TEST PLANT AND DEVELOPMENT OF TOOLS FOR DESIGN OF COMBI-HEATING SYSTEMS FOR LARGE BUILDINGS

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Abstract

In design, control and installation of combined heating systems with solar energy utilization various tools are required in assuring rationality and cost effectiveness. A project was therefore initiated to develop such tools involving (a) building of a full scale plant for tests of combined heating systems containing solar collectors, pellet boilers, heat pumps and heat stores, (b) evaluation of system performance for some combined heating systems with varying control strategies through measurement, and (c) development of a user-friendly data soft ware tool for evaluating system performance of the kind of combined heating systems studied.

Results so far include building of the test plant and start of measurements of system and component thermal performance making use of the test plant. A TRNSYS deck of the system has been designed, and will be used for further investigations. From the results it can be concluded that user-friendly TRNSED data software would be possible to accomplish for calculation of thermal performance but also of economy, and climatic performance of combi-heating systems to best serve the needs expressed by the industrial partners of the project.

1. Introduction

In the work of changing-over from present days fossil fuel based energy systems to more sustainable and climate sound solutions, there is a special need in developing technologies and services that can be successfully commercialized. This requires that there are companies that can provide systems to reasonable costs and reliability, but also that the knowledge to design and construct, control, operate and maintain systems with new energy technologies is extended to a larger group of actors.

For integration of solar heating into the built environment, the solar heating system must be optimized as part of a combi-heating system in which a biomass boiler and/or heat pumps also would provide the building with heat. To effectively accomplish this a holistic approach is needed. Components and products that can work together and simultaneously be optimized for maximum cost effectiveness are needed for solar heating to become thrustworthy in the eyes of a potential solar energy user.

Thus, methodologies in form of simple design tools (simulation models) need to be developed for better system design and for predicting expected thermal performance and economical pros and cons from a consumer point of view.

With this as a starting point a joint project, the Flexifuel project, between the University of Kalmar, now the Linnaeus University, and the District Heating Group of Sustainable Sweden Southeast, SSSE was initiated some years ago. The industrial partners in this project became Euronom AB, Gila Control System AB, Sustainable Sweden South East, Kalmar Energy and KIFAB. The academic partners became the Linnaeus University, Denmark Technical University and the University of Gävle.

The following objectives for the Flexifuel project were agreed upon:

- Building of a full scale plant for testing of combi-heating systems
- Evaluation of system performance for specific combi-heating systems with varying control strategies through measurement
- Development of a user-friendly data software tool for evaluating system performance of the combi-heating systems studied.

The research is focused on thermal performance, cost effectiveness, as well as environmental and climatic qualities of combi-heating systems for larger buildings.

Results so far include building of the test plant and start of measurements of system and component thermal performance making use of the test plant. TRNSYS is used for modelling of the thermal performance and the most suitable models for the different components of the system have been identified and are presently used to predict measured thermal performance of the system. The user friendly software which will be more generally applicable will be based on TRNSED.

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2. Test Plant

The principle outline of the test plant is shown in Fig. 1 below.

The plant, which was completed in March 2010, is equipped with 25.1 m^2 of vacuum tube solar collectors (ExoSol® OPC 15), a ground source water/water heat pump, 17 kW (Exotic® S) , two air/water heat pumps, 20 kW each (ExoAir® Polaris 20), a three paths pellets boiler with a maximum output power of 120 kW (UNIC® TXN 380, Bio Comfort 120 kW), and two heat storage water tanks of 1 m^3 each (ExoTank® 1000i); one for storage of low temperature heat and one for storage of high temperature heat. For control and data monitoring the plant is equipped with a web based steering and data storage system.

The Flexifuel plant is now used for research purposes, but will be utilized for demonstration and education as well. It is also used for the heating of a larger building with a maximal heating demand of 120 kW and a yearly heating demand of 240 MWh. The heat load consists of six different parts which by use of bivalent valves can be adjusted individually to meet the demand from the different loads. The thermal performance of each component can be evaluated by measurements using heat flow meters and temperature sensors. The company Euronom AB in Kalmar is responsible for the plant and its operation and maintenance.

