7Y700 Sustainable Building and System Modelling

2012.06
Case Study

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Master: Building Service
Sustainable Energy Technology
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1.1 Objective
The report is written on the basis of final case study of course 7Y700 sustainable building and system modeling. The objective of the case study is to improve the system of the office model and validate systems in the Simulink to make the office more sustainable. The Simulink modeling focuses more on the validation of the improved systems rather than the control of the systems.

1.2 Methodology
Hambase is first used to realize the basic office model. The setup of Hambase file includes the basic physical information of the zones. The condition of walls, construction type of building components, orientations and internal conditions are able to be defined in the m file. With the use of Hambase Model, the office are modeled and compared to the results from other resources for validation. Then improvements of the systems are made and modeled in Simulink. With certain feedback control measures, the system is implemented in the model. The results from Simulink with improvements are compared with former results of Hamebase.

2.1 Case data
This study is based on one section in an existing building (Hooftgebouw in TU/e). The office section composes of three zones, 2 individual office rooms and one workspace (Fig. 1).

2.2 Case Systems
All the zones of office section are heated by a radiator and cooled by air conditioner with free cooling. The detailed information of the systems and schedule of occupancy are listed in Appendix.

2.3 Energy demand
The indoor climate of the office section is simulated by using HAMBase. The main objective of HAMBase is the simulation of the thermal and hydric indoor climate and the energy consumption. Details of the case study for geometry, material properties and boundary conditions of the HAMBase model can be found in Appendix. The result from HAMBase is validated and verified by compared to the results from VABI-Elements (Fig.2).
As can be seen from Fig.2, the difference between the results may result from:

a) The adjacent walls (in green) in HAMBase are assumed to be adiabatic walls; thus, no heat transmission happens, while in VABI, these walls can only be set a low U-value.

b) The assumed natural ventilation of the model may be different.

3.1 Improvements
To improve energy performance of the case, several passive designs and sustainable energy resources are applied and incorporated in the system, including a geothermal heat pump (Aquifer, water to water), Fan coil (heating and cooling), heat recovery (For winter condition) and solar PV panels (15 m² on the roof).

3.1.1 Geothermal heat pump (aquifer, water to water)
A geothermal heat pump is embedded in the system to satisfy both heating and cooling demand. After logical judgment, heating and cooling modes are specified into two different routes, which is explained in Appendix. Dynamic Coefficient of Performance (COP) depends on both the source temperature and heat pump output temperature, which promotes to calculate the instant energy output. The ODEs and Simulink S-function are shown in Appendix.

3.1.2 Water to air fan coil unit and heat recovery
Fan coil unit (FCU) is a simple device consisting of a heating or cooling coil and fan, using the outlet water from heat pump for heating and cooling. Heat recovery refers to a counter-flow heat exchanger between the inbound and
outbound air flow. Since it makes use of waste heat, heat recovery is only be used with fan coil for heating in this system. The connection of fan coil and heat pump are shown in Fig.3. The explicit working principle and ODEs are illustrated in Appendix.

3.1.3 Solar PV panels
Solar PV panels is installed on the roof, with an inclination of 45°. The product information of the PV panel is provided in Appendix. The efficiency of the panels is hypothesized to decrease with increasing surface temperature. Fig.4 shows the principle of calculation of surface temperature. The detailed ODEs and simulink S-function are demonstrated in Appendix.

3.2 Control and operation
The complete model consists of the Hamebase model, system of improvements and controller. In Fig.5, the model of controller is shown.

There is one closed circuit:
An output of Hamebase model, the air temperature, is connected to input of the controller and output of the control, heating/cooling power is connected to an input of the heat pump.

There are two operation cycles, which is determined by the value of power after controller. The logic flow chart is in the Appendix.

a) Heating mode
If the power after controller is minus, heating mode works. Under this condition, the heat pump operates in condenser mode. The 18°C aquifer water goes into the evaporator side, heating up the water for heating use. The heated water is used for heating fan coil. Moreover, the inlet air is first pre-heated by heat recovery.

b) Cooling mode
If the power after controller is positive, cooling mode works. Under this condition, the heat pump operates in condenser mode. The 12°C aquifer water goes into the condenser side, cooling the water for cooling use. The cooled
Results Analysis

4.1 Temperature simulation

From Fig. 8, the indoor temperature of three zones can be seen. Since zone 1 and 2 are almost the same, there are 2 lines seen in the temperature simulation result. It is considerable to get higher temperatures in zone 1 & 2 because of the east orientation. The whole system is well controlled to obtain comfortable room temperature in each specific zone: 22 ~ 30°C for zone 1 & 2 and 18 ~ 25°C for zone 3.

Compared to the results without heating and cooling (in Appendix), which has a temperature range from -5 to 37°C, the indoor temperature has been considerably improved.

4.2 Energy savings

Based on the application of both improved designs and renewable energy sources, input energy for system operation has decreased dramatically as well as output energy for sustain a comfortable environment, which is shown in the bar chart (Fig. 9).

