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 global attention as ambitious projects are successfully implemented in different 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 a cost-effective and low carbon heat supply. The next advance to come will be even larger systems – in the MEGA to almost GIGA-size. These larger systems will be able to meet the increasing energy demand of city districts and even 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 so SHC Task 55 is collecting and disseminating 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 solar district cooling (SDC) systems. Task participants are collecting research results on options and measures to realize sophisticated SDH and SDC systems. The work is focused 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.

SHC Task 55 is collaborating with the IEA Technology Collaboration Programme on District Heating and Cooling including Combined Heat and Power (DHC TCP) on this project.

Participating Countries

Austria
Canada
China
Denmark
Finland
France
Germany
Spain
Sweden
United Kingdom

Task Period 2016 – 2020
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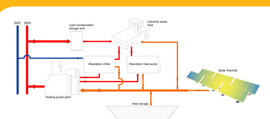

KEY RESULTS IN 2018

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 (SDH) systems, 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. The electricity consumed by the HP has to be considered in relation to the reduction or replacement of fossil energy as well as the time of electricity consumption and the composition of the electricity mix must be considered. Results show that heat pumps can be integrated into SDH systems to achieve a higher share of REs thus reducing/replacing the use of fossil fuels. Integration of a HP in a SDH can have environmental benefits, but careful planning is required and time of electricity use has to be considered.

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. Such a strategy is the solution of a mathematical optimization problem, an automatic formulation based on configuration and modular building blocks for the individual components.

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 automated continuous monitoring. It has a data-driven approach that 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 schematics, which can 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 with the current 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 license 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.

Big SolarX: 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 are often fully or partly public owned, municipal representatives can also be defined as a target group. Operational costs of the systems tend not to be impacted by fluctuations in variable costs since the energy input used is the sun, which is free and abundantly available. 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 higher specific heat content while at the same time reduced required volume.

Several efforts globally are underway to develop solar thermal large-scale systems that can be connected to existing or even newly built district heating networks. One of the most promising projects under investigation is in Graz, Austria. 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. Solar thermal collectors capture heat at temperatures of up to 95°C, some of which is used directly in the district heating network and some stored until autumn and winter. Stored heat is taken from storage with the 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, which reduces the required volume.

SHC TCP and DHC TCP hold joint workshop

A workshop on financial and infrastructural challenges to integrate district heating and solar thermal energy system was held in conjunction with the Solar District Heating Conference in Graz, Austria in April 2018. About 50 experts from SHC Task 55 and DHC Annex TS2 discussed public financing, the value of “green” in new SDH installations, and how to better inform SDH investors about the latest technology developments. Reports from this workshop will be posted on SHC Task 55 website in 2019.

Solar Academy training

A Solar Academy Training on SDH was organized by the China Academy of Building Research (CABR) and the company of Sunrain and supported by the China Renewable Energy Society State Key Laboratory of Building Safety and Built Environment. Over 100 people attended the training in Lianyungang, China.

The lecturers and topics were:

- Jan Erik Nielsen, Operating Agent of SHC Task 45 and Task 57, ESTIF Technical Consultant. Topic: system design and performance guarantee of solar district heating systems.
- Jianhua Fan, Tenured professor of civil engineering, Technical University of Denmark (DTU). Topic: 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). Topic: heat consumption calculation and HVAC (heating ventilation, air-conditioning) System Design on Local Buildings in China.
- Christian Holter, CEO of SOLID GmbH. Topic: case study of large-scale solar heating and cooling system.

This proved be a very fruitful event as it connected the largest SDH markets and nourished potential business developments. It also laid a strong foundation for international cooperation between Chinese organizations, universities and industry the field of solar thermal district heating and cooling.

Visit to Tibet's Langkazi solar thermal installation

There may be limited fossil fuels and expense transportation costs, but there is an abundance of solar radiation, especially in the winter months. This opened the door for the largest high altitude SDH plant in the world. The solar collector field is 22,275 m² and is located 2 km outside the city. The plant was visited by the Task 55 experts following the Task meeting and SHC Solar Academy Workshop.

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