Design Methodology for Combined Solar and Geothermal Heating Systems

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Introduction

Numerous simulation tools are currently in use to investigate the solar systems on the one side, and separate tools exist to design heat pump systems. It is in particular in the solar field that dynamic simulation with the use of statistical meteorological data has been established and proven to be capable for speeding up design and optimization of heating systems and for predicting the economic viability of the systems.

With integration of the heat pump as a new component in the simulation software Polysun, a new tool becomes available, which covers the entire range from combined solar and geothermal heating systems for single family houses up to big commercial installations. Therefore, a realistic design of integrated solar thermal and heat pump systems is feasible due to both the rich database obtained from real heat pump installations coupled to the geothermal heat source and the detailed numeric used to model the physical components.

The modular approach and the hydraulics focus on real available components allow the use of Polysun in the early planning phase, as a planning tool for the design of heating, as well as for the optimization of system components and control strategies.
It has been recognized that a physics based numerical treatment with a fully coupled system of equations is capable of predicting the system behavior and in principle is useful for analysis, design and optimization.

1. Numerical Models

A common approach for the numerical treatment of complex systems is an implicit solving of equations. The corresponding simulation approaches are mature and are already successfully used in TRNSYS [1] and IDA-ICE [2] as two examples. Polysun alternatively pursues a direct solution procedure, as it has been proved to be very effective according to SM07 [3]. Unlike similar programs in which every system has its own pre-calculated formula, each component is displayed as a separate item in Polysun, which only knows its direct neighbor components and those on appropriate interfaces of heat exchange. Then, all components can be controlled by several kinds of controllers available in Polysun.

2. Comparison between Solar and Heat pump Systems

It is important to have solar and geothermal energy sources in the same program. With the extended Polysun, solar systems can be compared directly with heat pump heating systems. For a comparison of the CO2 balances, thereby the local electricity generation mixture and the emission factors must be derived and considered. Besides, for the comparison of the costs, an uncertainty of the future electricity tariff should be taken into account as well.

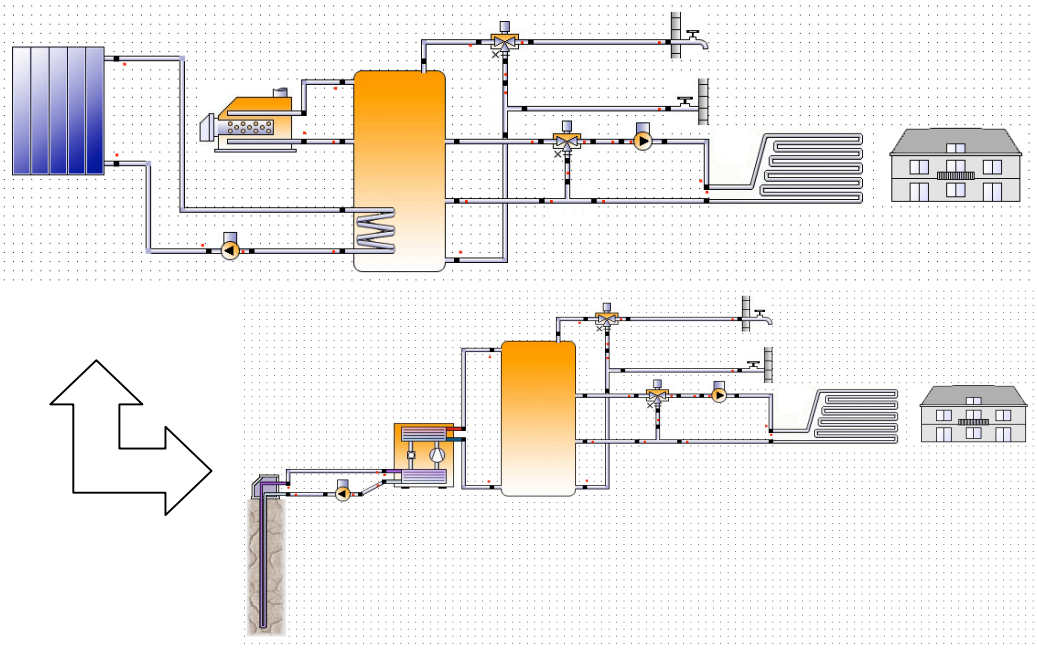

Figure 1: schematic comparison of a solar system and a geothermal heating system

2.1. Combination of solar energy and heat pumps as one System

For the combination of solar thermal collectors and heat pumps recently several new products were launched on the market.

Solar energy can be used however still much more efficiently, if the solar collectors are combined directly with a heat pump, in order to let the temperature of the heat source side (evaporator) of a heat pump raise and thus the performance figure to be improved (possible arrangement is shown in Figure 2).