Therefore, conclusions could be derived.

a) Total input energy

In the case of Hambese, the annual input energy is just 21.27GJ, while for the improved system it is only 15.23GJ which reduces 28.4% of the original value.

b) System efficiency

\[
\frac{Q_{\text{out}}}{Q_{\text{in}}} = \frac{145}{15} = 9.67
\]
b) Heating and cooling efficiency

Heating efficiency \( R_{h, \text{out}} = \frac{Q_{h, \text{out}}}{Q_{h, \text{in}}} = \frac{54.7}{2.63} = 20.8 \)

Cooling efficiency \( R_{c, \text{out}} = \frac{Q_{c, \text{out}}}{Q_{c, \text{in}}} = \frac{90.5}{12.6} = 7.2 \)

Normally, heating energy demand should be higher than cooling energy demand. However, in this case, heating demand is only approximately half of cooling demand, and heating efficiency has improved higher than cooling part. This is for the reason that heating recovery serves as an additional design only for heating, which plays an important role in the system.

c) Electricity generated

In Fig.9, according to the bar chart, the total energy demand is reducing dramatically. Furthermore, electricity generated by PV contributes to the sustainability of the case. From the simulation results, the electricity generated by PV cells on the roof is 7.34 GJ, with a surface area of 15 m\(^2\) and inclination of 45°. PV and grid almost have the same share of contribution to improved system.
Conclusion and Discussion

From the results, though the effect of the improvements performs as expected, problems still exist.

a) Since the input energy of the heat pump is a variable, depending on the temperature difference of the setpoint temperature and room temperature, the COP value is sometimes unrealistic. Though it has been limited by adding a limiter on the input power, unexpected value can still happen.

b) The cooling value of improvements is higher than the former case. The possible reason could be the presence of free cooling in the former case. In the new model with improvements, approaches of free cooling are not included.

c) After improvements, the cooling demand is higher than heating demand. The explanation for that may be the use of heat recovery for winter condition, which contributes to the reduction of heating consumption. Additionally, the inlet water for the heat pump is hypothesized to reach 40°C; thus, less energy is needed for the heating mode.

d) In the system, for part of electricity consumption, the energy need for water pump and fans are not calculated, which means the simulated electricity demand might be slightly smaller than the realistic need.

Furthermore, during the modelling of the system, with a limited knowledge of control and stateflow, limitations exist in the present model:

a) The switch of two operation mode of the system is transient, which is unstable and unrealistic.

b) The delay of the P control may lead to the insufficient energy output to the zones.

With a further study on control, hopefully, solutions could be found on these problems and insufficiency.
Appendix A: Detailed Data of Case

Office Condition:
A 3-zone model

<table>
<thead>
<tr>
<th>Dimension (L<em>W</em>H)</th>
<th>Wall Condition</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2850mm<em>3850mm</em>3000mm</td>
<td>1 external wall (East): Window: 2700*3000 2 internal wall</td>
<td>2 persons 8:00-17:00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 2850mm<em>3850mm</em>3000mm</td>
<td>1 external wall (East): Window: 2700*3000 2 internal wall</td>
<td>2 persons 8:00-17:00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 5800mm<em>7150mm</em>3000mm</td>
<td>1 external wall (West): Window: 5750*3000 2 internal wall</td>
<td>4 persons 8:00-17:00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HVAC system:
Heating: Radiator
Setpoint temperature: 20°C
Operation Schedule: 24hrs

Cooling: air conditioner with free cooling
Setpoint temperature: 26°C
Operation Schedule: 24hrs

Indoor temperature without heating and cooling system:
Purple line: Zone 1&2   Blue line: Zone 3
Appendix B: Heat Pump Model

ODEs of heat pump

\[ T_{\text{evap}} = \frac{T_{\text{evap \_in}} + T_{\text{evap \_out}}}{2} \]

\[ T_{\text{cond}} = \frac{T_{\text{cond \_in}} + T_{\text{cond \_out}}}{2} \]

\[ \text{COP}_{\text{carnot}} = \frac{273 + T_{\text{in}}}{T_{\text{ev}} - T_{\text{in}}} \]

\[ \text{COP} = \eta \times \text{COP}_{\text{carnot}} \]

\[ Q_{\text{cond}} = E_{\text{in}} \times \text{COP} \]

\[ Q_{\text{evap}} = E_{\text{in}} (\text{COP} - 1) \]

\[ C \frac{dT_{\text{evap}}}{dt} = m_{\text{evap}} \times c \times (T_{\text{evap \_in}} - T_{\text{evap \_out}}) - Q_{\text{evap}} \]

\[ C \frac{dT_{\text{cond}}}{dt} = m_{\text{cond}} \times c \times (T_{\text{cond \_in}} - T_{\text{cond \_out}}) + Q_{\text{cond}} \]

Operation Mode:

Winter condition

Summer condition

Fig. 1: Schematic view of operation mode of heat pump (Up: winter Below: Summer)
Appendix C: Logic Flowchart

Both the heat pump and fan coil unit operates with two modes. The transfer of the operation mode is realized on the judgement of value of the $Q_{\text{input}}$. The by-pass of heat recovery is realized by the selection and infiltration of input in the fan coil model. The following flowchart shows the simplified concept of the system operation.

Fig.1: Schematic view of operation flowchart
Fig. 1: Schematic view of complete model
20% EFFICIENCY
SunPower E20 panels are the highest efficiency panels on the market today, providing more power in the same amount of space.

