Smart Control for Coupled District Heating Networks

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Area 2.2
Automation and Control

Introduction

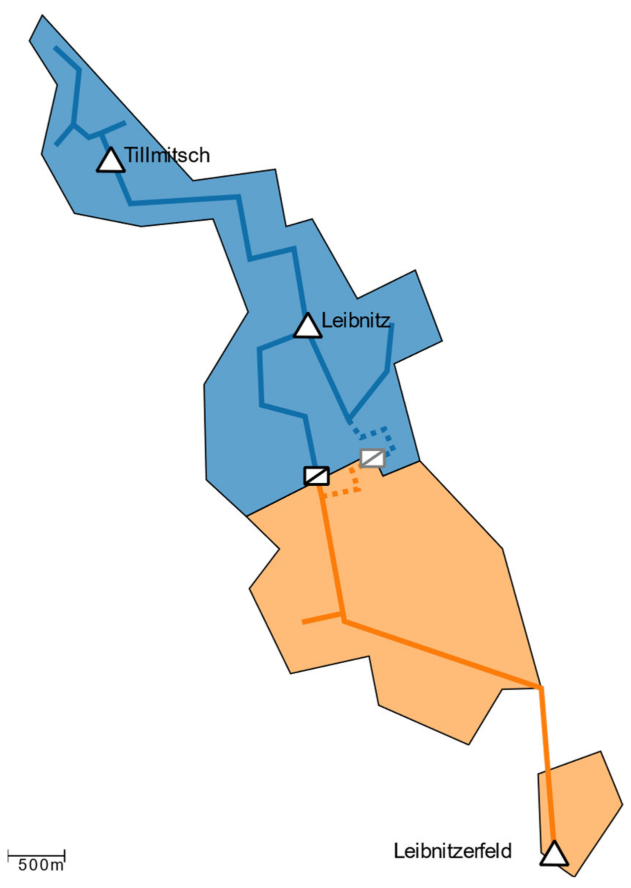
District heating (DH) networks have the potential for intelligent integration and combination of renewable energy sources, waste heat, thermal energy storage, heat consumers, and coupling with other sectors. For growing networks in close geographical proximity, often the possibility arises to couple them using bidirectional heat exchangers, possibly unlocking synergies and reducing costs for the consumers. Each DH network may consist of producers, consumers and thermal energy storage (TES) devices. Often, each of the coupled DH networks will be already controlled via low-level controllers. Hence, a high-level control approach is needed, that coordinates the heat exchange between the networks and takes renewable energy sources and the TES capacities in each network into account. These supervisory controllers are generally referred to as energy management systems (EMS).

Energy Management System (EMS)

Optimization-based energy management systems are a promising high-level control approach for coupled DH networks. These rely on mathematical optimization to devise an optimal operation plan for all production units, considering varying prices, future demand and yield predictions, and operational constraints. For this, typically, mixed-integer linear problems have to be solved in real-time. However, extending an optimization-based EMS for coupled DH networks with a multi-owner structure is non-trivial, see [1]. Additionally, modelling thermal systems is a challenge since it introduced non-linear relations between mass flow and temperature. However, using discrete mass flows at constant temperatures enables detailed thermal modelling within the realm of MILP, see [2]. An **optimization-based EMS has been implemented**, addressing the mentioned issues, and evaluated in the following case study.

Case Study

The case study consists **of three DH networks located near Leibnitz, Austria**: Tillmitsch, Leibnitz in the middle, and Leibnitzerfeld in the south. Each of the three DH networks has a local heating centre with local production, thermal energy storage and demand from the DH network. Additionally, at Leibnitzerfeld a considerable amount of industrial waste heat is available. The details of the heating networks are summarized below.



