Component Modelling: BTES

Case definition

Borehole thermal energy storage: Important component

Storing surplus heat in the ground during summer season significantly reduces the energy required for heating during winter season. Seasonal thermal energy storage has thus become very popular for both residential and commercial buildings. As a key component with very high initial costs, borehole thermal energy storage requires careful design. The number of boreholes and their depth should not only be decided based on capacity calculations, but also on the dynamic response and its effects on system performance.

Component modeling

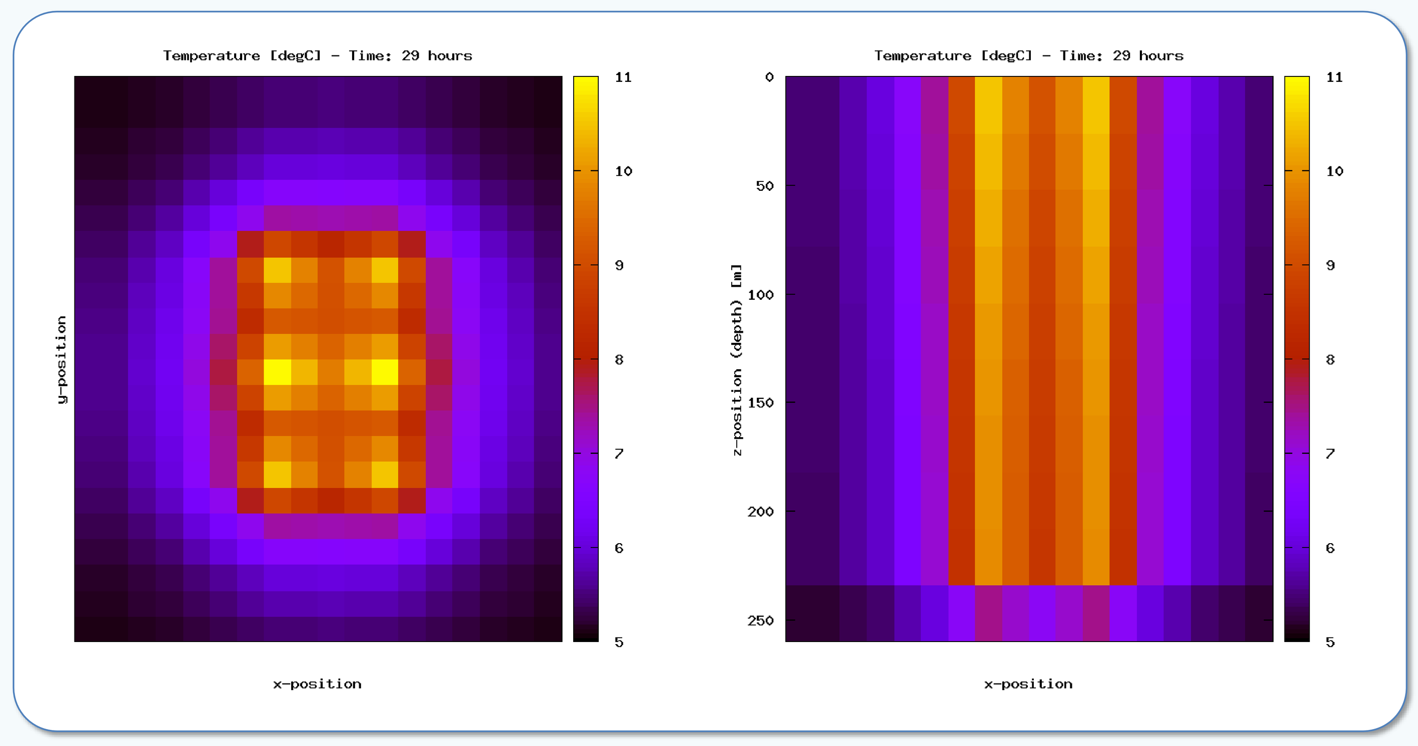
From detailed to simplified

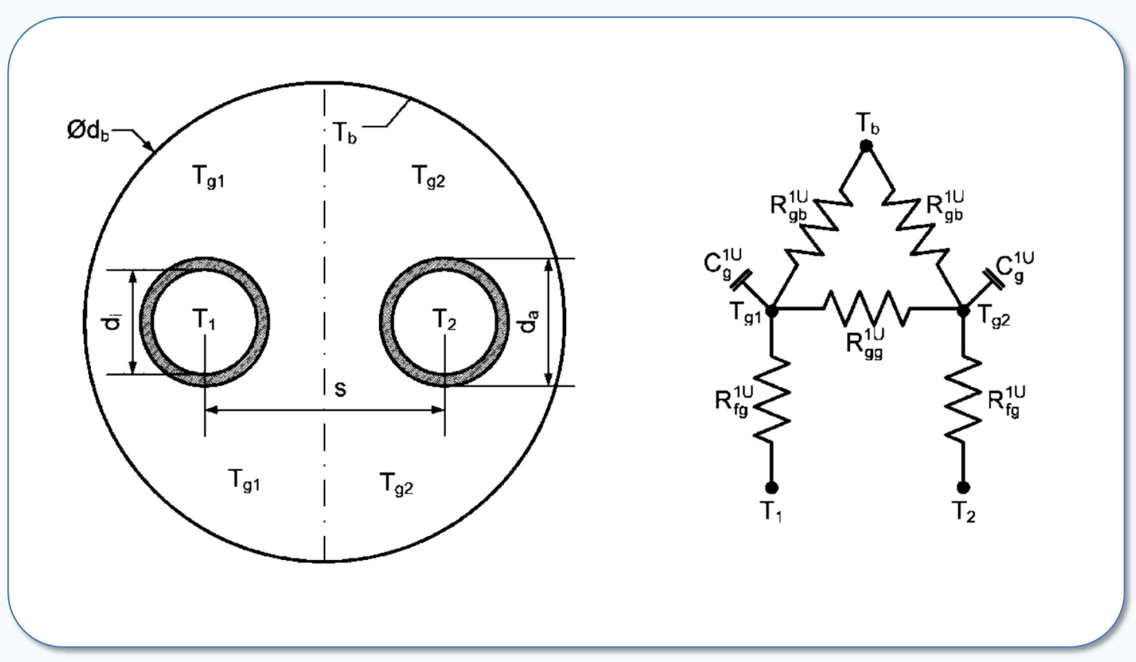
The simulation time is higher for more detailed models than for simplified ones. It is of interest to keep simulation time low, as optimization requires numerous simulation runs. Therefore, the aim was to build a model that is rather simple but still accurate.

As a first step, several boreholes were simulated with great detail and compared to published experimental data. As an example, a temperature distribution of six boreholes can be seen in the figure to the right.

