, the pressure in the Wels heating network return pipe can fall below the minimum static pressure which, due to the height of the exhibition hall roof, is necessary for the operation of the system.* Therefore, so that a higher pressure and a sufficiently high boiling temperature can be accommodated in the solar thermal loop, a heat exchanger became necessary, although the same water flows on both sides. The use of water is also advantageous in this respect, as, if an anti-freeze mix were used in the collectors, the heat exchanger would have to have been at least three times as big.

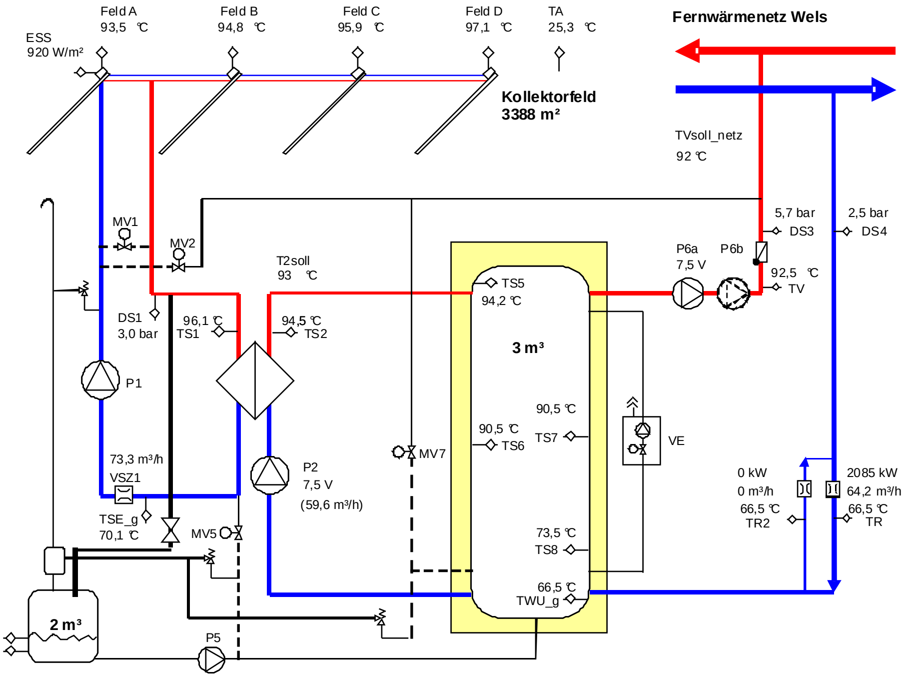
3.) *High feed temperatures of at least 85℃ are req uired throughout the year, and in winter temperatures of up to 115℃ are desired.* In order to provide considerable yields, it was decided to use CPC evacuated tube technology, which supplies an appreciably higher power density in this temperature range than any other solar thermal collector technology.

4.) *Unfortunately, the exhibition hall roof does not point to the south, but around 45° to the south-west.* In addition, around 10% of the roof always lies in the shadow of its supporting structure and parts of the building. CPC evacuated tube technology is also the best choice in this regard, as this design has the lowest reduction in performance when the orientation deviates from the south and when the position of the sun in the sky deviates from its midday position.

5.) *Differences in height of around 10 metres exist between the exhibition hall roofs.* To avoid possible gravity circulation inside the collector field, it was subdivided into a 15m-high 3000-m² field and a 25m-high 400-m² field.

6.) *In winter pressure differences of up to 9 bars with the district heating network have to be considered.* In turn, the pressure drop in the collector field is around 1.5 bars. Therefore a hydraulic mixing cylinder, which can be filled and further emptied in around 2.5 minutes, was placed between the solar thermal system and the district heating network. 2 pumps were connected in series to transfer the heat from the mixing cylinder to the network. A single pump can cope with the volume flow rate of around 65 m^3/h for a pressure difference of up to 5 bars, while the second must help for greater pressure differences. An electrical energy input of approximately only 6.5 MWh is needed for the pumps and valves of the solar thermal system. However, for the feed into the heating network an additional 20 MWh accumulates due to the high pressure differences. Exactly the same pump energy is saved in the district heating network headquarters though, when the solar thermal system supports the power plant.

7.) *At no time is any air allowed to enter the heating grid pipes or any heating grid water allowed to be lost, and all water which returns to the district heating network must be degassed.* Consequently, under the control of sensors the collector field is automatically and continuously degassed after its filling and during further use. Despite this, filling the field with district heating network water is so easy that the collector field can be comfortably filled and brought into operation by a single engineer in 1 to 2 hours. In addition, there's only one ventilation point in the whole system, and that's the hydraulic mixing cylinder. That aside, the collector field is completely free from fittings such as ventilators, chokes, control valves and the like. This is important for a long lifetime of use, for the optimal operation, for safety against frost and for bringing the collector field into operation easily.



picture 3: Simplified Scheme, snapshoot and touchscreen display of the controller