MAXIMUM SYSTEM OUTPUT
Comprehensive inverter compatibility ensures that customers can pair the highest-efficiency panels with the highest-efficiency inverters, maximizing system output.

REDUCED INSTALLATION COST
More power per panel means fewer panels per install. This saves both time and money.

RELIABLE AND ROBUST DESIGN
SunPower’s unique Maxeon™ cell technology and advanced module design ensure industry-leading reliability.

THE WORLD’S STANDARD FOR SOLAR™
SunPower™ E20 Solar Panels provide today’s highest efficiency and performance. Powered by SunPower Maxeon™ cell technology, the E20 series provides panel conversion efficiencies of up to 20.1%. The E20’s low voltage temperature coefficient, anti-reflective glass and exceptional low-light performance attributes provide outstanding energy delivery per peak power watt.

SUNPOWER’S HIGH EFFICIENCY ADVANTAGE

<table>
<thead>
<tr>
<th>THIN FILM</th>
<th>CONVENTIONAL</th>
<th>SERIES 18</th>
<th>SERIES 19</th>
<th>SERIES 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>14%</td>
<td>18%</td>
<td>19%</td>
<td>20%</td>
</tr>
</tbody>
</table>

MAXEON™ CELL TECHNOLOGY
Patented all-back-contact solar cell, providing the industry’s highest efficiency and reliability.

sunpowercorp.com
**MODEL: SPR-435NE-WHT-D**

### ELECTRICAL DATA (Measured at Standard Test Conditions (STC): Irradiance 1000W/m², AM 1.5, and cell temperature 25°C)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Power (+/-5%) P&lt;sub&gt;nom&lt;/sub&gt;</td>
<td>435 W</td>
</tr>
<tr>
<td>Cell Efficiency η</td>
<td>22.4%</td>
</tr>
<tr>
<td>Panel Efficiency η</td>
<td>20.1%</td>
</tr>
<tr>
<td>Rated Voltage V&lt;sub&gt;mp&lt;/sub&gt;</td>
<td>72.9 V</td>
</tr>
<tr>
<td>Rated Current I&lt;sub&gt;mp&lt;/sub&gt;</td>
<td>5.97 A</td>
</tr>
<tr>
<td>Open-Circuit Voltage V&lt;sub&gt;oc&lt;/sub&gt;</td>
<td>85.6 V</td>
</tr>
<tr>
<td>Short-Circuit Voltage I&lt;sub&gt;sc&lt;/sub&gt;</td>
<td>6.43 A</td>
</tr>
<tr>
<td>Maximum System Voltage</td>
<td>IEC 1000 V</td>
</tr>
<tr>
<td>Temperature Coefficients</td>
<td></td>
</tr>
<tr>
<td>Power (P) –0.38%/K</td>
<td></td>
</tr>
<tr>
<td>Voltage (V&lt;sub&gt;oc&lt;/sub&gt;) –235.5mV/K</td>
<td></td>
</tr>
<tr>
<td>Current (I&lt;sub&gt;sc&lt;/sub&gt;) 3.5mA/K</td>
<td></td>
</tr>
<tr>
<td>NOCT</td>
<td>45°C +/- 2°C</td>
</tr>
<tr>
<td>Series Fuse Rating</td>
<td>20 A</td>
</tr>
<tr>
<td>Limiting Reverse Current (3 strings) I&lt;sub&gt;r&lt;/sub&gt;</td>
<td>16.1 A</td>
</tr>
<tr>
<td>Grounding Positive grounding not required</td>
<td></td>
</tr>
</tbody>
</table>

### ELECTRICAL DATA (Measured at Nominal Operating Cell Temperature (NOCT): Irradiance 800W/m², 20°C, wind 1 m/s)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Power P&lt;sub&gt;nom&lt;/sub&gt;</td>
<td>323 W</td>
</tr>
<tr>
<td>Rated Voltage V&lt;sub&gt;mp&lt;/sub&gt;</td>
<td>67.2 V</td>
</tr>
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<td>Rated Current I&lt;sub&gt;mp&lt;/sub&gt;</td>
<td>4.81 A</td>
</tr>
<tr>
<td>Open-Circuit Voltage V&lt;sub&gt;oc&lt;/sub&gt;</td>
<td>80.1 V</td>
</tr>
<tr>
<td>Short-Circuit Voltage I&lt;sub&gt;sc&lt;/sub&gt;</td>
<td>5.20 A</td>
</tr>
</tbody>
</table>

### MECHANICAL DATA

- **Cells**: 128 SunPower Maxeon<sup>TM</sup> cells
- **Front Glass**: High-transmission tempered glass with anti-reflective (AR) coating
- **Junction Box**: IP-65 rated with 3 bypass diodes 32 x 155 x 128 mm
- **Output Cables**: 700 mm cables / Multi-Contact (MC4) connectors
- **Frame**: Anodised aluminium alloy type 6063 (silver)
- **Weight**: 28.6 kg

### DIMENSIONS

[Diagram showing dimensions]

Please read safety and installation instructions before using this product, visit sunpowercorp.com for more details.