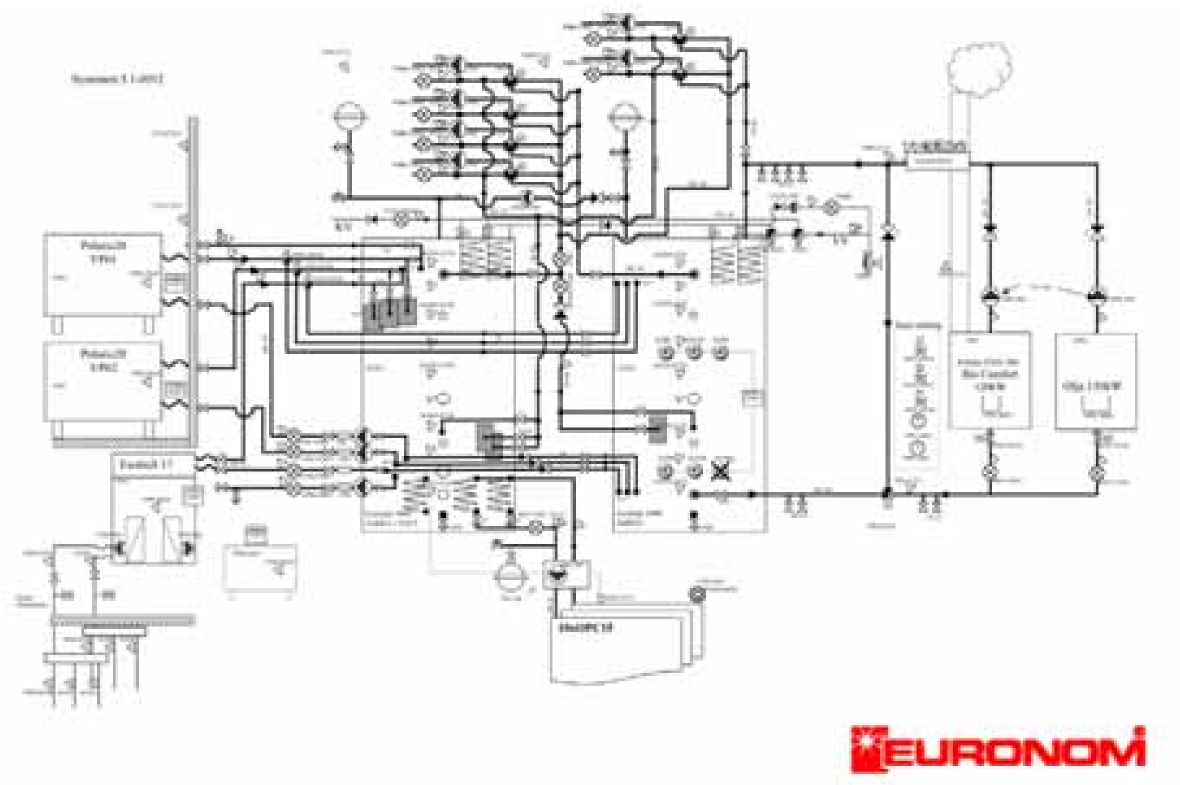

Fig. 1. The Test Plant.

When running the test plant the following priorities are made. When the solar collector temperature exceeds the temperature at the bottom of the low-temperature heat storage tank, the solar heating system is activated. If the stored heat in the low-temperature tank can not meet heating demand the heat pumps are used as complementary heat source for charging the low-temperature heat storage tank. If the outdoor air temperature is lower than the yearly average outdoor air temperature, the air/water heat pumps are turned on before the ground source heat pump. If on the other hand the outdoor air temperature is lower than the average outdoor temperature the ground source heat pump is started first of the two kinds of heat pumps. When the heat demand is higher than can be met by use of one kind of heat pump both will become operative. If this is not enough, heat is extracted from the high-temperature heat storage tank and the pellets boiler is turned on for charging this tank. If the top temperature of the low-temperature heat storage tank exceeds the bottom temperature of the high-temperature storage tank, hot water from the first mentioned tank is used for charging the last mentioned tank.

