IDEAS SimpleHouse exercise instructions

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Introduction

The goal of this exercise is to become familiar with Modelica and the IDEAS library. Since the IDEAS library components are typically used by combining several components graphically, the use of equation falls outside of the scope of this exercise.

For this exercise you will create a model of a simple house, consisting of a heating system, one building zone and a ventilation model. The exercise starts from a template file that should not produce any errors. This file will be extended in several steps, adding complexity. In between each step the user should be able to simulate the model. I.e. no errors should be produced and simulation results may be compared.

Prerequisites are that you should have the latest version of Dymola installed. You should have a working compiler, and a license. Dymola can be downloaded from `http://www.3ds.com/products-services/catia/products/dymola/trial-version/`. Installation instructions for Dymola and a C-compiler can be found on `http://www.3ds.com/fileadmin/PRODUCTS/CATIA/DYMOLA/PDF/Installation.pdf`. The latest version from the IDEAS library should be downloaded and opened in Dymola. To verify you installation try to simulate `IDEAS.Fluid.Actuators.Dampers.Examples.Damper` by opening the simulation tab (bottom right) and by clicking simulate ().

In the following sections the simple house model is discussed in several steps. Each step first qualitatively explains the model part. Secondly the names of the required IDEAS models are listed. Thirdly we provide high-level instructions of how to set up the model. If these instructions are not clear immediately, have a look at the model documentation and at the type of connectors the model has, try out some things, make an educated guess, etc. Finally we provide reference results that allow you to check if your implementation is correct. Depending on the parameter values that you choose, results may differ.

1 Building wall model

Qualitative discussion Even though one of the goals of IDEAS is to provide detailed building envelope models, a very simple building envelope model will be constructed manually using thermal resistors and heat capacitors. The house consists of a wall represented by a single heat capacitor and a thermal resistor. The thermal resistor and boundary temperature are already added in the template. The wall has a surface area of A_wall = 100 m^2, a thickness of d_wall = 25 cm [1], a thermal conductivity of k_wall = 0.04 W/mK, a density of rho_wall = 2000. The heat capacity value of a wall may be computed as $C = A \cdot d \cdot c_p \cdot rho$.

Required models In this first step only the Modelica Standard Library (MSL) model `Modelica.Thermal.HeatTransfer.Components.HeatCapacitor` is required.

Connection instructions Connect the heat capacitor to the thermal resistor.

Reference result If you correctly added the model, connected it to the resistor and added the parameter values for C [2] then you should be able to simulate the model. To do this, go to the simulation tab (see bottom right), open the simulation options ('setup') and set the model 'stop time' to 1e6 seconds. You can now simulate the model. You can plot individual variables values by clicking on their name in the variable browser on the left. Now plot the wall capacitor temperature value 'T'. It should look like Figure 1.

[1] We suggest to declare these parameters in the equation section similar to the example, but this is not required.

[2] Double-click on a component to see a list of its parameters. Gray values indicated default values.

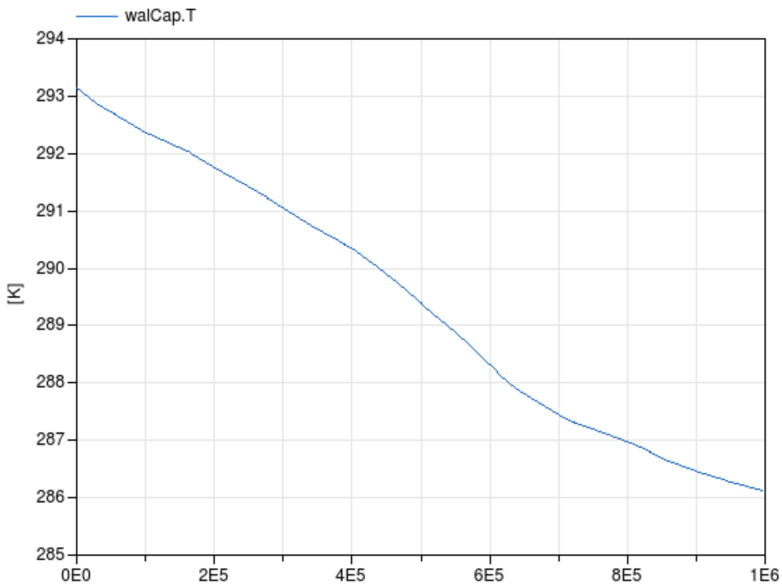

Figure 1: Wall temperature in K as function of time in seconds

2 Building window model

Qualitative discussion The window has a surface area of 2 m^2. In this simple model we will therefore assume that two times the outdoor solar irradiance is injected as heat onto the inside of the wall.