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function [sys,x0,str,ts] = buildmodsfun(t,x,u,flag,inputfilename)

% WAVOSFUN41 Wavo S functie Versie 3
%           * Tgemid. discrete update
%           * Vochtinput
%               * RV begrenzingen
%               * Meer Outputs, interpolatie P.fxxxx variabelen
% %
% JvS nov, 2001

global P Pu Tm InClimate Building Profiles Varu Control Output

switch flag

%%%%%%%%%%%%%%%%%%
% Initialization %
%%%%%%%%%%%%%%%%%%
case 0
  [sys,x0,str,ts]=mdlInitializeSizes(inputfilename);

% % Derivatives %
%%%%%%%%%%%%%%
case 1
  sys=mdlDerivatives(t,x,u);

% % Update %
%%%%%%%%%%
case 2,
  sys=mdlUpdate(t,x,u);

% % Output %
%%%%%%%%%
case 3
  sys=mdlOutputs(t,x,u);

% % Terminate %
%%%%%%%%%%%%%%%%
case 9
  sys = [];       % do nothing

otherwise
  error(['unhandled flag = ',num2str(flag)]);
end

% end mixedm
function [sys,x0,str,ts]=mdlInitializeSizes(inputfilename)

global P Pu InClimate Profiles Building Varu Control zonetot Output

global Cx1 Cx2 Cv1 Cv2 Ldet Ldeta Lx1 Lx2 Lv1 Lv2 Lrcvx Ca fbv0 Lxa Facp
Facet Link

global figainx figaina Tglase fgtrans fzonab Te Pe Gint figainxOud
figainaOud TglaseOud RVe

global fgtransOud fzonabOud TeOud PeOud GintOud Lgtot Lvv Lv rvmax rvmin

eval(['clear ' inputfilename]);
eval(inputfilename);
disp(['loading ' inputfilename]);

[Varu, Building, Control, Elan, x0]=Wavoinit1205(InClimate, InBuil, Control);

zonetot=Building.zonetot;

% SIMULINK PARAMETERS
set_param(gcs,'StartTime','0');
set_param(gcs,'StopTime',[num2str(InClimate.aantaldagen) '*24*3600']);
set_param([gcs '/Selector'],'Elements','[1:' num2str(zonetot) ']
''),'InputPortWidth',num2str(3*zonetot+2));
set_param([gcs '/Selector1'],'Elements','[1:' num2str(zonetot) '+[1:
num2str(zonetot) ']+[1:
num2str(zonetot) ']]','InputPortWidth',num2str(3*zonetot+2));
set_param([gcs '/Selector2'],'Elements','[1:' num2str(zonetot) '+[1:
num2str(zonetot) ']]','InputPortWidth',num2str(3*zonetot+2));
set_param([gcs '/Selector3'],'Elements',num2str(3*zonetot+1),'InputPortWidth',num2str(3*zonetot+2));
set_param([gcs '/Selector4'],'Elements',num2str(3*zonetot+2),'InputPortWidth',num2str(3*zonetot+2));
set_param([gcs '/Mux1'],'Inputs',num2str(zonetot));
set_param([gcs '/Mux2'],'Inputs',num2str(zonetot));

P=[];
Pu=0;

sizes = simsizes;
sizes.NumContStates = 6*zonetot;
sizes.NumDiscStates = 0;
sizes.NumOutputs = 3*zonetot+2;
sizes.NumInputs = 2*zonetot;
sizes.DirFeedthrough = 0;
sizes.NumSampleTimes = 1;

sys = simsizes(sizes);
%BASIS INVOER file

str = [];
ts = [0 0] ; % sample time

%fplant=zeros(zonetot,1);
%Gextra=zeros(zonetot,1);

%SIMULINK PARAMETERS:

%Px=Pvin;

--

Ta=10*ones(zonetot,1);
Tx=Ta;
[Control,Varu]=wavosimx_4(1,Tx,Ta,Varu,Profiles,Building,Control,InClimate);

Control,Varu=Wavovaru1205(1,Tx,Ta,Varu,Profiles,Building,Control,InClimate);

%Parameters
P.fplant=0;
P.Gextra=0;

%Hulpvariabelen:
figaina=Varu.figaina;
figainx=Varu.figainx;
Tglase=Varu.Tglase;
fgtrans=Varu.fgtrans;
fzonab=Varu.fzonab;
Lgtot=Varu.Lgtot;
Gint=Varu.Gint;
Pe=Varu.Pe;
Te=Varu.Te;
RVe=InClimate.kli(1,5)/100;
Lvv=Varu.Lvv;
Lv=Varu.Lv;
figainaOud=figaina;
figainxOud=figainx;
TglaseOud=Tglase;
fgtransOud=fgtrans;
fzonabOud=fzonab;
TeOud=Te;
GintOud=Gint;
PeOud=Pe;
%Tset=Control.Tsetmin;
%Tsetmax=Control.Tsetmax;
rvmax=Control.rvmax;
rvmin=Control.rvmin;

