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ATES Smart Grids research project overview and first results

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Background: ATES is application is growing
Application of seasonal Aquifer Thermal Energy Storage (ATES) contributes to energy saving and Greenhouse Gas (GHG)-reduction goals (CBS, 2015; EU, 2010, 2014). Recently it was shown that ATES is applicable in several parts of the world (Bloemendal et al., 2015). While in most parts of the world adoption is just beginning, in the Netherlands progressive building energy efficiency regulation already caused the adoption of ATES to take off (Heekeren and Bakema, 2015; Sommer et al., 2015). As a result of the large number of ATES systems in the Netherlands, the subsurface plays a crucial role in the energy saving objectives of The Netherlands (Kamp, 2015; SER, 2013).

Problem: suboptimal use of the subsurface for energy storage
ATES systems accumulate in urban areas, as can be expected with a large growth of ATES systems; at many locations in Dutch cities demand for ATES transcends the available space in the subsurface (Li, 2014; Sommer et al., 2015). Within in the Dutch legal framework and state of technology optimal use of the subsurface is not secured; i.e. minimizing the total GHG emissions in a certain area. (Bloemendal et al., 2014; Li, 2014). The most important aspects in this problem are A) the permanent and often unused claim resulting from static permits and B) excessive safety zones around wells to prevent interaction. Both aspects result in an artificial reduction of subsurface space for potential new ATES systems. Recent research has shown that ground energy storage systems could be placed much closer to each other (Bakr et al., 2013; Sommer et al., 2015), and a controlled/limited degree of interaction between them can actually benefit the overall energy savings of an entire area.

Solution: the approach and first results of our research project on ATES Smart Grids
The heating and cooling demand of buildings is a dynamic and hard to predict process, due to effects such as weather, climate change, changing function and usage of buildings over time. This naturally also applies to the required storage capacity in the subsurface. Because of these uncertainties the only way to optimally use the subsurface is to shift the organization of the subsurface space use from the planning phase to the operational phase.
Our solution therefore provides a framework in which adaptability plays a key role. Optimal use can only be achieved when users have insight in the status and their effect on the resource they are exploiting (Ostrom, 1990). Therefore exchange of information is necessary for individual users to adapt their operation based on the current state of the subsurface and their energy demand via a controller and compensation measures.

To arrive at a proof-of-concept based on our approach, we use expertise and models from different fields such as administrative policy and decision making, systems and control, and hydrogeology. A central element is the so-called agent-based model (ABM), which is a technique widely used in administrative policy and decision making in order to simulate the behavior of actors. Each agent has a controller that determines how the geothermal energy system must satisfy the energy demand of the building. Thus properties and characteristics of the building and the system are included in this controller. We apply a so-called Model Predictive Control (MPC) approach, which means that the controller takes into account the expected energy demand in the future, and also how its control strategy influences the performance of its own resources. The computed control action is implemented on a groundwater model of the area including all geothermal energy systems, which then serves as the basis for planning the control actions over the next period.

This concept is developed in 3 steps up to the scale of a typical Dutch town. Currently we have a proof-of-concept based on a fictitious academic model (1), which we are currently scaling up to the city-center area of Utrecht (2) after which we then incorporate the entire city of Amsterdam (3). The first results of the academic model are promising (Jaxa-Rozen et al., 2015), it shows that stable situations result even for ATES system that are placed a lot closer together than what current regulations would dictate. This has a positive effect on the total

GHG emission reduction, but a negative effect on individual efficiency.

In the presentation at EGU we will show results from the academic case, discuss several challenges for the optimization and present details on the analytical geohydrological ATES well model required for the controller to keep track of energy losses in its own wells.

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