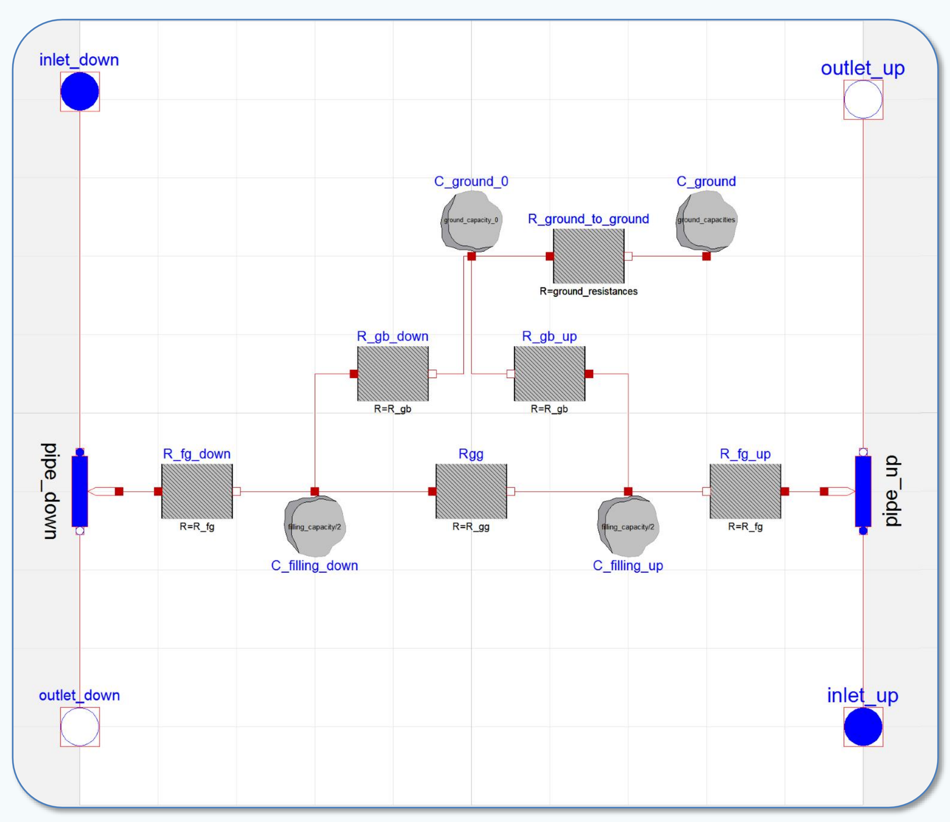
Based on a journal paper from Bauer, et. al. (2011), a simplified model was programmed which lumps the capacities of the fluid in the pipes, the filling material, and the surrounding ground. To add more detail, the ground was discretized and consists of several cylindrical shells.

```
equation
  //Main heat balance equation per element
   for iz in 1:(nz) loop
     for iy in 1:(ny) loop
       for ix in 1:(nx) loop
        (if ix >1 then (Tnode[ix,iy,iz]-Tnode[ix-1,iy,iz])/Rx else (Tnode[ix,iy,iz]-heatPort_w[iy,iz].T)*2/Rx)
      + (if ix < nx then (Tnode[ix,iy,iz]-Tnode[ix+1,iy,iz])/Rx else (Tnode[ix,iy,iz]-heatPort_e[iy,iz].T)*2/Rx)
      + (if iy>1 then (Tnode[ix,iy,iz]-Tnode[ix,iy-1,iz])/Ry else (Tnode[ix,iy,iz]-heatPort_front[ix,iz].T)*2/Ry)
      + (if iy<ny then (Tnode[ix,iy,iz]-Tnode[ix,iy+1,iz])/Ry else (Tnode[ix,iy,iz]-heatPort_back[ix,iz].T)*2/Ry)
      + (if iz>1 then (Tnode[ix,iy,iz]-Tnode[ix,iy,iz-1])/Rz else (Tnode[ix,iy,iz]-heatPort_s[ix,iy].T)*2/Rz)
      + (if iz < nz then (Tnode[ix,iy,iz]-Tnode[ix,iy,iz+1])/Rz else (Tnode[ix,iy,iz]-heatPort_n[ix,iy].T)*2/Rz)
      + der(Tnode[ix,iy,iz]/TimeFactor)*cp*massNode
      + Qext[ix,iy,iz]
      = 0;
       end for;
     end for;
   end for;
```