Cx1=Elan.Cx1;
Cx2=Elan.Cx2;
Cv1=Elan.Cv1;
Cv2=Elan.Cv2;
Ldet=Elan.Ldet;
Ldeta=Elan.Ldeta;
Lx1=Elan.Lx1;
Lx2=Elan.Lx2;
Lv1=Elan.Lv1;
Lv2=Elan.Lv2;
Lrcvx=Elan.Lrcvx;
Ca=Elan.Ca;
fbv0=Elan.fbv0;
Lxa=Elan.Lxa;
Facp=Elan.Facp;
Facset=Elan.Facset;
Link=Elan.Link;
nnmax=InClimate.aantaldagen*24;
Output.Transout=zeros(nnnmax,zonetot);
Output.Ventout=zeros(nnnmax,zonetot);
Output.Humout=zeros(nnnmax,zonetot);
Output.Txout=zeros(nnnmax,zonetot);
Output.figainout=zeros(nnnmax,zonetot);
Output.Rvaout=zeros(nnnmax,zonetot);

% end mdlInitializeSizes

%=================================================================
% mdlDerivatives
% Compute derivatives for continuous states.
%==========================================================================

function sys=mdlDerivatives(t,x,u)

P_Pu zonetot
C1 C2 Cv1 Cv2 Ldet Ldeta Lx1 Lx2 Lv1 Lv2 Lrcvx Ca fbv0 Lxa Facp
Facset Link
figainx figaina Tglase fgtrans fzonab Te Pe Gint TglaseOud
figtransOud TeOud PeOud Lgtot Lvv Lv rvmax rvmin

%tfrac=abs(floor(t/3600)-t/3600) %0<tfrac<1
 tfrac=min(t/3600-Pu,1);

Tp=x(1:zonetot);
Tq=x(zonetot+[1:zonetot]);
Ta=x(2*zonetot+[1:zonetot]);
Fp=x(3*zonetot+[1:zonetot]);
Fq=x(4*zonetot+[1:zonetot]);
Fx=x(5*zonetot+[1:zonetot]);

P.fplant=u(1:zonetot);
P.Gextra=u(zonetot+[1:zonetot]);

TglaseU=TglaseOud+tfrac*(Tglase-TglaseOud);
fgtransU=fgtransOud+tfrac*(fgtrans-fgtransOud);
TeU=TeOud+tfrac*(Te-TeOud);
PeU=PeOud+tfrac*(Pe-PeOud);

Tx=( diag(Lxa+Ldeta+Lgtot+Lx1+Lx2) - 
Ldet )\( Lxa.*Ta+Lx1.*Tp+Lx2.*Tq+fgtransU+...
ex1 = 2.71828182845904;

% Phi factor
fP1 = PsTw/2340;
fP2 = (1./(1+2340*fbv0./PsTa));

% RV begrenzingen alleen voor lucht
Fxmax = rvmax.*PsTa./(fP2*2340);
Fxmin = rvmin.*PsTa./(fP2*2340);
s3 = (Lv.*fP2.*((Fx<Fxmin).* (Fxmin-Fx)+(Fx>Fxmax).* (Fxmax-Fx))...
     -Link.*(fP2.*((Fx<Fxmin).* (Fxmin-Fx)+(Fx>Fxmax).* (Fxmax-Fx)))...*2340*0.62e-8;

sys = [xdot1; xdot2; xdot3; xdot4; xdot5; xdot6];

% mdlDerivatives

% mdlUpdate
% Handle discrete state updates, sample time hits, and major time step
% requirements.

function sys = mdlUpdate(t,x,u)

global P Pu InClimate Building Profiles Varu Control Output zonetot Ldet Ldet Lx1 Lx2

global Lrcvx figainx figaina Tglase fgtrans fzonab Te Pe Gint RVe

global TglaseOud fgtransOud TeOud PeOud Lgtot Lvv Lv rvmax rvmin

Puvorig = Pu;
\[ \text{Pu} = \max(\lfloor \text{Pu floor}(t/3600) \rfloor) \]
\[ \text{Pu} = \max(\lceil \text{Pu ceil}(t/3600) \rceil) \]

\text{if} \quad \text{Pu} \neq \text{PuOrig}

\[ \% \text{Bewaar oude waarden} \]
\[ \text{TglaseOud} = \text{Tglase}; \]
\[ \text{fgtransOud} = \text{fgtrans}; \]
\[ \text{TeOud} = \text{Te}; \]
\[ \text{PeOud} = \text{Pe}; \]
\[ \text{Ta} = x(2*\text{zonetot}+1: \text{zonetot}); \]
\[ \text{Tx} = \text{P}.\text{Tx}; \]

\[ \% \left[ \text{Control}, \text{Varu} \right] = \text{wavosimx}_4(\text{Pu}, \text{Tx}, \text{Ta}, \text{Varu}, \text{Profiles}, \text{Building}, \text{Control}, \text{InClimate}) \]

\[ \left[ \text{Control}, \text{Varu} \right] = \text{Wavovaru1205}(\text{Pu}, \text{Tx}, \text{Ta}, \text{Varu}, \text{Profiles}, \text{Building}, \text{Control}, \text{InClimate}) \]

\[ \% \text{Tset} = \text{Control}.\text{Tsetmin} \]
\[ \% \text{Tsetmax} = \text{Control}.\text{Tsetmax} \]
\[ \text{rvmax} = \text{Control}.\text{rvmax} \]
\[ \text{rvmin} = \text{Control}.\text{rvmin} \]

