BYGGFORSKNINGSRÅDET

BFR-SEAS DAGAR

Deltagarlista
Sammanfattningar av föredag

28 - 29 november 1995

BFR
S:t Eriksgatan 46, Stockholm

SIMULATION TOOLS FOR CSHPSS SYSTEM USING A GROUND DUCT STORE

D. Pahud and G. Hellström
Department of Mathematical Physics, Lund Institute of Technology,
Box 118, S-221 00 Lund, Sweden

1. Introduction

Unlike conventional technologies, the design of a solar heating system using a duct store in the ground is based on heat output (kWh) rather than heat demand (kW). It requires design procedures that account for the different thermal processes involved. It is important to assess both short-term and long-term performances. For example, the heat transfer along the ducts is influenced by different factors, such as the last days of operation of the system and the average ground temperature in the store, which normally varies on a seasonal basis. A transient effect, due to the warming of the surrounding ground, is usually observed during the first years of operation, and affects the thermal performances of the system. In order to obtain an accurate evaluation of the system heat balance, system performances have to be calculated with high resolution over several years, or even the life-time of the system. The final design is generally established with the help of detailed computer simulations, and relies on the ability of the computer programme to reproduce the actual characteristics of the planned system.

2. Objectives

Simulations of CSHPSS systems with a duct store are investigated, based on two basic system designs (i.e. with or without a short-term water buffer tank). The principal objectives are to develop reliable and accurate simulation tools, and to characterise such systems, in order to establish optimal ratios between the different subsystems' size as well as to find an optimal strategy for optimal system operation. These tasks involve:

- the set up of two systems' designs, comprising the complete system layout and connections between the different subsystems (system with and without short-term buffer tank);
- the build up of the simulation tools using TRNSYS, a well-known modular programme for the simulation of partial or complete energy systems.
- the study of some aspects in order to check the validity of the existing modules in particular cases; finding the limitations of the simulation tools;
- improvement of the existing modules when required (e.g. the duct store module);
- having reasonably fast simulation tools for practical use (according to the system layout);
- verification with more detailed programmes; (which tend to be time consuming and not as flexible).

3. Results

Detailed programmes were developed to compute in greater detail the thermal response of a duct store coupled to a solar collector field. A reference system was defined and simulations were conducted for a typical summer month. The following analyses were carried out:

- weather data time-step effect on the simulated thermal performances of a solar plant that uses a seasonal duct storage in the ground;
- heat capacitive effects of the collector array or the ground heat exchanger on the thermal performances of the simulated system;
- the main features that a duct store model should present in order to compute with acceptable accuracy the heat transfer between the heat carrier fluid and the ground (temperature- and flow- dependent borehole thermal resistance, etc.);

The main results and conclusions related to these studies were:

- the common use of hourly rather than 2 minute weather data values results in a slight deviation in the global simulated performances. For a typical summer month (June), the cumulated energies (collected and stored) are always smaller, but the deviation is limited to 2%. It can be concluded that it is quite reasonable to use hourly meteorological data values in order to perform detailed simulations of a solar heating system using a duct store.
- heat capacitive effects of the collector array are usually small, provided that the effective heat capacity of the collector array remains below 10 kJ/m2K. Nevertheless, some simulations showed that they could be quite significant, with larger values (total collected solar heat decreased by approximately 10 % with a 30 kJ/m2K heat capacity value).
- heat capacitive effects of the ground heat exchanger, simulated for a typical summer month (June), can significantly enhance the mean collector efficiency in some extreme cases. These effects usually remain small. They can be ignored, provided that a sufficiently large buffer tank (> 60 litres/m^2 of collector area) and/or a performant collector array are used (collector loss coefficient of 3-4 W/m^2K at high temperature).
- the local solutions, accounting for the heat transfer between the heat carrier fluid and the duct store, require special care when computed. In order to perform accurate simulations and proper sensitivity analyses, the fluid-to-ground thermal resistance should depend on the flow conditions. The axial effects, due to a varying fluid temperature along the flow channels, are accounted for with the concept of effective fluid-to-ground thermal resistance. This latter, derived from a uniform heat flux along the borehole, enables us to closely reproduce the results obtained with a detailed computation of the heat transfers inside the ground heat exchanger. Furthermore, the local solutions should be able to take into consideration a serial connection of the boreholes, as well as a vertical division of the store volume.

The detailed programmes were used to build up and validate simulation tools developed with TRNSYS. The version of the duct heat storage model (DST) for TRNSYS is improved, based on the results of analyses performed with detailed programmes. The new improvements permit a study of special problems, such as the radial stratification of the ground temperatures within the store volume, the effect of the flow conditions on the thermal performances of the system, or the effect of the heat exchange between the ducts in the borehole.

4. Benefits

Some special studies related to the simulation of a CSHPSS system with a ground duct store have been carried out. The result (see section Results) may be useful for those concerned with the simulation of such systems.

A new version of the duct storage component (DST) has been developed for TRNSYS, together with two basic system layouts. Detailed analyses and optimisations of solar heating systems with a seasonal duct store are now possible. The world wide use of TRNSYS by researchers and consultant engineers improves the transmission of knowledge and international co-operation.

5. Future developments

The next version of DST for TRNSYS will be three-dimensional and will take into account the possibility of a ground water flow.

A three-dimensional water storage model for TRNSYS, based on the stratified storage temperature model (SST) will soon be available and will complete the existing cylindrical models for TRNSYS (SST,MST and XST). Simulations of rock cavern storage, for example using three cavern in a row (as it is the case in some places in Sweden), will be possible.

In the mean-time, a case study under typical Swiss conditions will be performed with the design tools.

References

1. D. Pahud, Development of System Simulation Tools of Central Solar Heating Plants with a Seasonal Duct Store in the Ground, Department of Mathematical Physics, University of Lund, Sweden (1995).

2. G. Hellström*), L. Mazzarella**) and D. Pahud*), Duct Ground Heat Storage Model. Lund - DST. TRNSYS Version October 1995, *)Department of Mathematical Physics, University of Lund, Sweden. **) ITW, Universität Stuttgart, Germany, Dipartimento di Energetica, Politechnico di Milano, Italy (1995).