3. Computer simulation

3.1. TRNSYS

TRNSYS is a commonly used simulation environment when modelling energy systems [1]. It is a Fortran based program containing a number of types, previously written miniature programs, which connected to each other create complete systems. The first types were developed in 1974 by the Solar Energy Laboratory at the University of Wisconsin, USA, and the interface of Fortran resembles that of Simulink.

Selected TRNSYS types from both the standard library and the commercially available TESS library have been used to describe the program; see Fig. 2. The TRNSYS model has the advantage of being validated by experimental data from the test-plant. To arrive at a user-friendly software suitable for the industry, the TRNSYS program will at a later stage be transformed into a TRNSED version.

In order to gain an active participation from the industry, the model has to meet a number of demands. The foremost is the necessity for calculation speed. The industry has expressed wishes to show potential customers systems "on the spot" with a maximum calculation time of 2 - 3 minutes. This creates a trade-off situation between less complexity for speed, and a high level of detail for accuracy. For example, TYPE 668 and TYPE 557 used for the ground heating pump, offer a high level of accuracy without reducing the speed of the program significantly, whereas a new simpler model has been created for the air-based heat pump. Tap water heating has been ignored, since Euronoms tap water use is very low.

The model consists of a number of types [2], the most important of which are stated below:

TYPE 15 (weather model)

Type 15 provides input to the solar collectors, the heat pumps and the heating demand in type 12. The used weather files are obtained from Meteonorm weather files over Växjö, Sweden, close to the test plant in Kalmar, Sweden.

TYPE 12 (house)

The simplest model for a load has been used since the house characteristics are not the main focus of the program. In the TRNSED application of the model, easily available house characteristics such as yearly energy usage will be used and translated into the model. The type may be changed later in the process to allow for multiple types of heaters (e.g. floor heating, radiation heaters and such).

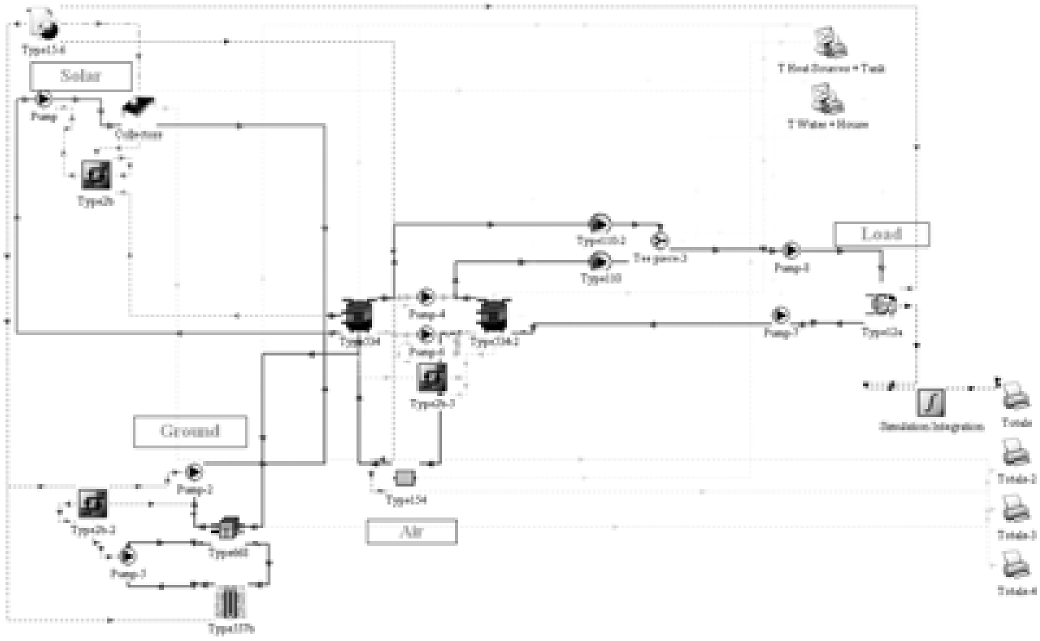

Fig. 2. The TRNSYS deck.