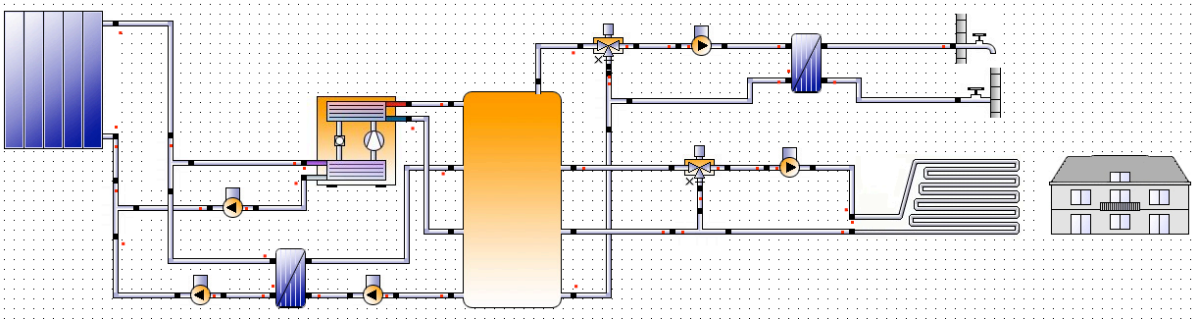

Figure 2: Direct connected solar thermal and heat pump system implemented in Polysun

A further possible system concept consists of the fact that solar energy from the collectors is led into the ground-source loop fields and be stored. The main reason for having such a system is that in many ground-source heat pump systems, the earth temperature drops gradually after years of energy exploitation. This could reduce the performance of the heat pump drastically. Therefore, the earth is then needed to be restored and this can be done by delivering heat from a small collector field. The design of such a system is possible in an appropriate extension of Polysun (see Figure3).

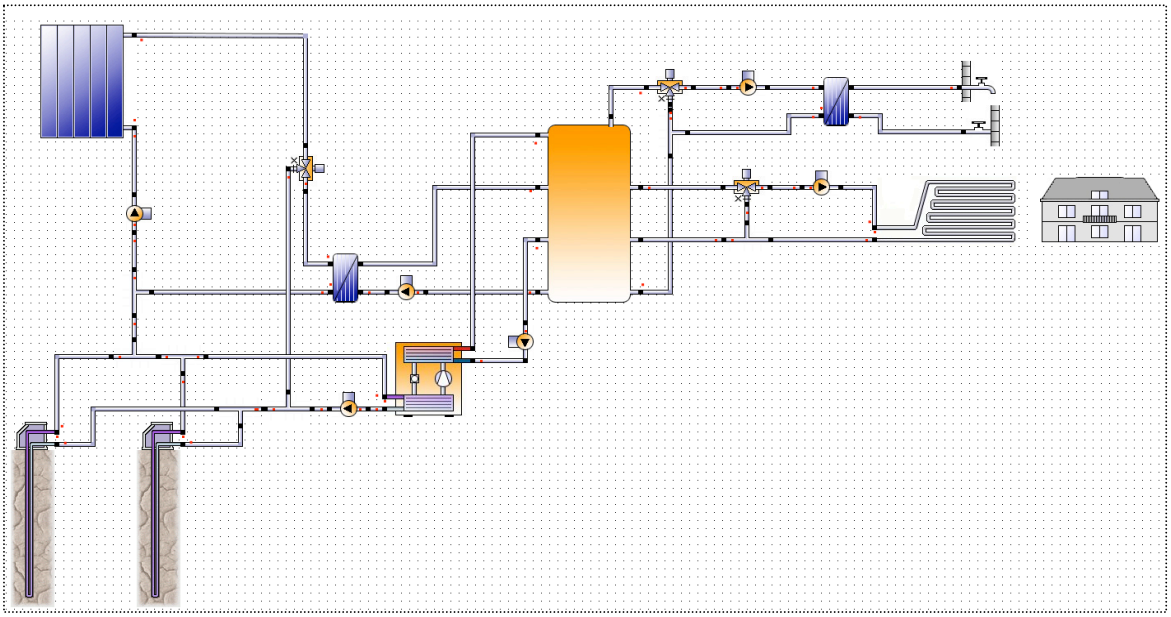

Figure 3: System with the capability of solar regeneration of ground-source loop fields

3. Conclusion

The freedom in the system design permits the comparison of the different approaches, which plays an important role particularly with the combination of different energy suppliers as in the present example heat pumps and solar thermal collectors.

Further important conditions, which are already realized in Polysun:

- In the program, meteorological data are already available, which is important for the computation of the heating load as well as for the interpretation e.g. of air-water heat pumps (outside temperature, air humidity). If a location is not yet introduced, Polysun can calculate the information for the new location by interpolating the existing meteorological data (Meteonorm of the company Meteotest is integrated in Polysun).
- Variable time step: A yearly simulation can be obtained with a variable time step changing from 1 second to 720 second resulting in decent times and high accuracy.
- Automatic controller behavior: Important components in the system tuning are controls. These are implemented in Polysun likewise close-to-reality.
- Building simulation: Polysun contains an integrated building simulation for the determination of the dynamic building load.
- Comprehensive component selection already existing: The current function range in Polysun covers already all important components of a heating system (storage tanks, boilers, pumps, heat exchangers, mixing valves, controllers, buildings).
- Result selection and visualization in a friendly graphic user interface.

Polysun offers a modular concept for setting up the heating systems, which permits the computer-assisted evaluation of different system types.

4. References

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(3) SM07.S. A. Mathez. Polysun 4: Simulation of systems with complex hydraulics. Proceedings Otti-Conference, May 2007.