SOLAR COOLING – A WORLDWIDE PROVEN TECHNOLOGY

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Abstract

Worldwide located large scale solar cooling plants with a collector area up to 3900 m² represent S.O.L.I.D.'s experiences in this field. The selected references of solar cooling plants are situated on three different continents: America, Asia and Europe. Providing options between different concepts of sizing and business models (e.g. ESCO[1]s) allow individual solutions to meet the personal demand of the client. Every region has different framework conditions and challenges but professional experience and innovative ideas form the basis for well operating solar cooling plants and satisfied customers. Moreover future development trends of conventional refrigerants in terms of ozone depletion potential (ODP) and global warming potential (GWP), as well as raising electricity prices and weak distribution grids during peak times show that there has to be an alternative to conventional systems. Successful solar cooling project examples verify that solar cooling already is a proven technology which has a huge potential to become one of the mayor alternative solutions for the worldwide increasing demand for air conditioning!

1. Introduction

S.O.L.I.D. has more than 10 years experience in the construction and financing (using contracting models) of solar thermal plants from 25m² to 7,000m². Since 2003, a number of solar cooling projects have also been carried out. Currently 12 projects with a total cooling power of 1.5 MW and collector area of more than 3,500 m² (2.5 MW) are already operational. For these projects, the solar plant covers most of the cooling demand and in some cases, as conventional back-up systems aren't always available, the required cooling is supplied to 100% by the solar cooling plant. The extension wing of the United World College of South East Asia (UWCSEA) is designed with a solar thermal system providing solar cooling and domestic hot water (DHW) for the campus. This project is currently in construction phase. With a collector area of 3,870 m² and a chiller capacity of 1,500kW it will be the largest solar cooling plant in the world and in addition it will operate as the first solar cooling ESCO in the world.

2. Selected large scale solar cooling plants in America, Asia and Europe

In each of the following solar cooling plants the key items such as cooling load, collector area, storage capacity and a short explanation of the system are given:

2.1 126m² solar cooling plant in Arizona, USA

The first solar cooling system has been erected approx. 20 km north of Phoenix, Arizona. The partners; S.O.L.I.D. USA, the Maricopa County Desert Outdoor Center and Arizona Public Service (local energy supplier) together were called on to identify cost reducing measures for the existing compressor water chiller.

[1] ESCO: Energy Service Company

The existing system with a cooling power of approx. 50 tons / 175 kW was dimensioned to easily cope with peak loads in the local desert climate. The solar cooling system was designed with a base-load capacity of 20 tons / 70 kW. S.O.L.I.D. installed a solar refrigeration unit, which uses Lithium Bromide as the thermal transfer medium and is currently being driven by 126 m² of solar thermal panels.

Fig. 1 Desert Outdoor Center in Arizona

A 4 m³ buffertank serves as an intermediate heat store. The control system gives priority to the solar cooling unit, therefore the existing compressor water chiller is only used when load peaks are higher than the solar contribution.

Another interesting feature about this project is the construction method:

The Absorption-type refrigerator complete with necessary pumps, the solar interconnection including expansion vessels and safety equipment, and the entire control system were shipped after first being fully installed in a container in Austria.

With this method, the unit can be quickly erected on site, furthermore the reliability of operation is assured as a trial run can be done in the pre-fitted container before it is shipped. An Internet connection in the container is used both to carry out remote maintenance as well as to report any faults.

2.2 638m² solar cooling plant in China, Asia

The installation of a 1,305 m² Austrian produced solar plant has been completed on the roof of the swimming pool in Qingdao. Solar energy will now be used to provide the Olympic Village and Sports Hall with cooling and warm water. The plant is also coupled with the local district heating network, which takes care of possible peak loads.

The roof of the swimming pool provided a particular challenge during this project, as the collectors had to follow the curved architecture. As well as the solar collectors used for this project, all pump and control units for the plant were produced in Austria and shipped to Qingdao. The installation was carried out using local personnel in China & one Austrian site manager.

The plant is remotely controlled from Graz using tele-monitoring. Our experienced engineers can constantly monitor the plant in Qingdao and alter settings if necessary.

This enables us to guarantee optimal performance of the plant.

