SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

2018 HIGHLIGHTS

Task 55 – Towards the Integration of Large SHC Systems in DHC Networks

THE ISSUE

In recent years, megawatt-scale solar thermal district heating (SDH) systems have gained increasing attention globally. Several ambitious projects were successfully implemented in countries such as Austria, Germany, Italy, France, Spain, and Norway. Large-scale SDH systems and their large-sized seasonal storages have become attractive options for cost effective and low carbon heat supply. In the next step, large systems will become even bigger and likely grow from MEGA to almost GIGA-sized installations. These systems will be able to meet the increasing energy demand of city districts and of whole cities. Compared to conventional heat generation systems, the effective operation of a SDH network and its seasonal storage can guarantee a primary energy consumption reduction of >70% in thermal needs. However, the actual integration of large solar thermal systems into existing and new networks faces several challenges. Expertise on the integration of large solar thermal systems into district networks is limited. Therefore, SHC Task 55 collects and disseminates technical and economic solutions to leverage large-scale solar thermal district heating and cooling systems worldwide.

OUR WORK

SHC Task 55 aims to provide a platform for practitioners and scientists to present the benefits and challenges of SDH and SDC systems. It collects research results on options and measures to realize sophisticated SDH and SDC systems by focusing on characteristics of solar thermal systems, technical and economic specifications of district heating networks that are relevant for the integration of solar thermal systems and hybrid technologies, analyses of system components and their integration, modular designs of large SDH/SDC systems, and economic requirements of large SDH/SDC systems in different market regions. Finally, SHC Task 55 collaborates with the IEA Technology Collaboration Programme on District Heating and Cooling including Combined Heat and Power (IEA DHC).

Participating Countries

Austria
Canada
China
Denmark
Finland
France
Germany
Spain
Sweden
United Kingdom

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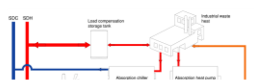

KEY RESULTS IN 2018

Integrating heat pumps into SDH systems

Large-scale thermal energy storage (TES) will be required regardless of the future composition of the energy system. In solar district heating systems (SDH), the solar contribution can be significantly increased with large-scale TES. A heat pump (HP) can be integrated into the SDH system to further reduce or even replace the fossil backup (BU). The electricity consumed by the HP has to be considered in relation to the reduction or replacement of fossil energy. The time of electricity consumption and the composition of the electricity mix must be considered.
Results show that heat pumps can be integrated in SDH systems with the aim of achieving higher share of REs and thus reducing/replacing the use of fossil fuels.
The mismatch between (electricity) demand and RE availability should be considered, e.g. by means of time dependent primary energy conversion factors. Integration of a HP in a SDH can have environmental benefits, but careful planning is required and time of electricity use hast to be considered. With constant PE factor the benefit of using a HP is overrated. However, first of all, a significant reduction of the energy demand of the building stock is a prerequisite for a sustainable energy system.

Modular Energy Management System for the Operation of Cross-Sectoral Energy Systems

A modular energy management system must decide when to switch on/off producers, at which power levels producers should run, when to store how much energy in energy buffers and when to buy/sell how much energy from grids.
The optimal SDH strategy depends on unknown future demand, fluctuating yield from renewable sources, and the development of prices. An optimal strategy is the solution of a mathematical optimization problems, automatic formulation based on configuration and modular building blocks for the individual components. The on/off decisions lead to mixed integer (linear) programs (MILP).
Automatic problem formulation from system configuration:
Individual component models are combined to obtain a single model of the entire energy system. Distributors create links between the components' outputs via equality constraints (energy/mass balance). A prediction model is constructed based on the current state, future decision variables as well as predicted disturbances. Costs are calculated from the decision variables and predicted outputs of the system.

The complexity of cross-sectoral energy systems calls for support by computers and algorithms. Formulating the problem as a mathematical optimization problem delivers automatic solutions even for complicated configurations. A modular design allows easy experimentation with different configurations, adaption to newly installed technologies, and easy interface definition to process control system visualization and simulation.