\[ \text{figaina} = \text{Varu}.\text{figaina}; \]
\[ \text{figainx} = \text{Varu}.\text{figainx}; \]
\[ \text{Tglase} = \text{Varu}.\text{Tglase}; \]
\[ \text{fgtrans} = \text{Varu}.\text{fgtrans}; \]
\[ \text{fzonab} = \text{Varu}.\text{fzonab}; \]
\[ \text{Te} = \text{Varu}.\text{Te}; \]
\[ \text{Gint} = \text{Varu}.\text{Gint}; \]
\[ \text{Pe} = \text{Varu}.\text{Pe}; \]
\[ \text{RVe} = \text{InClimate}.\text{kli}(\text{Pu}, 5)/100; \]
\[ \text{Lgtot} = \text{Varu}.\text{Lgtot}; \]
\[ \text{Lvv} = \text{Varu}.\text{Lvv}; \]
\[ \text{Lv} = \text{Varu}.\text{Lv}; \]

\text{if} \quad 1 == 1
\[ \text{Tp} = x(1: \text{zonetot}); \]
\[ \text{Tg} = x(\text{zonetot}+1: \text{zonetot}); \]
\[ \text{Fp} = x(3* \text{zonetot}+1: \text{zonetot}); \]
\[ \text{Fq} = x(4* \text{zonetot}+1: \text{zonetot}); \]
\[ \text{Fx} = x(5* \text{zonetot}+1: \text{zonetot}); \]
\[ \text{Tw} = \text{Tx} + (-\text{Lx1}.*(\text{Tx}-\text{Tp})-\text{Lx2}.*(\text{Tx}-\text{Tq})+\text{fgtrans}+\text{fzonab}-\text{Ldeta}.*\text{Tx}+\text{Ldet}.*\text{Tx})./\text{Lrcvx}; \]

\[ \text{Output}.\text{Transout}(\text{Pu}, :) = (-\text{fgtrans}+\text{fzonab}+\text{Lgtot}.*(\text{Tx}-\text{Tglase})+\text{Ldeta}.*\text{Tx})'; \]
\[ \text{Output}.\text{Ventout}(\text{Pu}, :) = (\text{Lv}.*(\text{Ta}-\text{Te})')'; \]
\[ \text{Output}.\text{Humout}(\text{Pu}, :) = \text{P}.\text{Gextra}*2500000'; \]
\[ \text{Output}.\text{Twout}(\text{Pu}, :) = \text{Tw}'; \]
\[ \text{Output}.\text{Taout}(\text{Pu}, :) = \text{Ta}'; \]
\[ \text{Output}.\text{Txout}(\text{Pu}, :) = \text{Tx}'; \]
\[ \text{Output}.\text{figainout}(\text{Pu}, :) = \text{figainx}+\text{figaina}; \]
\[ \text{Output}.\text{Rvaout}(\text{Pu}, :) = \text{P}.\text{Rva}'; \]

\text{if} \quad \text{Pu} == \text{InClimate}.\text{aantaldagen}*24
\[ \% \text{ save Output Output} \]
\text{% end}
sys=[];
% end mdlUpdate

function sys=mdlOutputs(t,x,u)

% Return output of the unit delay if we have a
% sample hit within a tolerance of 1e-8. If we
% don't have a sample hit then return [] indicating
% that the output shouldn't change.

global P zonetot

global Ldet Ldeta Lx1 Lx2 Lxa Facp Facset figainx Tglase fgtrans fzonab
Lgtot fbv0
global Te RVe

Tp=x(1:zonetot);
Tq=x(zonetot+[1:zonetot]);
Ta=x(2*zonetot+[1:zonetot]);
Fx=x(5*zonetot+[1:zonetot]);

Tx=( diag(Lxa+Ldeta+Lgtot+Lx1+Lx2) -
    Ldet )/( Lxa.*Ta+Lx1.*Tp+Lx2.*Tq+fgtrans+...
        fzonab+figainx+Lgtot.*Tglase+(1-Facp).*P.fplant ) ;

ex1=2.71828182845904;
machtTa=17.08*Ta./(234.18+Ta);
if Ta<0
    machtTa=22.44*Ta./(272.44+Ta);
end;
PsTa=611*ex1.^machtTa;
Rva=min(Fx./(PsTa/2340+fbv0),1);

P.Tx=Tx;
P.Rva=Rva;
Tcom=Tx+Facset.*(Ta-Tx);
sys=[Tcom;Ta;Rva;Te;RVe];

% end mdlOutputs
Heat pump

%heat pump

function [sys,x0,str,ts] = wpsfun2(t,x,u,flag)

% if primary_energy>=0
% u(1)=Tvi=T_aquifer_water_cool  %=12;
% u(2)=Tci=T_inlet_water          %=40;
% u(5)=E=primary_energy;
% else  u(7)=Tvi=T_supply_water   %=12;
%       u(8)=Tci=T_aquifer_water_hot %=18;
%       u(5)=E=(-1)*primary_energy;
% end

