Comprehensive Comparison of Different Models for Large Scale Thermal Energy Storage

IRES 2021

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Austrian FFG Flagship Project (Energieforschung)

giga_TES
Giga-Scale Thermal Energy Storage for Renewable Districts

Total cost: 4.4 M€
Funding requested: 3.3 M€
Duration: 36 Months
Work Package structure

WP2: Boundary Conditions, for Technology Development and System Integration (SOLID)

WP3: Giga-Scale Thermal Storage Technology Development (ste.p)

WP4: Materials Development and Testing (JKU)

WP5: Computer Assisted Storage Optimisation (UIBK)

WP6: System Integration and Storage Management (AEE INTEC)

WP7: Exploitation and Dissemination (AEE INTEC)

Boundary conditions

storage requirements:
- temperature
- load profiles
- volume
- location

evaluation
dimensioning

materials
Large-scale TES construction types

- Tank (cylinder)
- Steep pit
- Hybrid
- Shallow pit (cone, pyramid)

Source: ste.p
Modelling TES

Motivation

• Improve Modelling of TES
  • Models for complex geometries
  • Models accounting for ground water flow
  • Component and system level models
  • Improve simulation performance
• Intermodel comparison (cross-validation)
• Model calibration and validation

Performance Assessment of TES

Hybrid TES geometry
- dam
- cuboid
- pyramid stump

\[ V = 100,000 \text{ m}^3 \]
modeling process of large-scale TES in DH systems

From component Level to system level

Pre-Design (feasibility), System Integration

Storage Optimisation
  • Component level
  • TES Level
  • ...

System Optimisation
  • TES integration
  • Control
  • ...

Environmental Impact Assessment
DH and TES Tools and Scope

District heating system

TES (TES component)

Environment

- TRNSYS (FD, 2D (3D))
- Modelica (FD, 2D)
- Matlab/Simulink (FE, 2D)
- Comsol (FE)
- ANSYS (CFD)
- Feflow (FE)
TES and environment

Interaction between TES and environment

- Influence of ground water (flow) on thermal losses
- Influence of TES on ground water temperature (limit max. GW temperature)

Example. Ground water flow in surroundings of TES (COMSOL)
TES model validation (Comsol, Droninglund Pit TES)

- **Validation case:**
  - Dronninglund pit TES in Denmark
  - $V_{pit} \approx 60,000 \text{ m}^3$
  - $a = b = 90 \text{ m}$
  - $a_1 = b_1 = 26 \text{ m}$
  - $h = 16 \text{ m}$
  - $\alpha = 26.5^\circ$

- **Measured data:**
  - Year: 2015
  - Hourly resolution flowrates and temperatures

TES Models overview

a. COMSOL Multiphysics (UIBK);
b. TRNSYS (SOLITES, PlanEnergi,):
   • Type 1300/Type 1301 (SOLITES);
   • Type 1322 (PlanEnergi)
   • Type 342 (PlanEnergi);
c. Modelica/Dymola (AEE INTEC).
d. Modelica/Dymola (UIBK).
e. Matlab/Simulink (UIBK)

- tank (cylindrical and cuboid) and pit (cone, pyramid stump)
- $V_{TES} = 100,000 \text{ m}^3 \text{ and } h_{TES} = 25 \text{ m}$;
TES Models-Tools Comparison

Case Study

TES with $V_{TES} = 100,000 \text{ m}^3$ and $h_{TES} = 25 \text{ m}$;

Two primary cases:

a. **Case 1**: no insulation on the sidewall and bottom;

b. **Case 2**: insulated sidewall and bottom ($U_{side} = U_{bottom} = 0.3 \text{ W/(m}^2\text{.K)}$).

Cover

a. $U_{top} = 0.05 \text{ W/(m}^2\text{.K)}$;
b. $U_{top} = 0.1 \text{ W/(m}^2\text{.K)}$;
c. $U_{top} = 0.15 \text{ W/(m}^2\text{.K)}$. 

$T_{amb}$ and $h_{air} = 25 \text{ W/(m}^2\text{.K)}$
TES Model Comparison - Steps

1) Cooling Curve
2) Load Profile (Discharge and Charge massflow and temperature)
3) Load Curve (Load Profile (Power, T) and Source Profile (Power, T)
Example TES Matlab/Simulink

FD fluid domain and FE solid domain

coupling
Example TES Matlab/Simulink

FD fluid domain and FE solid domain
FE based TES (Comsol, Matlab/Simulink)

- Cylinder
- Pit
- Dam
- Hybrid
- Partially buried
- etc.
Cover insulation and thermal bridge

- no overlap no insulation, cover 0.1 W/(m² K)
- 2 m overlap no insulation, cover 0.1 W/(m² K)
Exampl Tank (cylinder) vs. Pit (cone)

Matlab/Simulink

100,000 m³, 25 m, 34°
100,000 m³, 25 m, 90° (50 m, 90°)
Results
Conclusions

Different TES models in different platforms available
TES model comparison reveals some deficiencies (improvements ongoing)
After parameterisation, generally good agreement
Significant differences in model flexibility and simulation speed

Further work within IEA ECES Annex 39.
Acknowledgements

This project is financed by the Austrian “Klima- und Energiefonds” and performed in the frame of the program “Energieforschung”. It is part of the Austrian flagship research project “Giga-Scale Thermal Energy Storage for Renewable Districts” (giga_TES, Project Nr.: 860949). Therefore, the authors wish to acknowledge the financial support for this work.