Development and optimization of Underground Thermal Energy Storage Systems

(Proposer: Dr. Antonio Galgaro)

The possibility to meet the thermal energy availability and production with the user requests is a concrete and interesting solution voted to maximize the efficiency and to reduce the energy losses and greenhouse emissions. The possibility to store the waste heat and the excessive heat production in the underground in the warm season to recover it during cold periods or a daily heat storage to put in phase heat sources and needs, enables energy cost saving and environmental protection.
During the last decades, the increasing number of biomass co-generation power plants and solar thermal system developed worldwide and the growing needs for more efficient energy use in buildings due to heating and cooling made the employment of Underground Thermal Energy Storage (UTES) systems increasingly interesting. UTES technologies include borehole Thermal Energy storage, aquifer storage, cavern and pit storage. Which of these technologies is selected strongly depends on the local geological conditions and heat storage settings. The geological component in these systems constitutes the fundamental and invariant element for the evaluation of the potential of such solutions, will then be studied integrated systems of thermal accumulation in the subsoil, using both matrices water, that ground, and/or cementitious materials. The PhD topic is focused on the studies regarding underground thermal storage capability, which ensure the transfer of thermal energy to and from the ground layers (e.g. clay, sand, salts, rock) and permits low heat losses, thanks to the subsoil thermal stability and inertia. Most of such high to low temperature UTES options will be studies, such as rocks masses in natural conditions, measuring the fundamental thermal properties and mechanical stresses, induced by temperature alterations, in laboratory and field environments, on different lithology, and the heat transfer processes involved, by means of FEM codes analyses. The thermal alteration induced in the ground by heat exchange processes are usually evaluated by means of heat transfer and groundwater flow numerical models that need to be validated through the comparison with experimental data, which are often missing due to the difficulties of in-field measurements. For this purpose, an available middle-scale physical model of a ground heat exchange system will be used in order to directly measure the heat transport processes occurring in the ground in simplified and controlled conditions. The outputs will give a deeper understanding of the complex involved physical processes and can be used to calibrate and validate multi-physics numerical models. Furthermore, the thermal storage capabilities of composite materials (e.g. ceramics, concrete, PCM (phase change materials)) will be analyzed, in different composition and operational conditions, in order to evaluate the best composition in terms of performance, efficiency, availability and costs. The final purpose of the research consists in the trialling of a thermal storage system, characterized by high efficiency and reproducibility in different geological contexts. The research project is characterized by a high level of innovation and potential applicative useful outcomes (such as district space heating and cooling or industrial heat/cool demand processes. The research activity is based on a multiscale laboratory and on-site tests as well as applications of coupled physical and numerical modelling, in order to analyze the involved heat transfer processes, heat losses and induced thermo-mechanical effects on the storage materials.
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