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EUROTHERM

Numerical Heat Transfer Modeling of Large-Scale Hot Water Tanks and Pits

A. Dahash[1], F. Ochs[1] and M. Bianchi Janetti[1]
[1] Institute of Construction and Material Science; Unit for Energy Efficient Buildings; University of Innsbruck, Innsbruck, Austria

Introduction and Motivation

- Large-scale thermal energy storage (TES) is a key component for transition into sustainable energy utilization in urban centers.
- TES operation has an impact on the surroundings that is poorly investigated in literature.
- The influence of complex geometries and existence of groundwater cannot be examined with existing models.
- This paper describes the development of an axial symmetrical model for circular TES systems with its surrounding environment.

TES Numerical Modelling

- A numerical model consisting of two component-level models is developed in COMSOL Multiphysics. One is TES fluid domain model, which is developed as 1-D model, while the other is an axial symmetrical 2-D model to represent the surroundings.
- Energy balance equation for TES fluid domain:

$$(\rho A c_p)\frac{\partial T(t)}{\partial t} = -(\rho \dot{V}_w c_p)\frac{\partial T(t)}{\partial z} + A\nabla\cdot(\lambda_w \nabla T) - \dot{Q}_{loss,i}$$

- The approach was developed for a 3-D model, which enables to consider ground water flow.

Table. 1: Model parameters and its corresponding values

Parameter	Tank	Pit
Height	50 m	50 m
Base diameter	50,5 m	20 m
Top diameter	50.5 m	75.7 m
Slope angle	90°	60.9°

Parameter	Value
Overall cover heat transfer coefficient	0.15 W/(m².K)
Overall wall heat transfer coefficient	0.3 W/(m².K)
Overall bottom heat transfer coefficient	0.3 W/(m².K)
Ground thermal conductivity	1.5 W/(m.K)

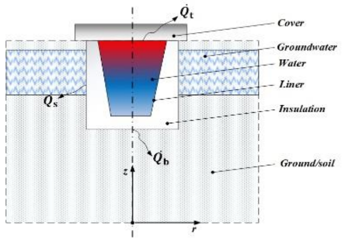

Fig. 1: Schematic overview of an underground pit with its surroundings.

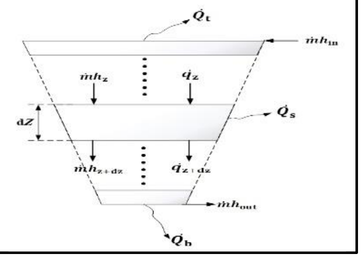
Fig. 2: 1-D finite differential element of the underground pit TES.

Simulation Results

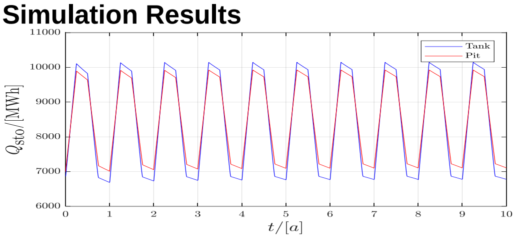

Fig. 3: Energy stored in the underground TES over 10 years.

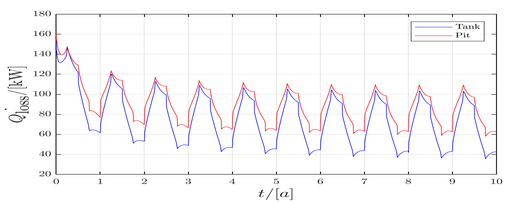

Fig. 4: Total thermal losses from the underground TES over 10 years.

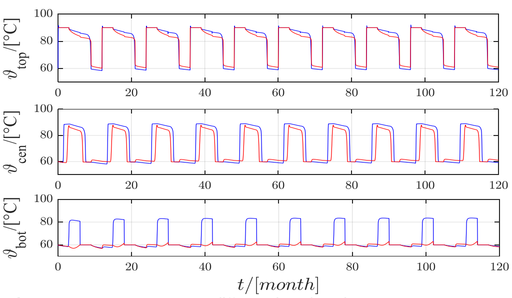
Fig. 5: Water temperature at different locations in TES over 10 years.

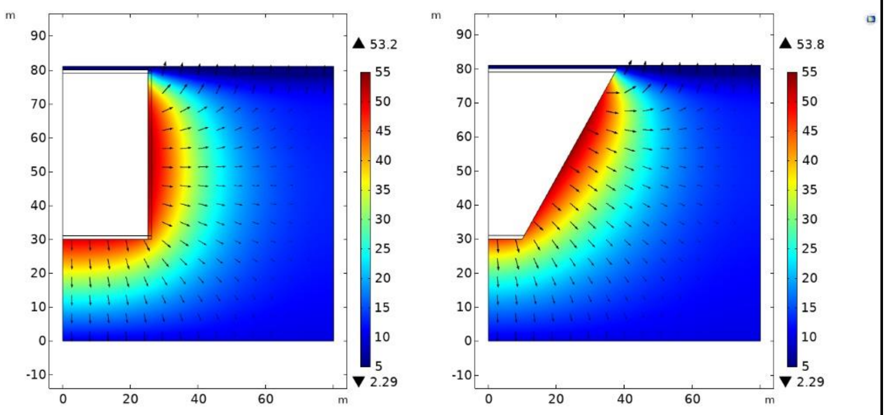
Fig. 6: Contour plots for the surroundings of the tank (left) and the pit (right) TES at the end of the 10th year.

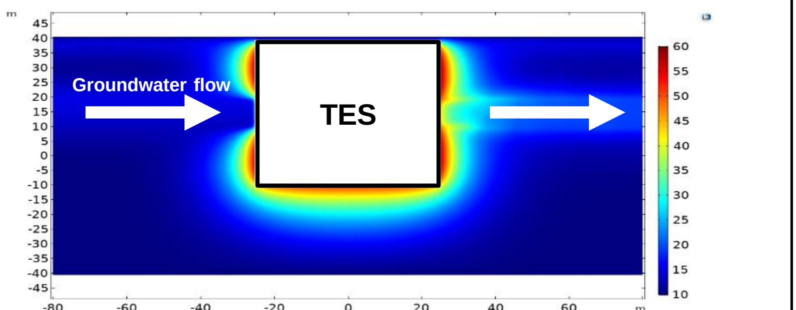

Fig. 7: Surroundings temperature in degree C for a tank with groundwater flow at the end of the 5th year.

Conclusions

- The thermo-hydraulic behavior of the storage medium is correctly implemented and delivers qualitatively correct results.
- Validation of the model is ongoing.
- The ground is highly influenced, depending on the level of insulation and depending on the ground properties and ground water conditions. Surrounding's temperature can exceed 40 ° C.

Outlook

The developed model can assist the development of cost-effective TES constructions and investigate both, the thermal performance of the TES and its influence on the surroundings.

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