Required models

- `Modelica.Blocks.Math.Gain`
- `Modelica.Thermal.HeatTransfer.Sources.PrescribedHeatFlow`

Connection instructions To be able to use the value of the outdoor solar irradiance you will need to access our weather data reader. To do this, make a connection to the 'weaBus' block. In the dialog box select '<add variable>' and here select `HDirNor`, which is the direct solar irradiance on a surface of 1 m^2, perpendicular to the sun rays.

Reference result The result with and without the window model is plotted in Figure 2.

3 Air model

Qualitative discussion To increase the model detail we now add an air model assuming the zone is 8 x 8 x 3 m in size. The air will exchange heat with the wall. This may be modelled using a thermal resistance where $R = \frac{1}{hA}$ with A the heat exchange surface area and we choose $h = 2\,\mathrm{W/(m^2\,K)}$.

Required models

- `IDEAS.Fluid.MixingVolumes.MixingVolume`
- `Modelica.Thermal.HeatTransfer.Components.ThermalResistor`

Connection instructions The `MixingVolume` 'Medium' parameter contains information about the type of fluid and its properties that should be modelled by the `MixingVolume`. Set [3] its value to 'MediumAir', which is declared in the template.

Reference result The result with and without the air model is plotted in Figure 3.

[3] Click the right small arrow and 'edit text' in the parameter dialog box, or use the Modelica text view.

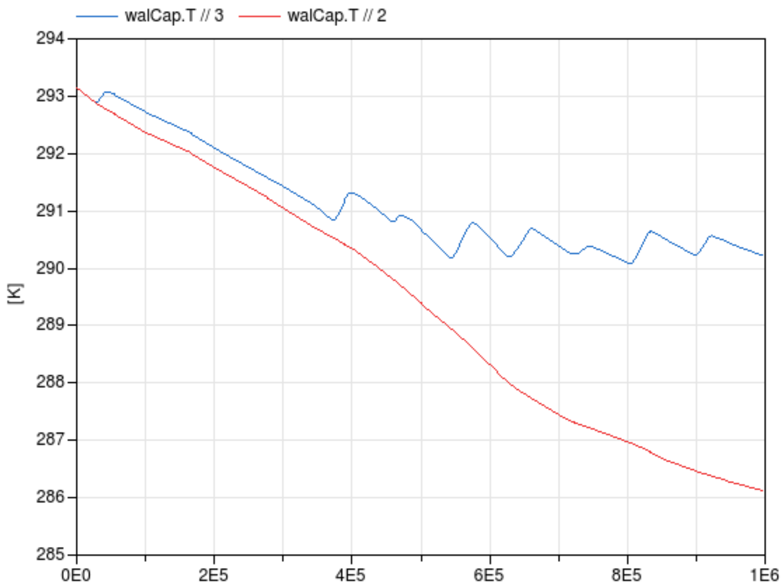

Figure 2: Wall temperature in K as function of time in seconds, with and without window

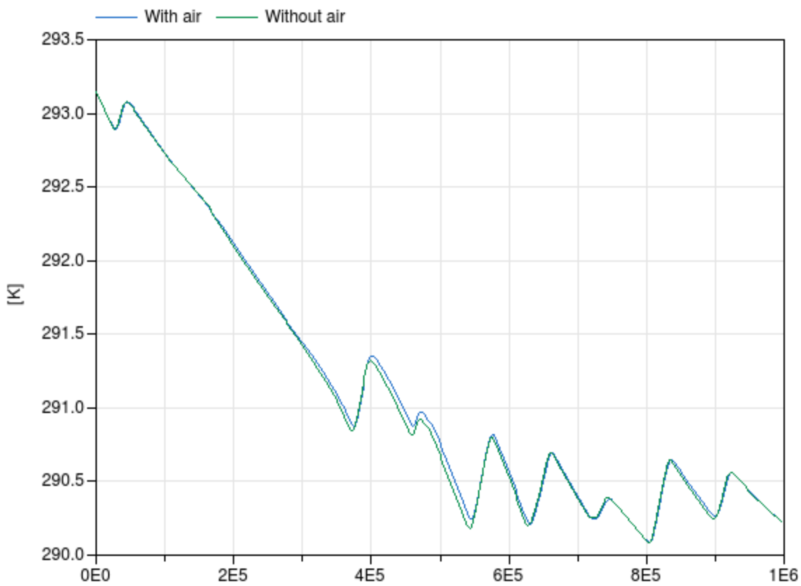

Figure 3: Wall temperature in K as function of time in seconds, with and without air model

