Poster abstract

Integrated building energy management using aquifer thermal energy storage (ATES) in smart thermal grids

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Poster Abstract: Integrated Building Energy Management Using Aquifer Thermal Energy Storage (ATES) in Smart Thermal Grids

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ABSTRACT

Aquifer Thermal Energy Storage (ATES) is an innovative building technology that can be used to store thermal energy in natural subsurface formations [1, 4, 10]. In combination with a heat pump, ATES can reduce the energy demand of larger buildings by more than half, which has made the technology increasingly popular in northern Europe (see Figure 1). Furthermore, the climate and subsurface conditions required for ATES use can be found in areas across Europe, Asia and North America. By the middle of the century, roughly half of the world's urban population is therefore expected to live in areas technically suitable for ATES [2].

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However, the deployment of this technology in Europe has already raised some issues to consider for policymakers and building operators. In particular, recent work shows that operational uncertainties limit the performance of ATES systems under current methods for design and operation (e.g. [11]). These uncertainties include short-term variations in energy demand due to weather and occupancy, and longer-term trends in climate and aquifer conditions. As a result, building operators may for instance only use a fraction of their planned storage capacity, trading off energy savings for increased flexibility [7, 8]. Given that ATES planning policies are typically already conservative to avoid thermal interactions between adjacent systems, this can artificially constrain the adoption of ATES in dense areas, as allocated subsurface volume remains unused.

To maximize the long-term potential of ATES as an energy-efficient building technology, improved energy management frameworks are therefore necessary to better integrate the planning and operation of ATES under uncertainty. To this end, this poster presents the following novel contributions:

We show how the dynamic management of thermal interactions can significantly improve the specific energy savings provided by

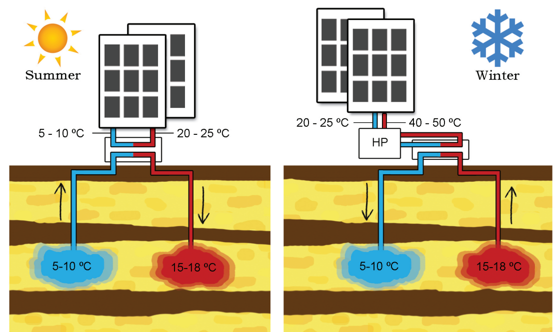

Figure 1: Operating modes of an ATES system during summer and winter seasons.

ATES under operational uncertainties, when combined with suitable spatial planning [3, 6, 7]. To achieve this goal, we develop a probabilistic dynamical energy management framework for physically coupled systems illustrated in Figure 2 for neighboring ATES systems. This framework is first tested using an idealized case study for centralized control, which assumes a complete exchange of information between three neighboring buildings. This case study is simulated in a coupled agent-based/geohydrological environment. Compared to a reference case without information exchange, centralized control allows ATES wells to be placed more densely without degrading thermal recovery, thereby using subsurface volume more efficiently. Figure 3 shows the simulated ATES thermal efficiency as a function of spatial density, for the reference and centralized control cases.

We extend this concept to a more practical setup, which preserves the privacy of individual ATES systems and addresses the computational issues of the centralized approach arising at a larger scale. To this end, we propose a distributed and decentralized probabilistic dynamical energy management framework [9]. This framework allows a plug-and-play capability such that each system can plug in or plug out without impacting overall performance. These developments will be tested in a realistic case study of ATES system planning in the city of Utrecht, in The Netherlands.

The modularity of the plug-and-play control framework allows the independent design of low-level building climate control systems. As future work, detailed control-oriented building and HVAC models will be developed and integrated in the distributed and decentralized probabilistic dynamical energy management framework. A proof-of-concept pilot study is considered involving several industrial partners in Amsterdam, The Netherlands. The aim of this

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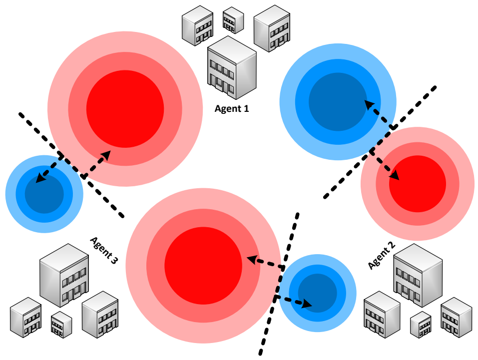

Figure 2: Idealized three-building ATES case study. Each building has a single ATES system which consists of a warm and a cold well. Warm and cold wells are shown with red and blue circles. The unwanted mutual interactions between ATES systems are shown via black dashed lines. Figure is taken from [10].

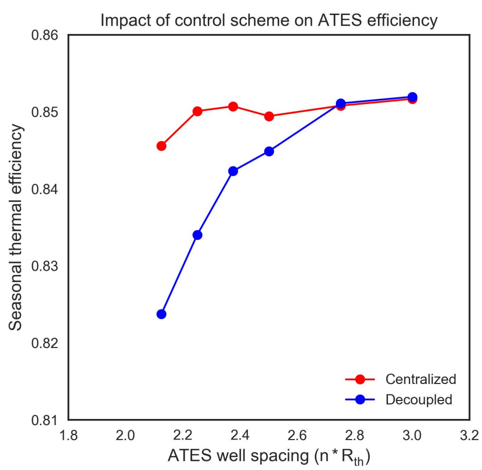

Figure 3: Simulated thermal efficiency of ATES systems with centralized and decoupled control, as a function of the distance between ATES wells (defined as a multiplier of the thermal radius Rth). In the reference decoupled case, thermal interferences degrade efficiency at smaller distances.

future work is to assess the performance and modularity of the high level energy management considering different low-level control framework scenarios. A runtime coupled low-level control architecture using Matlab and the well-known transient systems simulator Trnsys [5] will also be developed to assess the performance of the proposed framework with complex building simulation models.

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