TYPE 534 (tank)

TYPE 534 has been selected as a tank model due to its capacity for multiple inlets and outlets at differing nodes. The number of nodes inside the tank has been set to five for two reasons: the first being to reduce calculation time, and the second being that five is the number of temperature measurements available inside the test plant tanks. Inlets and outlets have been set to heights resembling the experimental facility.

TYPE 668 (water/water heat pump)

A TESS model that uses external files containing data for the capacity and power draw, based on the entering load and source temperatures [3]. To simplify the use of this model for the industry-friendly TRNSED application, data files have been written in such a way that the pump gives approximately 1 kW. The user can then change the size of the heat pump through selecting “number of identical heat pumps” to the desired pump size. (In our case 17 identical heat pumps since we have a 17kW heat pump)

TYPE 557 (ground heat exchanger)

The vertical ground heat exchanger model, Type 557, is the most commonly used model in ground-source heat pump applications. In the model, it is used with one U-tube ground heat exchanger, with the heat carrier fluid circulating in the U-tube.

TYPE 154 (air/water heat pump)

To avoid long calculation times, a new Type was created and named 154. Type 154 is a very simple model of a heat pump that through linear regression creates a function from given performance data. The function created is used to gain the heat provided to the tank at the outdoor temperature. The data is based on the Swedish SP-tests of heat pumps, which provide heat gained and COP at varying outdoor temperatures. [4]

TYPE 1 (solar collector)

In this early stage of the program, Type 1 has been used as a solar collector. A modification of Type 136, which is developed from Type 132 in TRNSYS 15 and includes condensation, long wave radiation and wind [5], will be used in the final version.

4. System Performance

The experimental test plant was unfortunately completed so close to the deadline of this paper, that no experimental data could be collected in time. For preliminary calculations, data needed to characterize the different components of the system were simply gathered from the test reports on the various components that were available [6] However, the TRNSYS simulations of the test plant made to this date, provide some examples of how the different heat sources interact with each other.

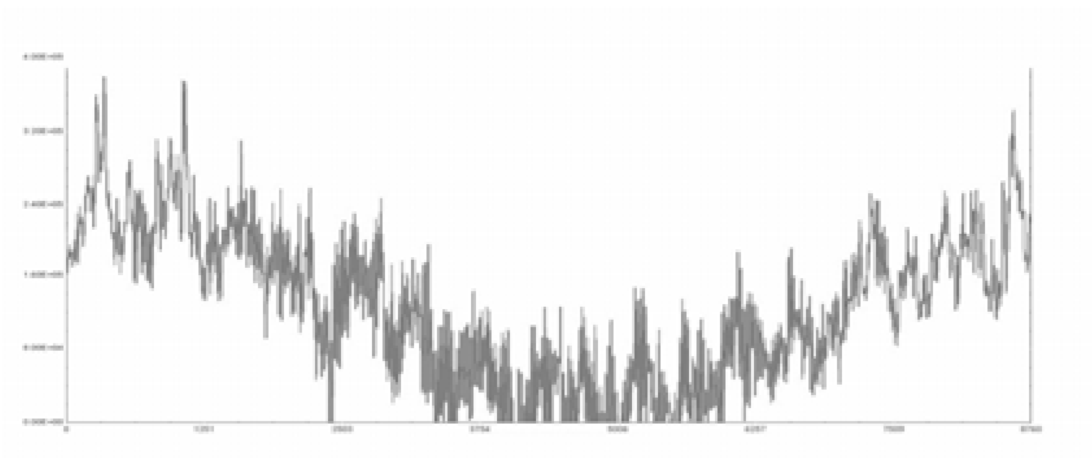

Fig. 3. Required energy [kJ] to heat the Euronom building to 20ºC over the course of one year