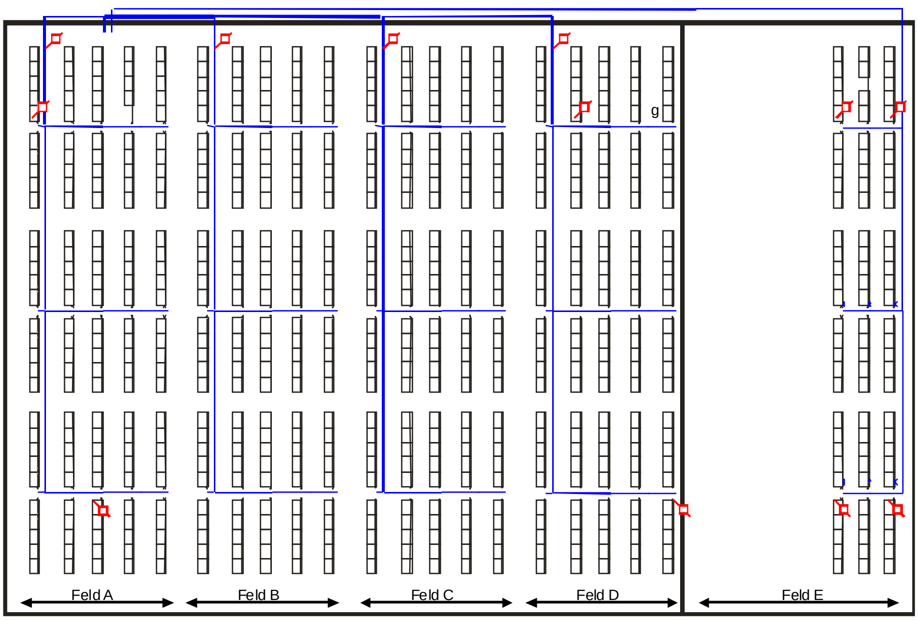
8.) *The solar thermal system must be self-protected against thermal stagnation, including stagnation due to a power cut.* It was therefore designed so that, if it begins to boil, the water is forced very quickly from the collectors and, depending on the circumstances, is taken up by either commonly the heating network or alternatively the (Ausdehnungsgefäßen). Before the plant was brought into operation, tests run at midday with a cloudless sky found that this process takes place silently and without external energy in a few minutes. Afterwards, the solar thermal system refills itself independently and functions again as before. If the heating network is shut off for repair work and the solar thermal system therefore finds itself in a thermal standstill, the water is removed by a receiver tank. This water is later automatically pumped from the tank back into the system. The collector field can also be ´started hot`, if superheated steam with a temperature of up to 300℃ is present in the collectors.

9.) *The solar thermal system must be protected against frost, including in the case of a power cut.* In normal operation, small quantities of heat are pumped into the solar thermal system to keep it frost-free. It is expected that a maximum of 50 MWh (3% of the solar yield) will be needed for this. In the case of a power cut, an uninterruptible power supply ensures the frost protection of the system. This requires less than 100 W of electrical energy as, during a power cut with a risk of frost damage, the Wels heating network automatically takes over the work of the pumps. This water technology has been tested over 60,000 times since 2003, including in hundreds of large-scale solar thermal installations.

Technical Parameters

Temperature	85...110 ℃
Volume (incl. tubes)	ca. 12 m³
Gross collector area	3388 m²
Peak power / rated power	2.8 / 2.37 thermal MW
Max. continuous output	1.8 MW
Expected yield	1.300 MWh / year
Electrical energy use	6 MWh / year
Network pumps	20 MWh / year
Solar fraction	<2 % in winter up to 50 % in summer

picture 4: Some hundreds of meters different pipes collect the heat from the roof. Thanks to exact calculations the complete roof installation doesn't contain any de-aerators, throttles, valves and supporting pipes according to "Tichelmann".



picture 5: The collector field

Costs and profitability

The total cost of the solar thermal system was around 1.85M Euros. Around half of this was spent on the collectors along with the stands, the connection systems, the controls and sensors as well as all the planning. The other half was spent on the support structure of the collectors, the tubes and compensators, the pumps, valves, closed expansion vessels, the hydraulic switch, the thermal isolation of all components and the whole electric and hydraulic installation. Despite the south-west orientation of the collectors and the year-round shade from the buildings and the supporting structure of the hall roof, a yield of at least 1,300 MWh is expected. In 20 years of operation, this results to around 26 GWh, or a price of barely 70 Euros per MWh. This rough estimate neglects many factors, the most important of which is inflation. For how much will 70 Euros be worth in 20 years? And how much will 26 MWh cost in 20 years? The solar thermal installation could also work for 25 or 30 years. As a large proportion of the costs consisted purely of research and development and, with hindsight, there was more potential for saving on the installation, such a system will be from now on for 50…60 Euro/MWh in Central Europe and for 15…25 Euro/MWh on other continents with more sunshine and lower labour and material costs. The given costs contain no distorting funding. Comparison with current energy prices show that solar heat production, as the most effective form of solar energy use, is now ready for independence from (development funds). Recalling the goal of climate protection, it is good to know that the solar thermal system in Wels saves 400 tonnes of CO_2 every year and in other locations could save up to 900 tonnes. However, due to the current low heating prices, at the moment the investor will only save at most 60,000 Euros per year. Therefore, an appreciation of the bigger picture and political will is required to build such solar installations today. Large-scale solar thermal system such as that in Wels could immediately fulfil, without further development, up to 10% of German energy needs (corresponding to around 400 billion kWh). This would require a collector area of around 1,000 km^2, around 0.25% of the area of Germany, and would save 100 million tonnes of CO_2 a year.

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