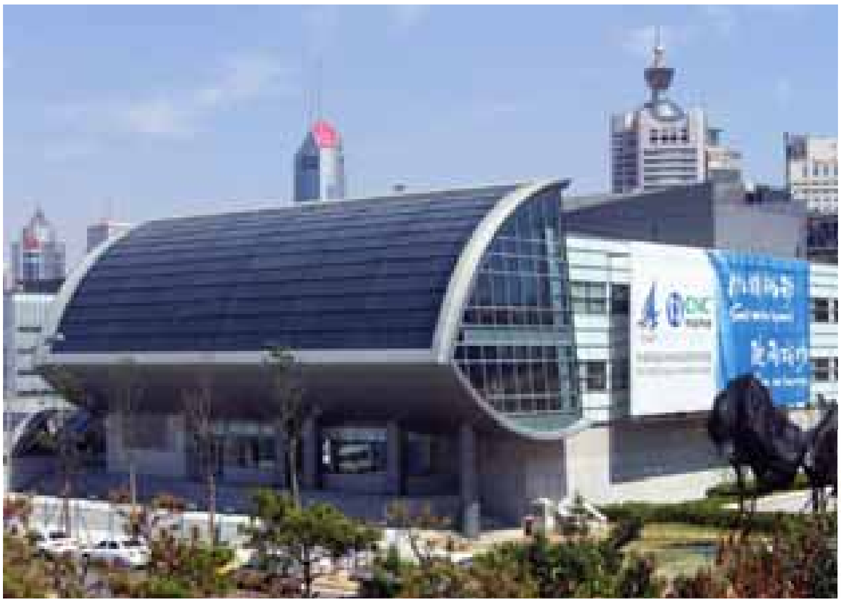

Fig. 2. Sports Hall in Qingdao

2.3 1,579m² solar cooling plant in Lisbon, Europe

S.O.L.I.D. has set new standards in the field of solar cooling systems with the commissioning of the solar system situated on top of the bank building of the largest bank in Portugal, Caixa Geral de Depósitos (CGD), in Lisbon. This prestigious project, in cooperation with local partners like Energia de Portugal (EDP) as main partner and several others, was able to start all-out operations in August 2008. The project is considered to be the largest solar cooling system for office buildings in the world.

Fig. 3. CGD in Lisbon

The dimensions of the project are described best by the following figures for the building:

- External physical dimensions, approx. 200 x 80 m/656 x 262 ft
- 17 floors (11 above ground, 6 subterranean) between the mechanical room and the collector arrays

- 100,000 m²/1.1 Mio ft² of office space
- 6,000 permanently employed persons in the building
- 2,500 – 3,000 menus to be prepared per day in the internal restaurant

The energy generated by the collector area, which encompasses 1,579 m²/16,996 ft², is fed directly to two tanks, each with a capacity of 5.5 m³/1,453 galUS.

The energy then is distributed behind those two tanks by seven pump units.

Online tele-monitoring shows today that the predicted energy gain of 900,000 kWh/year is easily reached.

An absorption cooling unit is powered by the solar plant; the generated cold water is fed into the existing cooling distribution system. Furthermore, the energy is used for the auxiliary heating system of the ventilation appliances as well as contributing to the heating of warm water.

- Collector area: 1,579 m²/16,996 ft²
- Deployment of high-temperature collectors
- Storage capacity: 2 x 5.5 m³/1,453 gal US buffers
- Capacity of cooling unit: 545 kW / 155 tons
- Capacity for auxiliary heating system: max. 700 kW / 2.4 Mio.BTU/h
- Capacity for heating of warm water: max. 150 kW/ 0.5 Mio.BTU/h
- Commissioned 2008
- Detailed monitoring during summer 2010/2011 in the course of the R&D project "SolarCooling Monitor"

3. Concepts of sizing a solar cooling plant

Often the most difficult stage of planning a solar cooling plant is to calculate the actual cooling demand. Norm calculations usually give the sum of multiple single peak loads resulting in a very high overall peak load. This demand however will only be required for a very small number of running hours. This explains why electrical cooling machines are mostly over-sized and therefore have to continuously modulate. This unstable operation leads to lower efficiency levels and unnecessarily high power connections. So peak load for sizing a solar cooling plant should be never used!

For sizing a solar cooling plant it is necessary to know the consumption profile of the customer as well as the solar gains in the particular region. Comparing these two profiles during a certain period of time, for instance on a daily, monthly or yearly basis makes it possible to chose one of the three concepts of sizing:

- The "solar instant"
- The "surplus during daytime"
- The "solar monovalent"

3.1 The "solar instant" concept

This concept shows the easiest and most secure way to size a solar cooling plant. The solar system provides never more than 100% of the actual load; therefore the solar energy is used immediately. With this system daily electricity peak is reduced and expensive energy can be saved. There is only a relatively small tank needed, however it is necessary to have a back-up system (either thermal or electric) to secure the supply of demand.

This system is easy to design and has the lowest investment compared to the other two concepts.