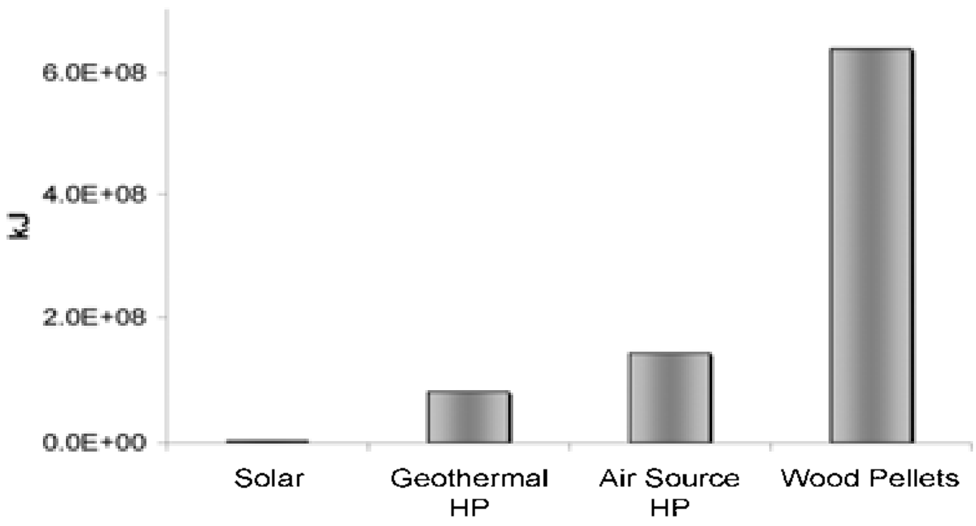

Fig. 4. Contribution from various heat sources (1 year)

The heat pumps mainly operates within their respective temperature range, above yearly outdoor temperature for the air-source heat pump and below for the geothermal. However, if the heating requirement of the building is not met by one of the heat pumps the other also contributes. This is especially true during spring and autumn, when the contribution of the air-source heat pump overlaps that of the geothermal as seen in Fig 5.

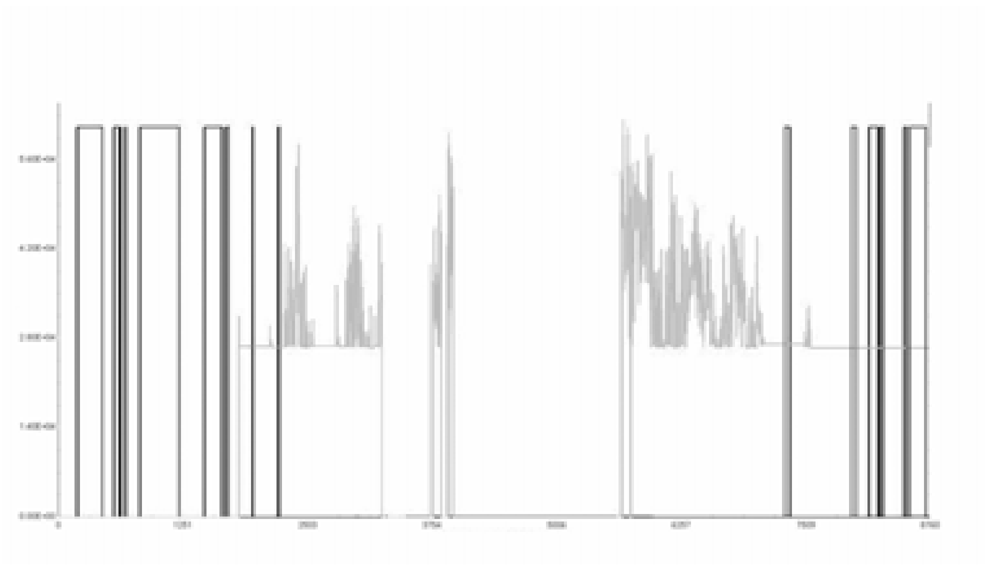

Fig. 5. Usable heat [kJ] from geothermal and air-source Heat pumps over one year. The lighter gray denotes the air-source heat pump contribution [KJ], the darker grey the geothermal [kJ].

5. Conclusion

From the preliminary results obtained to this date it can be concluded that a user-friendly TRNSED data software would be possible to accomplish for calculation of thermal performance but also of economy, and climatic performance of combi-heating systems to best serve the needs expressed by the industrial partners of the project.

Mooreover, the flexibility of the system gives great potential for research on the importance of the various factors that determine thermal performance of combi-heating systems and which most optimal solutions are for different applications.

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