# Stochastic Distributed Coordination of Energy Balance in Smart Thermal Grids

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## Description

Smart Thermal Grids (STGs) represents a new concept in the energy sector that involves the use of the smart grid concept in thermal energy networks connecting several households and greenhouses (agents) to each other via a transport line of thermal energy. One of the major challenges in sustainable energy systems is to improve the efficiency, reliability, and sustainability of the production and the distribution of energy. STGs can contribute to obtaining sustainable energy systems by introducing a reliable production plan using renewable energy sources such as solar or geothermal energy and provide efficient large-capacity storage unit. This results in a reduction of carbon dioxide ($CO_2$) emissions, improved energy efficiency, and the implementation of renewable energy systems [1].

In an STG setting, the agents have a potential to contribute to the overall energy balance. Every agent fulfills the role of a consumer when it demands more energy than it produces with its production units (e.g. micro-combined heat and power), and fulfills the role of a producer when the demand is less than the production of its production units [2]. Since the major energy consumption is typically used for thermal purposes, the motivation for STGs can be both economical and environmental. A better price is achieved with less energy transport when the resources are used more efficiently, while the thermal energy losses are reduced. We therefore foresee a shift towards a situation where a large number of small scale agents (e.g. utility companies and independent users) have more impact on the energy balance of the grid, while their optimal decisions are made by considering the thermal demand profiles, which are uncertain. The planning of thermal energy production to match supply and demand is challenging since predictions on the thermal energy demand are not perfect.

## Objectives

In [3], we formulated the production planning problems for a thermal grid with uncertainties in the consumer demand profiles as a finite-horizon chance-constrained mixed-integer linear optimization problem at each sampling time. This approach allows us to account for the stochastic uncertainty affecting the system, but also leads to a complex optimization problem that is in general hard to solve. Therefore, we proposed a unified framework to deal with such problems for uncertain systems, while providing a-priori probabilistic certificates for the robustness properties of the resulting solutions.

Our methodology is based on solving a random convex optimization problem to compute the uncertainty bounds using the so-called scenario approach [4, 5] and then, solving a robust mixed-integer optimization problem with the computed randomized uncertainty bounds at each sampling time. Using a tractable approximation of uncertainty bounds, the proposed problem formulation retains the complexity of the problem without chance constraints [6, 7]. In the presented thermal grid application this implies that a robust mixed-integer program is solved to provide a day-ahead prediction for the thermal energy production plan in the grid.

This proposal concentrates toward investigating the potential of substituting the developed control scheme with a more sophisticated scheme based on distributed setting, enabling to inherit probabilistic performance guarantees regarding the satisfaction of the energy balance in a smart thermal grid. Substantial current research focuses on formulating a distributed model predictive control similar to [8, 9, 10].

Of course other methods and directions, depending on the student's interest, could be analyzed and investigated. The mentioned goals here should be understood as some input thoughts and not as strictly recommended tasks.

## Requirements

The project combines rigorous mathematical aspects with practical research and would be an excellent experience for those wishing to go to either industry or academia. A background in convex optimization is required. Any knowledge in optimal control is useful, however not required. The work loads are as follows:

- Theoretical: 20-30%
- Simulation: 80-70%

## Supervisors

Vahab Rostampour and Tamás Keviczky are with the Delft Center for Systems and Control (DCSC) at the Delft University of Technology (TU Delft). Interested students are highly motivated to contact any of the supervisors listed above to discuss further details about the mentioned project.

## References


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