New Applications for High Temperature Solar Energy based on SOLITEM Parabolic Trough Collectors

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Abstract

The sun is a sustainable energy source which delivers more energy than required for the whole world every day. The technologies to convert solar energy into final energy have been developed and improved over years. Most commonly known are the direct conversion into electricity with Photovoltaic cells, the usage for thermal applications with thermal collectors, and the operation of concentrating systems for huge power plants (CSP, Concentrating Solar Power).

Besides or between these commonly known paths, there are more possibilities given. This article describes the usage of solar concentrating systems in new ways and for new applications.

Dr. Ahmet Lokurlu has developed the worldwide first-proven, high-efficient economical system based on the novel technological development of Parabolic Trough Collectors (PTC). The system is the first which is useable for rooftop mounting. The solar energy can be used for example for solar cooling, solar steam generation and warm water supply.

Concentrating the solar radiation, the temperature level for the usage of solar thermal energy can be increased. The energy conversion is realized with high efficiencies in the single conversion steps. As the solar energy plants can be adapted to the given requirements very easily, the best solution for each application can be found.

Substituting the demand of conventional energy sources, such as electricity for compression cooling or fuel for steam or heat generation, economical advantages can be realized already today. Regarding the future development, while the sustainable energy source of the sun always will offer enough energy, and the prices of conventional energies will have to increase due to the exhaustion of limited energy sources, these economics must be improving in the future.

1. Introduction

Concentrating solar energy offers the possibility to reach higher temperature levels for the thermal energy usage. Especially at lower solar irradiation values, not-concentrating systems are not able to supply the energy at the required temperatures. Concentrating the radiation, the energy is bundled. Using water as heat transfer medium, about 180 °C can be reached inside the absorber tube. For higher temperature levels, e.g. up to 250 °C, the usage of thermal oils offers the advantage to be able to operate at lower pressure levels.

The application with a double-effect absorption chiller to generate cooling energy is supplied with solar generated hot water at 170 up to 180 °C. For solar steam generation, the steam pressure of the customers determines the required solar cycle temperature level. For most industrial applications, 5 bar steam (about 152 °C) is a standard, and the solar cycle is operated with 180 °C hot water temperature as well.

Besides the possibility to supply the required energy at the temperature level given from the customer's demand, concentrating the solar energy also offers the usage at high energy conversion efficiency. The high-temperature absorber surface area of a concentrating collector is smaller than the absorber surface of a not-concentrating one. Using a Parabolic Trough Collector with a glass tube built up round the absorber tube, the thermal losses can be decreased.

Fig. 1. SOLITEM Parabolic Trough Collector PTC 1800

Figure 1 shows the SOLITEM PTC 1800 Parabolic Trough Collector. The parabolic mirror is concentrating the Direct Normal Irradiation (DNI) onto the absorber tube, which is surrounded by the glass tube. The parabolic mirror of the PTC with 1,8 m aperture and the absorber tube with about 42 mm diameter give the concentration ratio of

$$c = 1800 / 42 = 42{,}86 \quad (1)$$

The efficiency was measured at the DLR, Deutsches Zentrum für Luft- und Raumfahrt, and has been published already [1]. With average operation values such as

- 800 W/m² DNI (Direct Normal Irradiation) which is focussed by the parabolic trough onto the absorber tube,
- 180/160 °C hot water temperature, i.e. 170 °C average, and
- 35 °C ambient temperature (average value for a solar cooling application),

the reduced temperature difference T_m values

$$T_m = (170 - 35) / 800 = 0{,}169 \text{ m}^2\text{K/W} \quad (2)$$

Figure 2 shows the performance of the PTC, the efficiency versus the reduced temperature difference. At the given value, the efficiency is 61%, i.e. 61% of the solar thermal energy are transferred to the hot water cycle. In other words, for the applications of solar cooling or steam generation described above, the solar collector field can be calculated with 60% average efficiency.

The high temperature applications are solar cooling with a high efficient double-effect absorption cooling process, solar steam generation, and other ones. Actually, the usage of the energy gained in the solar fields is combined with two new applications.

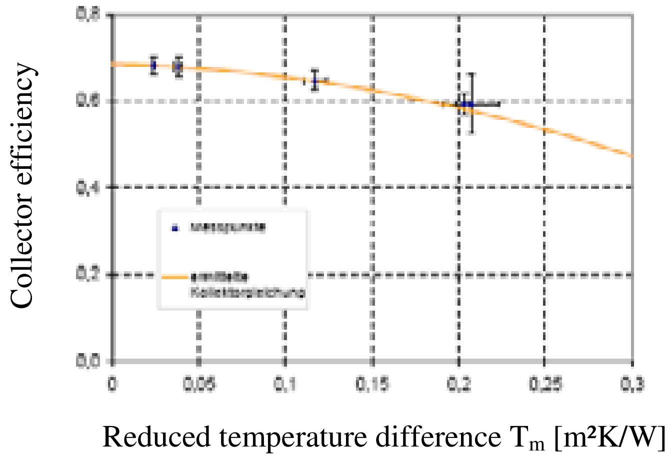

Fig. 2. Performance of the SOLITEM PTC 1800

One actual development is the usage of the thermal energy for the direct generation of electricity in a solar ORC (Organic Rankine Cycle) process. With the possibility to offer cooling, steam and electricity generation in one solar trigeneration plant at the same time, it will be the first realization of such a plant. In this way, all kinds of energy that are required by the customer can be supplied with solar energy.