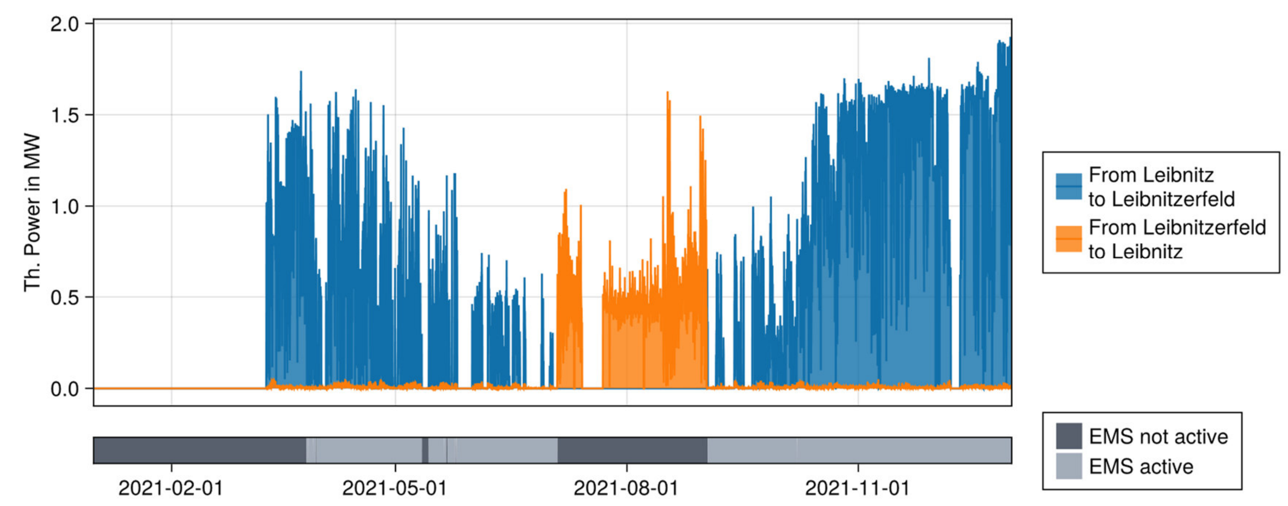
Details of the Heating Network

Network	Production Capacity	Annual Heat Demand	Storage Capacity	Annual Waste Heat Potential
Tillmitsch	Two 800 kW biomass boilers	~4 GWh	25m³	-
Leibnitz	3.2 MW and 2.4 MW biomass boilers	~12 GWh	75 m³	-
Leibnitzerfeld	6 MW gas boiler	~19 GWh	2 x 223 m³	~ 10 GWh

The networks of Tillmitsch and Leibnitz are directly hydraulically connected (1MW), and Leibnitz and Leibnitzerfeld are connected via a bidirectional heat transfer station (HTS) (4MW), that was built in the spring of 2021.

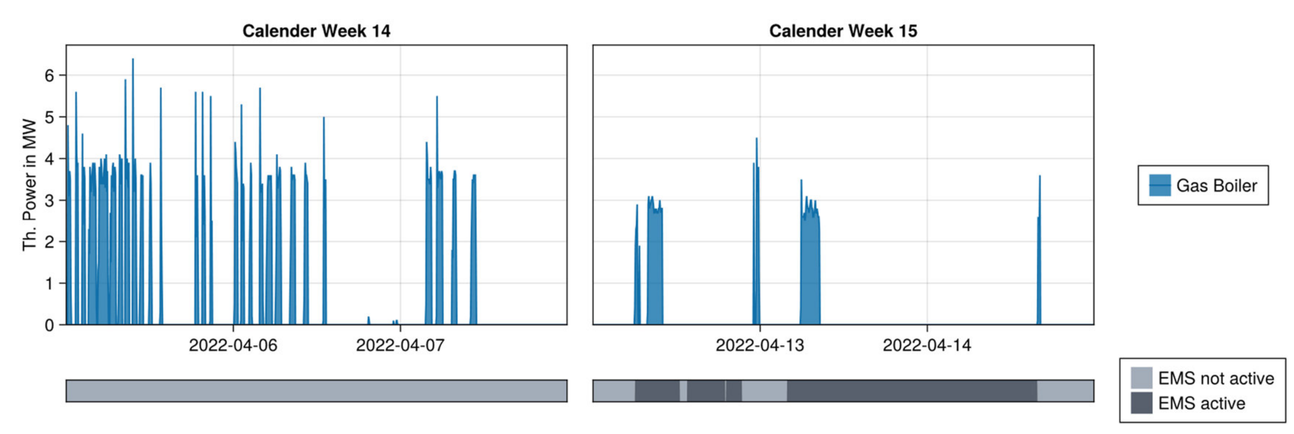
Implementation and Test Runs

The EMS was implemented in Julia and is operational since April 2021, shortly after the HTS was built. However, initially, the EMS was only allowed to control the HTS. All boilers in the three heating centres were still operated via their respective low-level controllers, which had to be considered by the EMS. The heat flows for 2021 are depicted below.

