IBPSA Project 1

Ice Tank Model

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Basic assumptions

Model based on paper from 2021 Int. Modelica Conference

An Ice Storage Tank Modelica Model: Implementation and Validation

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Governing equations

This model implements an ice tank model whose performance is computed based on performance curves.

The model is based on the implementation of Guowen et al., 2020 and similar to the detailed EnergyPlus ice tank model ThermalStorage:Ice:Detailed.

The governing equations are as follows:

The mass of ice in the storage m_{ice} is calculated as

$$d\,SOC/dt = \dot{Q}/(H_f \;\; m_{ice,max})$$

$$m_{ice} = SOC \;\; m_{ice,max}$$

where *SOC* is state of charge, $\dot{Q}$ is the heat transfer rate of the ice tank, positive for charging and negative for discharging, *Hf* is the fusion of heat of ice and $m_{ice,max}$ is the nominal mass of ice in the storage tank.

The heat transfer rate of the ice tank $\dot{Q}$ is computed using

$$\dot{Q} = Q_{sto,nom} \;\; q^*,$$

where $Q_{sto,nom}$ is the storage capacity and q^* is a normalized heat flow rate. The storage capacity is

$$Q_{sto,nom} = Hf \;\; m_{ice,max},$$

where *Hf* is the latent heat of fusion of ice and $m_{ice,max}$ is the maximum ice storage capacity.

The normalized heat flow rate is computed using performance curves for charging (freezing) or discharging (melting). For charging, the heat transfer rate q^* between the chilled water and the ice in the thermal storage tank is calculated using

$$q^* \Delta t = C_1 + C_2 x + C_3 x^2 + [C_4 + C_5 x + C_6 x^2]\Delta T_{lmtd}^*$$

where Δt is the time step of the data samples used for the curve fitting, $C_{1\text{-}6}$ are the curve fit coefficients, x is the fraction of charging, also known as the state-of-charge, and T_{lmtd}^* is the normalized LMTD calculated using Buildings.Fluid.Storage.Ice.BaseClasses.calculateLMTDStar. Similarly, for discharging, the heat transfer rate q^* between the chilled water and the ice in the thermal storage tank is

$$- q^* \Delta t = D_1 + D_2(1-x) + D_3 (1-x)^2 + [D_4 + D_5(1-x) + D_6 (1-x)^2]\Delta T_{lmtd}^*$$

where Δt is the time step of the data samples used for the curve fitting, $D_{1\text{-}6}$ are the curve fit coefficients.

The normalized LMTD ΔT_{lmtd}^* uses a nominal temperature difference of 10 Kelvin. This value must be used when obtaining the curve fit coefficients.

The log mean temperature difference is calculated using

$$\Delta T_{lmtd}^* = \Delta T_{lmtd}/T_{nom}$$

$$\Delta T_{lmtd} = (T_{in} - T_{out})/\ln((T_{in} - T_{fre})/(T_{out} - T_{fre}))$$

where T_{in} is the inlet temperature, T_{out} is the outlet temperature, T_{fre} is the freezing temperature and T_{nom} is a nominal temperature difference of 10 Kelvin.

Reference

Strand, R.K. 1992. “Indirect Ice Storage System Simulation,” M.S. Thesis, Department of Mechanical and Industrial Engineering, University of Illinois at Urbana-Champaign.

Guowen Li, Yangyang Fu, Amanda Pertzborn, Jin Wen and Zheng O'Neill. *An Ice Storage Tank Modelica Model: Implementation and Validation.* Modelica Conferences. 2021. doi: 10.3384/ecp21181177.

Package structure

- Ice
  - ControlledTank
  - Tank
  - Data
    - Tank
      - EnergyPlus
      - Experiment
      - Generic

Two options:

1. Ideally controlled tank (exact solution, not PI controller as was used in Modelica paper)

2. Tank only (allows for example glycol-water heat exchanger control)