A second new development is the application of high temperature solar energy in a Multi-Effect Desalination (MED) plant. With this application, the solar energy also can be used to offer clean and potable water.

As the solar collector fields can be adapted to the required demand very exactly, the Parabolic Trough system offers absolutely new applications and several new markets. The commonly known paths of the usage of solar energy can be added by additional ones.

2. General advantages

In general, the high-temperature solar energy solutions offer several advantages. The sustainable energy source enables zero-emission plants. The dependency on conventional energy sources is decreased. Solar cooling combines both the high efficiencies of the collector field and the double-effect chiller, as the high-temperature absorption process generates about times the cooling energy from one unit of solar thermal. The cooling demand is very often almost simultaneous with the offer of solar energy. The peaks in the consumption of electricity, or even stressing the grid caused by electrical operated compression cooling, are cut using the origin of the energy demand as energy source.

Operating a plant for solar cooling or steam generation at the right conditions, for example in Mediterranean states where both good values of solar irradiation and high expenses on conventional energy sources are given, the plant are working economically already today. With the increasing of the expenses on electricity and fuel, the economics are improved. This is possible without the necessity of any incentives. Regarding special sites such as Malta or Cyprus, a solar plant as described reaches amortisation times below 9 years at the actual conditions.

For this, the new applications are fitting very well into the international plans to increase the solar share of the energy supply in several states, and to reduce greenhouse gas emissions. Figure 3 shows the world's sunbelt, which offers the best conditions for the operation of CSP.

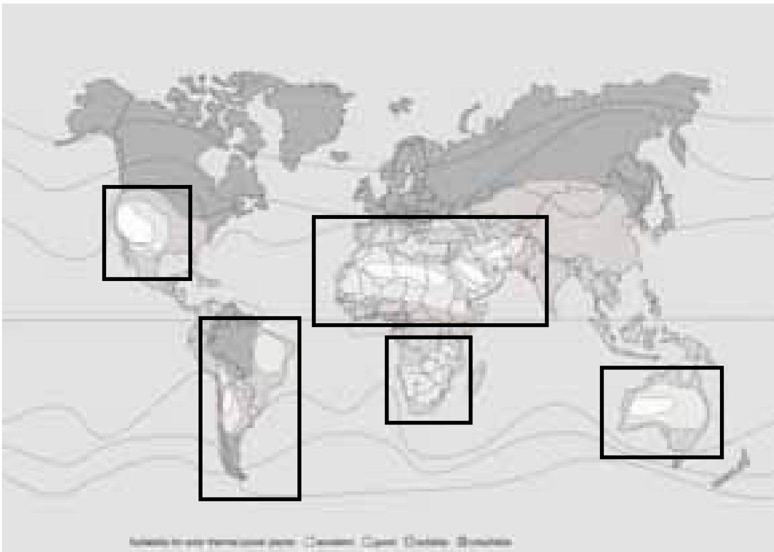

Fig. 3. The world's sunbelt.

3. Solar energy plants

Solar cooling, heating and process steam generation has been realized in different projects already. In 2004, a first installation for all three application, has been realized at the Iberotel in Dalaman, Turkey. This plant recently has been extended, to cover a higher share of the cooling demand with solar energy. Another application has been realized at the FritoLay PepsiCo plant in Tarsus. 600 kg/hr of steam (peak) can be generated with solar energy.

The plant design has to be adapted to the boundary conditions given from the customer and the installation site. The data of the solar irradiation are given from a data source such as METEONORM, and with the installation of the SOLITEM collector field, also are measured permanently. The expenses on energy are given from the customer and from other sources. For this, the plant design is done always with the aspects to obtain the highest possible amount of solar energy, and to operate the plant at the best economical conditions directly from the beginning.

The PTCs can be installed onto the ground, onto flat rooftops, or as a parking roof. With the given possibilities for installation and the energy demand, the collector field can be designed, choosing the type of collector, the number of collectors per row, and the number of rows. The PTCs can be built up in several sizes, usually e.g. with 6 PTC in one row, with one tracking system.

The one-axis tracking allows to align the parabolic mirrors to the sun very exactly. This tracking as the whole plant operation is done full automatically.

As well as the collector field can be scaled regarding the possibilities and requirements, all single components such as double-effect absorption chillers, steam generators etc. can be adapted to the customer's demand. One important item is to split the operation modes into solar cooling in the summer and heating in the winter mode, which can be useful for example to supply a hotel with a solar plant.