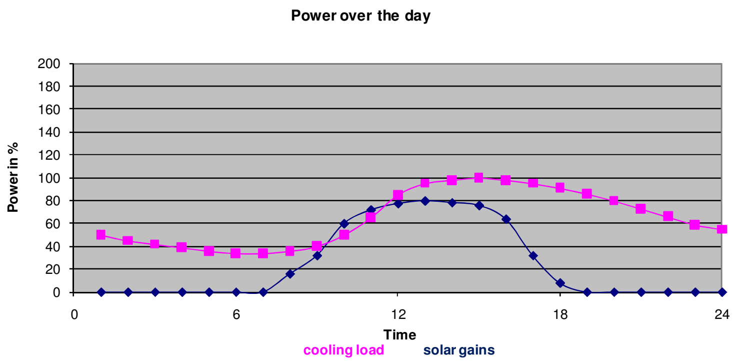

Fig. 4. “solar instant” concept

3.2 The “surplus during daytime” concept

The “surplus during daytime” concept has to deal with one challenge: the solar system provides 100% of the demanded energy on sunny days. The generated surplus of energy can be stored for the evening and night demand. For storing the surplus of heat, larger tanks are required. For covering the consumer’s total air conditioning demand, a thermal or electrical back-up system is needed. The big advantage is that during daytime the electric chiller can be turned off. Therefore expensive electricity at peak tariff can be saved which leads to higher energy savings.

To be able to design such a system, reliable information of a daily and yearly consumption profile is necessary (measured e.g. in ton hours chilled water). This concept allows best pay-back times!

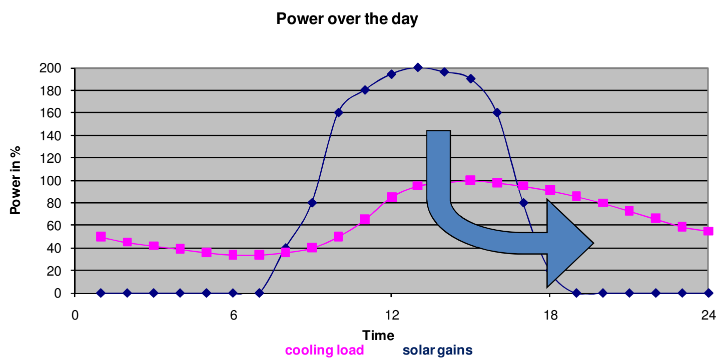

Fig. 5. “solar instant” concept

3.3 The “solar monovalent” concept

The most challenging concept is the “Solar monovalent“. In this case the Solar system provides 100% of the chilled water supply. No back-up system is needed. Bigger Tanks are required for storing all the heat. There will be situations of a surplus or a deficit of solar energy so this needs to be taken into account. Some auxiliary power (electricity) is required for own needs (e.g.: pumps, cooling tower, etc.). Like in “surplus during daytime” concept, very good information is needed on daily/ yearly consumption profiles.

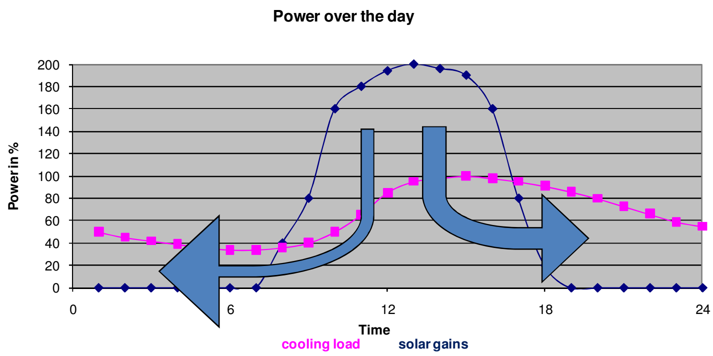

Fig. 6. “solar monovalent” concept

4. ESCo as business model for solar cooling

S.O.L.I.D. has more than 15 years experience as Energy Service Company but up to now solar cooling was not ready for this business model yet. Due to the fact that solar cooling already is a proven technology and with the combination of our experience we are going to have our first Energy Service Company in Singapore with the largest solar cooling plant worldwide.

The main advantages for the client are:

- No investment costs - financial risk is minimised
- Guaranteed development of solar energy price
- Complete energy service package provided by one company, no implication of the customer with technical issues
- Maximum solar output (is also the main ESCo interest)
- No problems with respect to operation and maintenance of the system
- Prestige (standing out from one’s competitors, a positive attitude towards new technologies)
- Marketing strategies (to also sell ecological advantages, to sell engineering)

4.1 3,870m² solar cooling plant in Singapore, Asia

The extension wing of the United World College of South East Asia (UWCSEA) is designed with a solar thermal system providing solar cooling and domestic hot water for the campus.

The solar system is estimated to help cooling an approximate office space of 20,000m² over a period of 6 to 8 hours depending on the climatic. Other than providing solar cooling for the new campus, the solar system will also prepare hot water for domestic purposes to areas such as student hostel toilets and sport amenities shower rooms. The domestic hot water preparation for the new campus will be fully provided by the solar system.