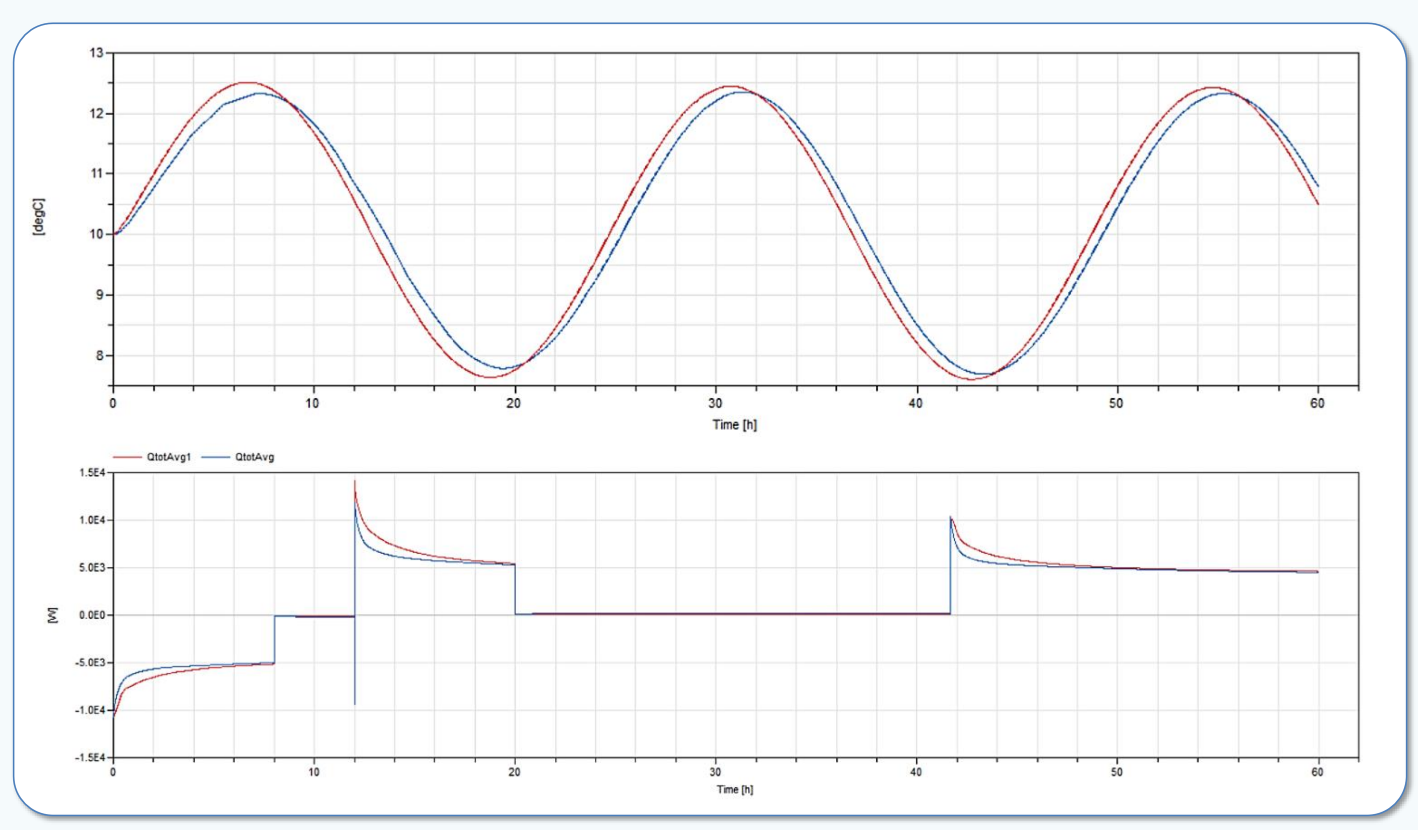


Bauer, D., et al. (2011). "Thermal resistance and capacity models for borehole heat exchangers." International Journal of Energy Research **35**(4): 312-320.



The two models were compared and the simplified model was adopted to show similar dynamic responses. Two examples from the testing phase can be seen in the bottom right figure.

By using this approach, the "light" model with ~1000 variables produces similar behavior and response as the full element-model with ~100 000 variables.



Simulation results for BTES response. Red = detailed model, blue = simple model

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