MINES PARIS | PSL | TTI.5° The Transition Institute

THESIS

OPTIMIZATION OF SHALLOW GEOTHERMAL ENERGY: FROM UNDERGROUND TO BUILDING

Project description:

The building sector consumes 43% of final energy in France, above the European average of 40% (Atam and Helsen, 2016). Moreover, with the recent democratization of teleworking, this domestic energy demand (heating, cooling, lighting) could be revised upwards. Domestic consumption is today mainly dependent on fossil fuels, which makes it very vulnerable to variable geopolitical trends, and generates significant greenhouse gas emissions.

In order to respect the commitments of the Paris climate agreement, it is necessary to adopt a responsible strategy of energy consumption by reducing the energy balance of buildings on the one hand and by using more renewable energy on the other. The latest IPCC report (April 2022) places renewable energies at the heart of any strategy to combat climate change. In France, the law on energy transition and green growth sets the share of renewable energies in gross final energy consumption at 32% by 2030. The need to massively deploy renewable energies is therefore becoming urgent. In this context, the underground allows us to respond in part by offering on the one hand access to an energy source (here thermal) and on the other hand to store it (Maragna and Tourlière, 2018). Geothermal energy is one of the renewable energy sources that can provide a very high energy to produce electricity (temperature up to 150°C for deep geothermal) or low or even very low energy to heat buildings. We are interested in this second category, where geothermal probes of a few tens of meters in length recover heat from the ground via a thermal exchange.

The ground temperature is practically constant within a few meters of the surface. At these depths, the temperature remains insufficient to be directly exploited, and a coupling solution with an electric heat pump is in most cases necessary. In combination with a reversible heat pump, the (ground source heat pump) GSHP can also act as a cooling source during the summer and allow buildings to be cooled. This is particularly interesting when the global warming factor is taken into account. Indeed, the demand for building cooling should increase by 750% for the residential sector and 275% for the tertiary sector by 2050 (Santamouris, 2016). It should also be noted that unlike other types of renewable energy (solar, wind, etc.) geothermal energy is not intermittent.

Despite a very favorable energy context, the massive use of geothermal energy is lagging in France compared to other European countries such as Germany and the Netherlands with, respectively, twice and seven times more geothermal installations in operation (AFPG 2019). This is partly related to the current sizing method, which is very simplistic and far from reality, and can lead to an oversizing of geothermal installations (in terms of length of thermal probe, power of the heat pump, etc.) and a final overcost of the project.

The objective of the proposed thesis is, on the one hand, to improve the sizing procedure by relying on a fine and more realistic modeling of the geothermal probes and, on the other hand, to optimize the operation of the overall system by relying on an intelligent piloting of the heat pump. This is part of a close collaboration between the two departments of Mins Paris PSL university: Geosciences Center and the Centre for Energy Efficiency of Systems (CES). The first task will concern the modeling of geothermal probes and will rely on the skills of the geomechanical team of the Geosciences Center. It will concern two scales: at the scale of a probe (or a group of probes) with all the surrounding complexities (soil heterogeneity, groundwater flow, etc.) and at the regional scale using a Machine Learning tool to enrich the existing thermal test database, to improve future probe sizing in the absence of thermal response test (TRT).

The second task will be based on the skills of the CES and will aim to optimize the overall sizing of the system (geothermal probes after the first task, heat pump and possibly the hot water storage tank). For this, the energy and economic performance of the system will be evaluated by considering an intelligent control that meets the thermal needs in real time while optimizing the coefficient of performance (COP) of the heat pump in the presence of storage. This will allow the identification of optimal and realistic combinations according to the energy needs of the building and the geothermal availability. The results of an ongoing project with the agglomeration of Fontainebleau (Plan Climat-Air-Énergie Territorial, PCAET) could supply this thesis for the original in-situ data. The developed methodology could be used as a decision-making tool and will contribute to the generalization of this technology which could reduce the dependence on gas in the building sector. It will also allow the evolution of the standard used today in the dimensioning of geothermal probes.

References:

AFPG (2019), La géothermie en Francs, étude de filière.

Atam E. and Helsen L. (2016). Ground-coupled heat pumps: Part 2—Literature review and research challenges in optimal design. Renewable and Sustainable Energy Reviews, 54, 1668-1684.

Maragna C., Tourlière B. (2018) - Potentiel du stockage de chaleur fatale en champs de sondes. Rapport BRGM/RP-67592-FR, 39 p., 26 fig., 4 tab., 1 ann.

Santamouris M. (2016). Cooling the buildings – past, present and future,Energy and Buildings,Volume 128, 617-638.

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