This project is currently in construction phase. The installation includes solar collectors placed on four roofs, storage tanks outside, a chiller, pumps and control unit and a hot water preparation system in the mechanical rooms. It is designed after the “solar instant” concept.

The thermal solar collector areas with a total surface of 3,870 m², are delivering solar heat into the storage tanks. The collector areas supposed to have a power output of 1,900 to 2,000 kW depending on the return temperature of our several consumers. The energy output on a sunny summer day will be approx. 10,000 kWh also depending on the return temperature.

The temperature level for domestic hot water is ~60°C. For this purpose the solar energy is fed preferentially into the storage tank of domestic hot water with a volume of 8m³. By using the solar energy the amount of gas energy for heating up the water is reduced. The residual temperature rise is done now by the electric heaters. The aim is to substitute as much gas energy as possible by the solar energy. The support of domestic hot water has first priority for using solar energy.

To compensate the dilation of the solar (and heat) medium, expansion vessels with a total capacity of 19 m³, are installed. An intermediate vessel protects the membrane of the expansion vessels against high temperature imported by hot solar medium. In case of maintenance the membrane can be changed without moving the vessel itself.

The operation of the absorption chiller is started after reaching min. 80°C in the two solar storage tanks with a total volume of 60 m³. The appropriate pumps are started in agreement with the start routine of the chiller.

The nominal capacity of the chiller is 1,500 kW. This capacity will be reached at an input temperature of the heat medium of app. 88°C. Input temperatures of the heat medium above 95°C can cause a malfunction.

The operation of the cooling tower is started by exceeding app. 30°C of the cooling medium outlet. To control the temperature of the cooling medium the speed of the fan in the cooling tower is controlled. To protect the absorption chiller against mud and other dirt from the cooling tower, a silt trap is installed in the solar circuit. It has to be cleaned at regular intervals by opening the valve at the bottom side.

The cooling medium is controlled and treated by a water treatment unit. The conductivity of the cooling medium is permanently controlled. After exceeding a certain level the waste water valve opens. This procedure is controlled by a separate control panel inside the water treat unit. This control panel also operates the conditioning of the cooling medium with biocide liquid to limit bacteria growth. If the biocide tank falls empty an alarm will rise. In consequence of opening the waste water valve, the water level inside the cooling tower drops and the make up water valve opens to let fresh water into the cooling tower (and the cooling circuit). This procedure will be repeated until the conductivity has reached a proper level.

Fig. 7. Architect’s impression: UWCSEA

With a collector area of 3,870 m² and a cooling capacity of 1,500kW it will be the largest solar cooling plant in the world and in addition it will operate as the first solar cooling ESCo in the world. It will be operational in early 2011. S.O.L.I.D.‘s affiliate ESCo company in Singapore operates the solar plant and charges capacity fee plus energy fees to the client (UWCSEA).

S.O.L.I.D. ESCo pays also for O&M. UWCSEA and S.O.L.I.D. ESCo close a contract over 20 years with the possibility of extension. Energy and Capacity rates are subject of variation according to the development of energy prices. An estimated yearly solar output guarantee is given to UWCSEA for a period of 25 years with a maximum deviation of 5%.

The 76,000 m² campus with the capacity to house 2,500 students will open in August 2011. This new campus, with the help of the solar thermal system got the Singapore's Building Construction Authority (BCA) Greenmark Platinum Certification, which is the highest grade in Singapore's green building grading system.

5. Future development trends

We have to watch the market of conventional refrigerants more carefully. In the past these products had ozone depletion potential (ODP) and nowadays they cause a significant global warming potential (GWP). This leads to the fact that these refrigerants get more and more restricted. Therefore new refrigerants are needed on the market which means that a lot of money needs to be invested and existing chillers need a modification.

The demand for air conditioning is more and more raising. Solar cooling can profit from this trend: If the peak of solar radiation is at the same time than the peak demand for cooling, e.g. air conditioning for offices, etc) supply and consumption will match perfectly. We can use the same radiation that creates the demand, to cover it, cut off electricity peaks and avoid extreme operations on the distribution grid. If peak electricity can be avoided, solar air conditioning saves the most expensive electricity!

The trend to ESCo operations as business model is getting stronger. Accelerating the growth of the solar thermal market worldwide by pushing ESCo projects is a very effective way to demonstrate the power of Solar Thermal energy. There is still little market penetration compared to other renewable energy sources. The main reasons are (1) hesitations from end users to take the investment of the initial costs and (2) doubts on reliability and durability of solar thermal installations. However, selling clean energy at a competitive price which includes engineering and design, building, commissioning, operation and service of the plant by a single contracting party is a very attractive way to serve customers with alternative and thus ecological energy sources. Long-term stability and durability of this model has been shown in nearly 15-year-old realised plants.