When connecting different components via a heating network and working with high-level or supervisory control methods for unit commitment, low-level control of the valves and pumps is usually neglected. However, the actual control of temperatures and mass flows can be a limiting factor because nonlinear and coupling effects are not considered and lead to bad performance of standard (PID) controllers. Using graphs as a tool to make heat networks understandable for computers, one can directly derive models for simulation (PDEs), hydraulics (ODEs) and thermal steady state (algebraic equations). The steady state calculation can be used to derive ideal steady state conditions to obtain the control objectives. The hydraulic model then can be used to implement model-based, nonlinear, multiple-input, multiple-output controllers that set the mass flows to be consistent with the steady state solution even in the presence of disturbances. Adding temperature controllers on top of that, the high-level control objectives are implemented with minimal need for human interaction (Muschick, Bioenergy2020+).

Advanced monitoring and predictive control strategies of large scale solar thermal systems

Methodiqa is a centralized software platform with an automated continuous monitoring. It has a data-driven approach, focuses on the modular plant configuration and reusable designs. The challenge is that data can have errors. A lot of SDH data originate from different plants with different hydraulic schemata, which can also be built decades apart and with different data formats.
The solution is a modular approach with import filters, pre-processing, plausibility algorithms, regularization and sensor checks to obtain clean data in the final database. Results show that a modular plant setup is often

feasible. Import filters are needed and no adaption of plants are needed. Powerful algorithms lead to long-term evaluations and are applicable across multiple systems. The fully automated software generates monthly reports and provides notification on selected results.

Predictive control strategies which consider future conditions can increase the monetary profit of large-scale solar thermal plants by about 2%. In order to consider future conditions prediction methods information on future heat demand of on-site consumers and future solar yield of the solar collector field are needed.
Problems of currently available prediction methods for the future solar yield are that they are not adaptive, mathematically complicated (e.g. artificial neural networks), and tailored for a specific application.
Requirements for a suitable method for predictive control strategies are that they are adaptive (self-learning), mathematically simple (easy to implement) and extensively applicable (valid for a wide range of collectors).
The parameters are determined automatically and continuously adapted by previous measurements. The developed method is based on linear regression and can be easily implemented on an off-the-shelf controller (PLC). It is further mathematically simple. No licence costs and no special software is necessary. The prediction method is based on static energy balances, proven and valid for a wide range of collectors, so it is extensively applicable.

BigSolarX: Investigation of the introduction of large scale solar thermal systems into district heating networks

DH operators and energy service utilities responsible for DH are the main target group for BIG SOLARX-concepts. However, since DH companies very often are fully or partly public owned, municipal representatives can also be defined as target group. Operational costs of the systems tend to be little exposed to fluctuations in variable costs since the energy input used is the sun which is free and abundantly available in nature. Therefore, prices are projectable over their operating lifetime of at least 25 years guaranteeing long-term price stability and security of supply. Top down in the long run, BIG SOLARX could cover 20% to 70% of the heat demand for each DH system. The solar system is thereby also supported by the hybrid technology of thermal heat pumps, allowing higher temperature differences in the storage and allowing higher specific heat content, by at the same time reduced required volume.

Several efforts globally are set out to develop solar thermal large scale systems which can be connected to already existing or even newly built district heating networks. One of the most promising projects was under investigation in Graz, Styria. The city has 250,000 inhabitants and an ever increasing district heating network. Together with local energy suppliers and international experts, a system design was developed as illustrated in Figure 1. Solar heat is captured by thermal collectors at temperatures of up to 95°C, and partly used directly in the district heating network, partly stored until autumn and winter times. Out of the storage the heat is taken both directly and later with support of a thermal driven heat pump. Specific synergetic combinations of these components guarantee flexibility in application and the possibility to integrate high solar shares into an existing system. Furthermore, the thermal heat pump allows higher temperature differences in the storage for higher specific heat content. This reduces the required volume (SOLID).