%u(1)=Tvi
%u(2)=Tci
%u(3)=Fa [kg/s] acquifer water
%u(4)=Fi [kg/s] inlet water
%u(5)=E  [W]  electricity power input
%u(6)=n  efficiency of heat pump
%Tve=x(1)
%Tce=x(2)
%COP=x(3)

switch flag,
    %%%%%%%%%%%%%%%%%%
    % Initialization %
    %%%%%%%%%%%%%%%%%%
    case 0,
        [sys,x0,str,ts]=mdlInitializeSizes;

    %%%%%%%%%%%%%%%%%%
    % Derivatives %
    %%%%%%%%%%%%%%%%%%
    case 1,
        sys=mdlDerivatives(t,x,u);

    %%%%%%%%%%%%%%%%%
    % Outputs %
    %%%%%%%%%%%%%%%%%
    case 3,
        sys=mdlOutputs(t,x,u);

    %%%%%%%%%%%%%%%%%
    % Unhandled flags %
    %%%%%%%%%%%%%%%%%
    case { 2, 4, 9 },
        sys = [];

    %%%%%%%%%%%%%%%%%
    % Unexpected flags %
    %%%%%%%%%%%%%%%%%
otherwise
  error(['Unhandled flag = ',num2str(flag)]);
end
% end wpfun1
%
%==========================================================================
% mdlInitializeSizes
% Return the sizes, initial conditions, and sample times for the S-function.
%==========================================================================
%
function [sys,x0,str,ts]=mdlInitializeSizes

sizes = simsizes;
sizes.NumContStates = 2;
sizes.NumDiscStates = 0;
sizes.NumOutputs = 7;
sizes.NumInputs = 8;
sizes.DirFeedthrough = 1;
sizes.NumSampleTimes = 1;

sys = simsizes(sizes);
x0 = [0; 20];
str = [];
ts = [0 0];

% end mdlInitializeSizes
%
%==========================================================================
% mdlDerivatives
% Return the derivatives for the continuous states.
%==========================================================================
%
function sys=mdlDerivatives(t,x,u)

% if primary_energy>=0
%   u(1)=Tvi=T_aquifer_water_cool  %=12;
%   u(2)=Tci=T_inlet_water         %=40;
%   u(5)=E=primary_energy;
% else  u(7)=Tvi=T_supply_water   %=12;
%   u(8)=Tci=T_aquifer_water_hot  %=18;
%   u(5)=E=(-1)*primary_energy;
% end

%u(1)=Tvi
%u(2)=Tci
%u(3)=Pv  [kg/s]
%u(4)=Fc  [kg/s]
%u(5)=E [W]  electricity power input
%u(6)=n  efficiency of heat pump
%Tve=x(1)
%Tce=x(2)
%COP=x(3)
if u(5)>700
  E=700;
else if u(5)>0 && u(5)<150
    E=150;
else if u(5)<0
    E=(-1)*u(5);
else
    E=u(5);
end
end

if u(5)>=0
    Tvi=u(1);
    Tci=u(3);
else
    Tvi=u(7);
    Tci=u(8);
end

Tvm=(Tvi+x(1))/2;
Tcm=(Tci+x(2))/2;

n=u(6); % transfer efficiency
Tvm=(Tvi+x(1))/2;
Tcm=(Tci+x(2))/2;

% COP / heat flows
COPcarnot=(273.15+Tcm)/(Tcm-Tvm);
% COPcarnot=(273.15+x(2))/(x(2)-x(1)); % [-], coefficient of performance carnot

COP=n*COPcarnot; %[-], real COP

% if COP<=0;
% COP=5;
%

Qc=E*COP;
Qe=Qc-E;

Cc=100000;
Cv=100000;
cv=4200; % water specific heat capacity J/K*kg
%cv=1000; % air specific heat capacity J/K*kg
%cc=1000; % air specific heat capacity
cc=4200; % water specific heat capacity

xdot(1)=(1/Cv)*(u(2)*cv*(Tvi-x(1))-Qe);
xdot(2)=(1/Cc)*(u(4)*cc*(Tci-x(2))+Qc);

sys = [xdot(1); xdot(2)];

% end mdlDerivatives
% %==========================================================================
% ===
% mdlOutputs
% Return the block outputs.
function sys=mdlOutputs(t,x,u)

n=u(6);
% cc=1000; % air specific heat capacity
cc=4200; % water specific heat capacity

if u(5)>700
    E=700;
else if u(5)>0 && u(5)<150
    E=150;
    else if u(5)<0
        E=(-1)*u(5);
    else
        E=u(5);
    end
end

if u(5)>=0
    Tvi=u(1);
    Tci=u(3);
else
    Tvi=u(7);
    Tci=u(8);
end

Tvm=(Tvi+x(1))/2;
Tcm=(Tci+x(2))/2;
COP=n*(273.15+Tcm)/(Tcm-Tvm);
% \text{COP} = \frac{n \times (273.15 + x(2))}{(x(2)-x(1))}; \text{[-], coefficient of performance carnot}

x(4)=u(4)*cc*(x(2)-Tci);

sys = [x(1); x(2); COP;x(4);Tvi;Tci;E];

end mdlOutputs
% heat exchanger

% T_condensor_out=u(1) [oC] cold air inlet temperature
% Tcout=x(1) [oC] cold air outlet temperature
% T_evaporator_out=u(2) [oC] hot air inlet temperature
% Tout=x(2) [oC] hot air outlet temperature
% mc=u(3) [kg/s] mass flow rate of cold side
% mh=u(4) [kg/s] mass flow rate of heat side
% cc=u(5); %air=1000 [J/kgK] heat capacity of cold side medium
% ch=u(6); %water=4200 [J/kgK] heat capacity of heat side medium
% k=u(7) k value
% Q=x(3) [W]
% T_after_recovery=u(8)
% Te=u(9)
% primary_energy=u(10)