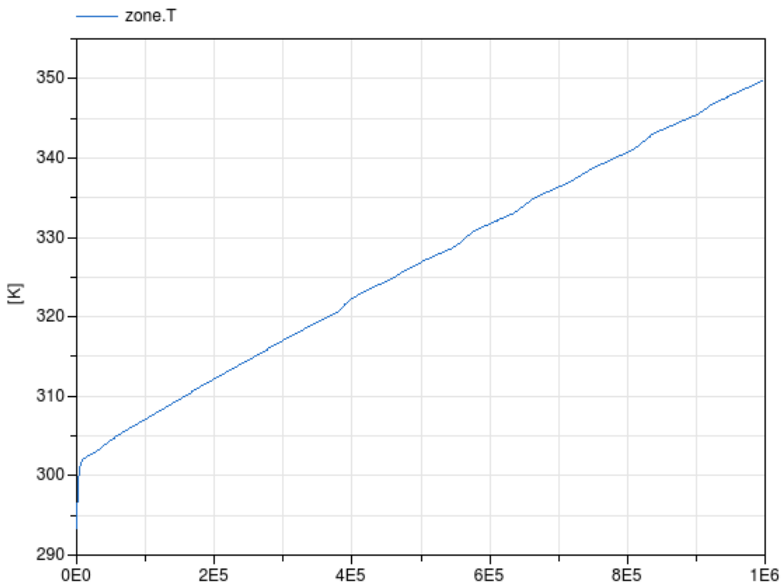

Figure 4: Air temperature in K as function of time in seconds

4 Heating model

Qualitative discussion The wall temperature (and therefore the room temperature) are quite low. In this step a heating system is added to resolve this. It consists of a radiator, a pump and a heater. The radiator has a nominal power of 3 kW for a temperature difference of 20 K between inlet and outlet of the radiator. The pump has a (nominal) mass flow rate of 0.1 kg/s. Since the heating system uses water as a heat carrier fluid, the media for the models should be set to MediumWater.

Required models

- `IDEAS.Fluid.HeatExchangers.Radiators.RadiatorEN442_2`
- `IDEAS.Fluid.HeatExchangers.HeaterCooler_u`
- `IDEAS.Fluid.Movers.FlowControlled_m_flow`
- `IDEAS.Fluid.Sources.Boundary_pT`
- `Modelica.Blocks.Sources.Constant`

Connection instructions Since the heating system uses water as a heat carrier fluid, the media for the models should be set to MediumWater.

Pressure difference modelling may be disregarded since the chosen pump sets a fixed mass flow rate regardless of the pressure drop.

The `Boundary_pT` model needs to be used to set an absolute pressure somewhere in the system. Otherwise the absolute pressure in the system is undefined.

The radiator contains one port for convective heat transfer and one for radiative heat transfer. Connect both in a reasonable way.

Set the heater input to 1, meaning that it will produce 1 time its nominal power.

Reference result The result of the air temperature is plotted in Figure 4. The temperature rises very steeply since the wall is relatively well insulated ($k = 0.04\,\mathrm{W/(m\,K)}$) and the heater is not disabled when it becomes too warm.

5 Heating controller model

Qualitative discussion Since the zone becomes too warm, a controller is required that disables the heater when a set point is reached. We will implement a hysteresis controller with a set point of 295.15 ± 1 K (21-23 °C). A temperature sensor will measure the zone air temperature.

