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Design of an Innovative Geothermal Heat Pump with a PCM Thermal Storage

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Abstract : This study presents an innovative design for geothermal heat pumps with the goal of maximizing the system efficiency (COP - Coefficient of Performance), reducing the soil use (e.g. length/depth of geothermal boreholes) and initial investment costs. Based on experimental data obtained from a two-year monitoring of a working prototype implemented for a commercial building in the city of Perugia, Italy, an upgrade of the system is proposed and the performance is evaluated via CFD simulations. The prototype was designed to include a thermal heat storage (i.e. water), positioned between the boreholes and the heat pump, acting as a flywheel. Results from the monitoring campaign show that the system is still capable of providing the required heating and cooling energy with a reduced geothermal installation (approx. 30% of the standard length). In this paper, an optimization of the system is proposed, re-designing the heat storage to include phase change materials (PCMs). Two stacks of PCMs, characterized by melting temperatures equal to those needed to maximize the system COP for heating and cooling, are disposed within the storage. During the working cycle, the latent heat of the PCMs is used to heat (cool) the water used by the heat pump while the boreholes independently cool (heat) the storage. The new storage is approximately 10 times smaller and can be easily placed close to the heat pump in the technical room. First, a validation of the CFD simulation of the storage is performed against experimental data. The simulation is then used to test possible alternatives of the original design and it is finally exploited to evaluate the PCM-storage performance for two different configurations (i.e. single- and double-loop systems).

Keywords : geothermal heat pump, phase change materials (PCM), energy storage, renewable energies
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