% Heating
% Tcin=T_after_recovery=u(8) [oC] cold air inlet temperature
% Tin=T_condensor_out=u(1) [oC] hot air inlet temperature
% E=mc*Cc*(Tcout-Tcin)

% Cooling
% Tcin=T_evaporator_out=u(2)
% Tin=Te=u(9)
% E=mh*Ch*(Thout-Thin)

function [sys,x0,str,ts]=sfunhvac(t,x,u,flag)
switch flag
 case 0,
 [sys,x0,str,ts]=mdlInitializeSizes;
 case 1,
 sys=mdlDerivatives(t,x,u);
 case 3,
 sys=mdlOutputs(t,x,u);
 case {2,4,9},
 sys=[];
 otherwise
 error(['Unhandled flag=',num2str(flag)]);
end

function [sys,x0,str,ts]=mdlInitializeSizes
sizes=simsizes;
sizes.NumContStates=2;
sizes.NumDiscStates=0;
sizes.NumOutputs=3;
sizes.NumInputs=10;
sizes.DirFeedthrough=1;
sizes.NumSampleTimes=1;

sys=simsizes(sizes);
x0=[0,0];
str=[];
ts=[0 0];
function sys=mdlDerivatives(t,x,u)
if u(10)>0
    Tcin=u(8);
    Thin=u(1);
else
    Tcin=u(2);
    Thin=u(9);
end
mc=u(3);
mh=u(4);
cc=u(5);  \%air=1000
ch=u(6);  \%water=4200
k=u(7);
Tcinc=x(1);
Thinc=x(2);
Cc=40000;
Ch=40000;
Q=k*((Thin+Thout)/2-(Tcin+Tcout)/2);
xdot(1)=(mc*cc*(Tcin-Tcout)+Q)/Cc;
xdot(2)=(mh*ch*(Thin-Thout)-Q)/Ch;
sys=[xdot(1),xdot(2)];
end

function sys=mdlOutputs(t,x,u)
mc=u(3);
mh=u(4);
cc=u(5);  \%air=1000
ch=u(6);  \%water=4200
k=u(7);
Tcinc=x(1);
Thinc=x(2);
if u(10)>0
    Tcin=u(8);
    x(3)=mc*cc*(Tcinc-Tcin);
else
    Thin=u(9);
    x(3)=mh*ch*(Thinc-Thin);
end
sys=[x(1),x(2),x(3)];
end
Heat recovery

% heat exchanger

%Cin=u(1) [°C] cold air inlet temperature
%Cout=x(1) [°C] cold air outlet temperature
%Cin=u(2) [°C] hot air inlet temperature
%Cout=x(2) [°C] hot air outlet temperature
%mc=u(3) [kg/s] mass flow rate of cold side
%mh=u(4) [kg/s] mass flow rate of heat side
%k=u(5) k value
%Q=x(3) [W]

function [sys,x0,str,ts]=sfunhvac(t,x,u,flag)
switch flag
  case 0,
    [sys,x0,str,ts]=mdlInitializeSizes;
  case 1,
    sys=mdlDerivatives(t,x,u);
  case 3,
    sys=mdlOutputs(t,x,u);
  case [2,4,9],
    sys=[];
  otherwise
    error(['Unhandled flag=','num2str(flag)]);
end

function [sys,x0,str,ts]=mdlInitializeSizes
sizes=simsizes;
sizes.NumContStates=2;
sizes.NumDiscStates=0;
sizes.NumOutputs=2;
sizes.NumInputs=5;
sizes.DirFeedthrough=1;
sizes.NumSampleTimes=1;

sys=simsizes(sizes);
x0=[0,0];
str=[];
ts=[0 0];

function sys=mdlDerivatives(t,x,u)
Tcin=u(1);
Thin=u(2);
mc=u(3);
mh=u(4);
k=u(5); % k value
Tcout=x(1);
Thout=x(2);
cc=1000; %air
ch=1000;  % air
Cc=40000;  % [J/kg] heat capacity of cold side
Ch=40000;  % [J/kg] heat capacity of heat side

Q=k*((Thin+Thout)/2-(Tcin+Tcout)/2);

xdot(1)=(mc*cc*(Tcin-Tcout)+Q)/Cc;
xdot(2)=(mh*ch*(Thin-Thout)-Q)/Ch;

sys=[xdot(1), xdot(2)];

function sys=mdlOutputs(t,x,u)
mc=u(3);
Cc=40000;

Tcout=x(1);
Thout=x(2);
cc=1000;  % air
%x(3)=mc*cc*(x(1)-u(1));

sys=[x(1), x(2)];