Cooperative Distributed Management in Building Climate Comfort Systems with Aquifer Thermal Energy Storage (ATES) Systems Smart Grids

Master Thesis Project

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Description

Global energy consumption has been increasing over the past decades due to increasing population and economic growth [1]. Considering the increasing energy demand worldwide, there has been a growing interest in energy saving technologies. A less well-known sustainable energy storage technology is Aquifer Thermal Energy Storage (ATES) that is used to store large quantities of thermal energy in underground aquifers enabling the reduction of energy usage and CO_2 emissions of the heating and cooling systems in buildings [2]. An ATES system can be considered as a heat source or sink, or as a storage for thermal energy [3]. It is especially suitable for heating and cooling of large buildings such as offices, hospitals, universities, musea (museums) and greenhouses. Most buildings in moderate climates have a heat shortage in winter and a heat surplus in summer. Where aquifers exist, this temporal discrepancy can be overcome by seasonally storing and extracting thermal energy in and from the subsurface. ATES can contribute significantly to reduce energy use for space heating [4]. Total energy savings may be improved by more efficient/optimal employment of the available space in the subsurface.

Objectives

A single ATES system generally consists of one or more pairs (doublets) of tube wells [3]. The well pairs simultaneously extract and infiltrate groundwater to store and extract thermal energy in aquifers, by changing the groundwater temperature in a heat exchanger which is coupled to the climate installation [5]. Since ATES systems are connected to the building they provide with thermal energy, they tend to accumulate in urban areas which puts stress on the limited subsurface space [4]. One of the barriers for development of ATES systems is the mutual interaction between different (neighboring) ATES systems in urban areas. In [3] and [4], we developed two different dynamical models for an ATES system. In the former one, we considered the energy content in both wells of an ATES system as the state, whereas in the latter case, we modeled more sophisticated detailed physical relations of an ATES system. Based on combination of the developed models in [3] and [4], we developed a new model that suits better for optimal control problems in [6].

This proposal concentrates toward investigating the following three directions. As for the first part, currently, we are working to develop another model based on the one in [6] that could cope with more realistic situations such as having a new installed ATES system, or when an ATES system is depleted completely. The student should be able to understand such a new model and to implement proposed control frameworks in [6]. We then focus toward the potential of substituting the developed control scheme (hierarchy distributed, price-based coordination) with another advanced scheme based on cooperative distributed setting such as distributed constrained consensus framework and enabling to inherit probabilistic performance guarantees regarding the satisfaction of the energy balance in a smart thermal grid. Finally, we will develop a framework to respect the privacy of the information for each building climate comfort systems (agents).

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 solid background in convex optimization is required. Any knowledge in optimal control is useful, however not required. The project is well suited for a student that enjoys to try out new ideas. By inspiration from the aforementioned problem, we promote to facilitate knowledge transfer from theory to practice. The work loads are as follows:

- Theoretical: 25-35%
- Computational: 75-65%

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

[1] V. Rostampour and T. Keviczky, "Robust randomized model predictive control for energy balance in smart thermal grids," *European Control Conference*, 2016.

[2] M. Bloemendal, T. Olsthoorn, and F. Boons, "How to achieve optimal and sustainable use of the subsurface for aquifer thermal energy storage," *Energy Policy*, vol. 66, pp. 104–114, 2014.

[3] V. Rostampour, M. Jaxa-Rozen, M. Bloemendal, and T. Keviczky, "Building climate energy management in smart thermal grids via aquifer thermal energy storage systems," *Accepted to Journal of Energy Procedia*, 2016.

[4] V. Rostampour, M. Bloemendal, M. Jaxa-Rozen, and T. Keviczky, "A control-oriented model for combined building climate comfort and aquifer thermal energy storage system," *Appear to European Geothermal Congress*, 2016.

[5] W. Ananduta, "Distributed energy management in smart thermal grids with uncertain demands," Master's thesis, Delft University of Technology, 2016.

[6] V. Rostampour and T. Keviczky, "Probabilistic energy management for building climate comfort in smart thermal grids with seasonal storage systems," *Submitted*, 2017.