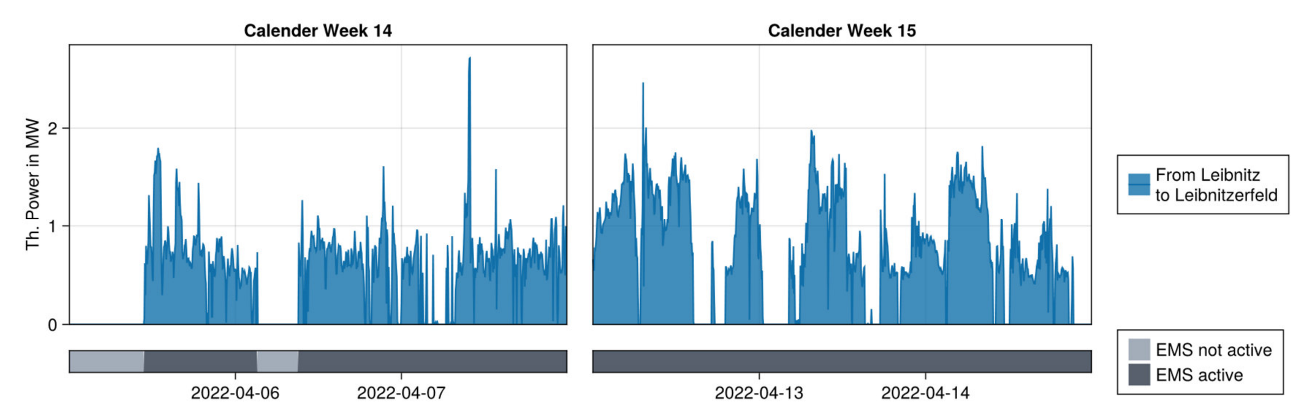


In total 1,2 GWh have been exported from Tillmitsch to Leibnitz (not depicted) and 3,7 GWh have been transferred from Leibnitz to Leibnitzerfeld, **saving about 930 t of CO2 emissions due to a reduction in the gas boiler operation**. Apart from a maintenance period during the summer, the EMS was operational most of the time. Unfortunately, the waste heat potential was not enough to supply all three networks during summer and the gas boiler had to be used.

During calendar week 15 of 2021 a test run, where all boilers were under the direct control of the EMS, was conducted. Exemplarily, the gas boiler operation with and without the EMS for both weeks is depicted below.



The EMS was able to **reduce the operation by about 70% and improve the operating conditions, i.e. longer run times and lower power levels**, compared to the reference week. During the test week, the EMS was able to **increase the heat transfer** considerably, **operating the HTS closer to its limits**.



Especially the maximum power level achieved was higher during the test week when the EMS had full control. For additional details see, [3].

Conclusion

The proposed EMS for coupled DH networks has been successfully implemented and tested on a real-world case study, showing the possibility of reducing CO_2 emissions and reducing fuel costs as well.

[1] Kaisermayer, V., et al., (2021). "Operation of Coupled Multi-Owner District Heating Networks via Distributed Optimization". Energy Reports, 7, 273–281. https://doi.org/10.1016/j.egyr.2021.08.145

[2] Muschick, D., *et al.*, (2022). "A multi-layer model of stratified thermal storage for MILP-based energy management systems". *Applied Energy*, 314, 118890. https://doi.org/10.1016/j.apenergy.2022.118890

[3] Kaisermayer, V., *et al.*, (2022). "Smart control of interconnected district heating networks on the example of '100% Renewable District Heating Leibnitz,'" *Smart Energy*, vol. 6. https://doi.org/10.1016/j.segy.2022.100069

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