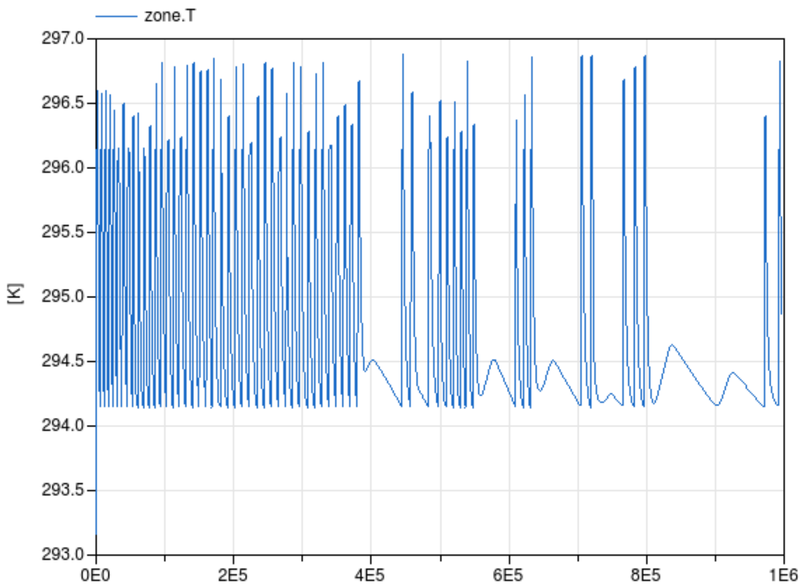

Figure 5: Air temperature in K as function of time in seconds with hysteresis controller

Required models

- `Modelica.Blocks.Logical.Hysteresis`
- `Modelica.Blocks.Logical.Not`
- `Modelica.Blocks.Math.BooleanToReal`
- `Modelica.Thermal.HeatTransfer.Sensors.TemperatureSensor`

Connection instructions The heater modulation level should be set to one when the heater is on and to zero otherwise.

Reference result Figure 5 shows the air temperature when the controller is added.

6 Free cooling model

Qualitative discussion Finally consider that the window has a size of 6 m^2 instead of 2 m^2. We will add a ventilation model that allows to perform free cooling using outside air when solar irradiation heats up the room too much. The system consists of a fan, a damper, a controller with an air temperature set point between 23 and 25 °C and a heat recovery unit with a constant effectivity of 85%. Damper and fan have a nominal pressure drop of 200 Pa. The nominal mass flow rate of the system is 0.1 kg/s.

Required models Use some of the previously used models and in addition to this:

- `IDEAS.Fluid.HeatExchangers.ConstantEffectiveness`
- `IDEAS.Fluid.Movers.FlowControlled_dp`
- `IDEAS.Fluid.Actuators.Dampers.VAVBoxExponential`

Connection instructions Connect the components such that they exchange mass (and therefore also energy) with the `MixingVolume` representing the zone air. Add a `boundary_pT` to draw air from the environment. Enable its temperature input and connect it to the 'TDryBul' variable in the weather data reader.

Reference result Figure 6 shows the result.

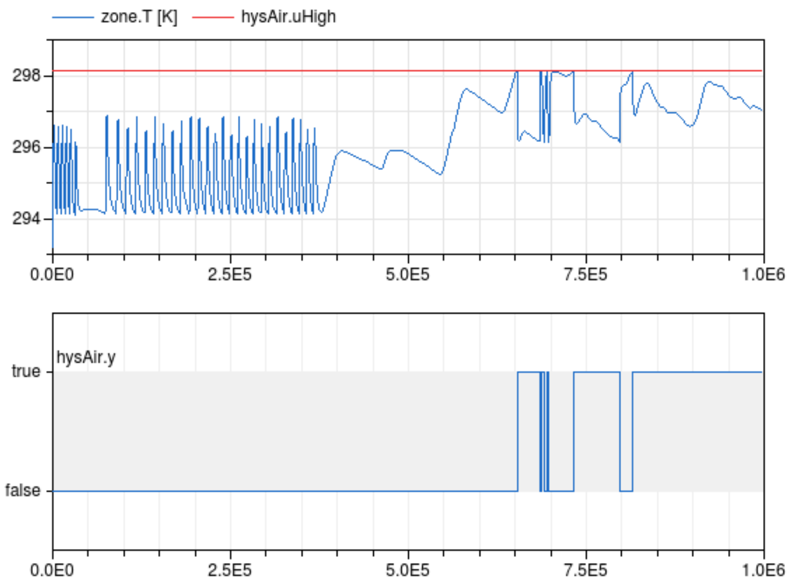

Figure 6: Air temperature, hysteresis controller upper bound and hysteresis output signal as function of time in seconds