KEY EVENTS IN 2018

SHC and DHC Collaboration: Joined Workshop of Task 55 and DHC Annex TS2

The Solar heating and cooling (SHC) program and the district heating and cooling (DHC) program had their first Expert Workshop next to the Solar District Heating Conference in Graz, April 2018. The focus of the workshop with about 50 participants from SHC Task 55 and Annex TS2 was on financial and infrastructural challenges to integrate district heating and solar thermal energy systems. On the one hand, public financing is still an issue. On the other hand, the value of “green” must be captured in new SDH installations. Markets and investors for SDH installations must be informed about latest technology developments. Barriers of SDH installations are still temperature requirements of DH, area needed, or storage requirements.

The involvement of utilities is one of the challenges within this cooperation.

Picture: Impression from the Joined Workshop SHC Task 55 and DHC Annex TS2

Document 1: A SWOT Analysis for the integration of Solar Energy into District Heating Networks will be finalized and published within the next 12 months on the Task 55 Homepage.

Document 2: Joined Workshop Summary will be published on the SHC Task 55 and on the DHC Annex TS2 Homepage within the next 6 months.

Document 3: A presentation of the joined workshop will be available within the next 6 months.

SOLAR ACADEMY TRAINING

Next to the SHC Task 55 Expert Meeting in Lianyungang, China, a Solar Academy Training was organized by the China Academy of Building Research (CABR) and the company of Sunrain. It was further supported by the China Renewable Energy Society State Key Laboratory of Building Safety and Built Environment. About 100 experts attended the training lectures.

Speakers were:

- Jan Erik Nielsen, Operating Agent of the IEA Solar Heating and Cooling Program for the Task 45 and Task 57, ESTIF Technical Consultant, shares the system design and performance guarantee of solar district heating system
- Jianhua Fan, Tenured professor of civil engineering, Technical University of Denmark (DTU), shares the system analysis and key component selection on solar district heating system.
- Ruicheng Zheng, Professor of China Academy of Building Research (CABR), Chief engineer of National Center for Quality Supervision and Testing of Solar Heating System (Beijing), shares the heat consumption calculation and HVAC (heating ventilation, air-conditioning) System Design on Local Buildings in China
- Christian Holter, CEO of SOLID GmbH, shares the case study of large-scale solar heating and cooling system.

The training course covered topics of building energy consumption, key components, system analysis and design, performance guarantees, case studies, as well as technical and economic requirements for the commercial solar district heating and cooling market. All presentations were available in both, English and Chinese.

It was a very fruitful step of the Solar Academy to invite experts from a number of IEA SHC Exco countries to come to China and give lectures. The measures connect the biggest SDH markets and nourish potential further business developments. It also lays a profound foundation of international cooperation between Chinese organizations, universities, industry and widely experienced countries in the field of solar thermal district heating and cooling.

VISIT OF TIBET LAGKAZI SOLAR THERMAL INSTALLATION

In Tibet, fossil fuels are only available in very small amounts. Transportation of such resources is very expensive in the Tibetan regions. However, high solar radiation is available, even higher in winter than in summer. At the SDH plant in Tibet, the solar collector field has a size of 82,000 m² and is located 2 km outside the city. For the system, a lot of components and know-how were imported from Europe, especially from Denmark and Germany. The organization of the construction was a big issue, because roads needed to be crossed and many permissions from the local authority and the government were necessary. The indoor temperature of the connected houses is designed with 18 °C, but now the program for insulating the houses was stopped and it is questionable how the temperatures can be reached without insulation. Because of the high altitude, the district heating can be run with relatively low temperatures of 65 °C.

Project details:

- Langkazi - 100.000m² residential heating space
- 22,275m² flat plate collectors; 15,000m³ pit storage
- DH net temp. 65/35
- 3MW electric boiler
- All implemented components from Europe
- Sponsored by China's central government

Further SDH systems shall be planned in the next years. To realize these plants, local production of components shall be realized as soon as possible in order to reduce transportation costs. The plant was visited in a technical tour by the Task 55 experts on the 3rd of November 2018. The following describes SHC Task 55's work on Taars-analysis and validation of a quasi-dynamic model for a solar collector field with flat plate collectors and parabolic trough collectors in series for district heating.