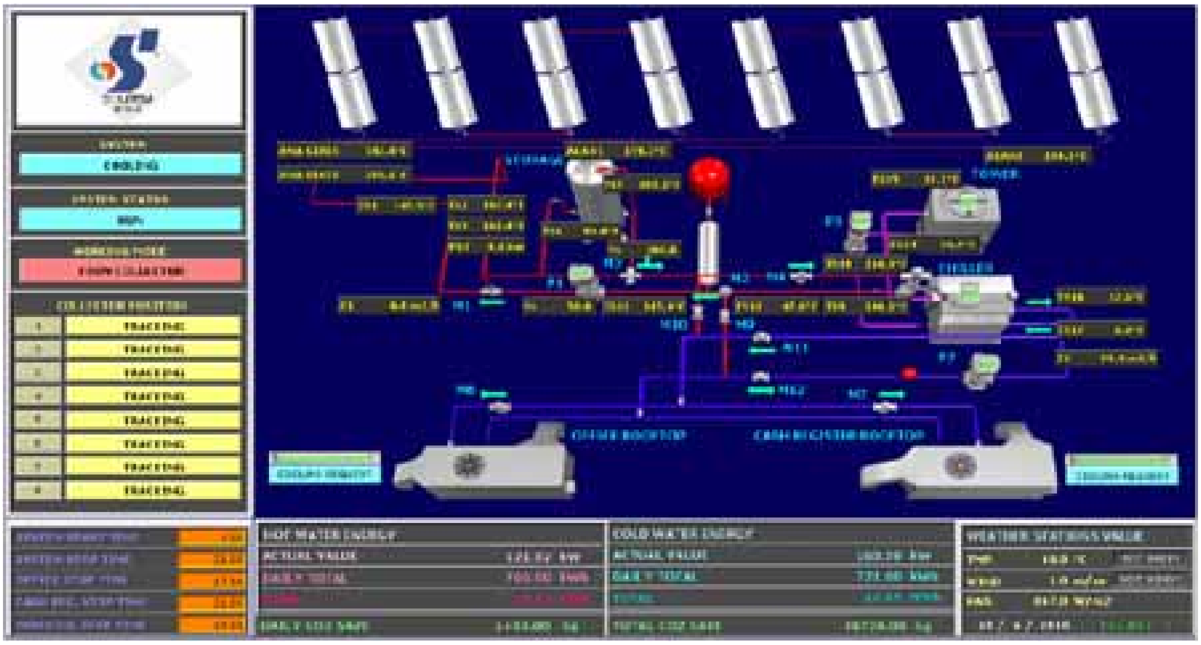

Fig. 4. Online Monitoring System

The exact adaption can be done in the best way when the energy demand structure, the load curves, and other specific details are given. If the energy is required also after sunset or very early in the morning, for example inside a production line, the high-temperature solar energy will be stored in a hot water buffer storage, sizing the storage volume in dependency on the difference between energy offer and demand.

In all applications, it is planned from the beginning to get the best solar yield and the optimal economics of the plant. The plant includes a weather station and an Online Monitoring System, giving the main important data on operation conditions, energy and carbon dioxide savings etc. onto an external monitor, which is used by the operator or the service.

4. Practical proceedings and forecasts

As many countries have respectable aims to extend the share of solar energy in their energy supply structure, and the possibilities are given, also taking into consideration new ways such as the described ones, it is a matter of time that the installation of high-temperature solar energy plants will proceed step by step. Any effects such as giving subsidies or an acceleration in the increase of the prices of conventional energy sources, as well as any measures to reduce greenhouse gas emissions, can speed up this process.

For this, it is strongly necessary to be prepared. SOLITEM invested in the production line in the Ankara factory. New machines have been installed, to increase the level of automation. Several different types of Parabolic Trough Collectors have been developed and tested.

New solar energy plants have been installed recently. New applications such as the trigeneration process and the solar MED desalination are in development.

Fig. 5. Automated manufacturing at the SOLITEM factory

5. Summary

The most innovative characteristics of the SOLITEM technology are:

- A performance that is up to three times higher than conventional systems.
- Rooftop-mountable, in-house developed collectors with self-protective mode.
- In-house invented, computerized tracking system to capture the highest solar yield at any time.
- Overall Energy Management System, including the Online-Monitoring System.
- Full compatibility with existing conventional systems.
- Bivalent operation modes (alternative supply with cooling or steam).
- The dependency on conventional fuels is decreased.
- The sustainable energy source as a "zero emission solution" avoids impacts on global warming and other consequences to the environment.
- A solar cooling system avoids the significant stressing of the electrical grid caused by conventional compression cooling.

References

[1] N. Janotte, S. Meiser, D. Krüger, R. Pitz-Paal, S. Fischer, H. Müller- Steinhagen, M. Walder; Bestimmung der thermischen Leistungsfähigkeit des Parabolrinnenkollektors PTC 1800; Gutachten vom deutschen Zentrum für Luft- und Raumfahrt