

MED 2018 Process automation challenge



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1 Introduction

This challenge will focus on the process of cooling a building that consists of three rooms with fan coils units (Fig. 1).

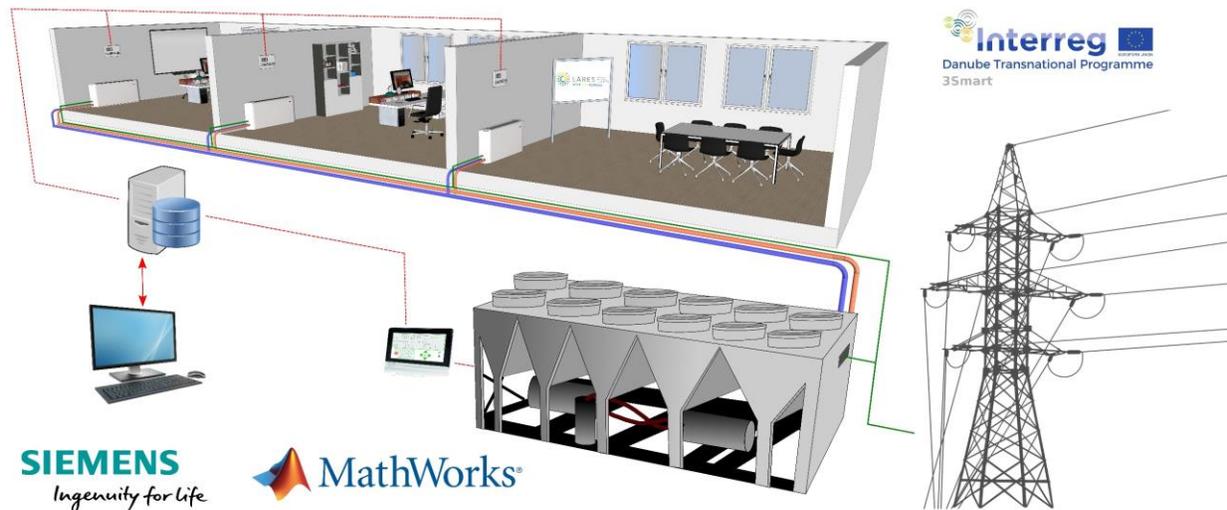


Figure 1. Case study considered for the MED2018 Process automation challenge.

The goal is to design a controller for fan coils fans on-off state and the chiller setpoint temperature. Fan coils are supplied with a cooling medium produced in the building's chiller. Besides the cooling energy from fan coils, the room temperature is dynamically influenced by solar irradiance, outdoor air temperature and heat disturbances like the presence of people or operation of equipment. For all of them there exists a prediction which is uncertain.

Fan coils' fans can be turned *on* or *off* and their on-off signals are the process control variables. The chiller provides the cooling medium with a constant flow during operating hours which is always distributed in the same way between the fan coils of the rooms, so the hydraulic situation is static and known. The starting temperature of the medium from the chiller towards the building is also a control variable of the process. There are heat losses along the distribution pipeline from the chiller to fan coils and from the fan coils output back to the chiller. The fan coils are described with the models of cooling power they provide to the rooms, which is for both their *on* and *off* fan state a function of the cooling medium temperature at the fan coil entrance, the known cooling medium constant flow and the room temperature. Besides the cooling power, the electrical power for fan operation is also known.

The chiller is supplied with electricity and its map of efficiency (ratio between the produced cooling power and the needed electrical power for that) with respect to the required cooling power and the outside air temperature is known. Upon the setpoint temperature command change, the associated medium temperatures affect the zones with a certain delay. The chiller's output temperature is constrained in such a way that it cannot be lower than the defined temperature threshold.

The price of electricity changes with 15 minutes time resolution and is known one day in advance.

2 Technical description

In the following subsections a detailed technical description of the case study process is given. It consists of mathematical models and accompanying descriptions. The process that is considered for the challenge is fully designed in MATLAB Simulink and the corresponding model and parameters can be found in supplementary materials. The technical description chapter is organized as follows. In Section 2.1 the heat pump model is described, Section 2.2 outlines the model of the hydraulic pump electrical consumption, while Section 2.3 provides the hydraulic, the temperature and the thermal losses model of the pipework. The detailed fan coil unit thermodynamic and electrical consumption model is given in Section 2.4. Section 2.5 describes mathematical model of the considered case-study building part.

2.1 Heat pump model

In the considered process a heat pump is used to transfer heat energy from outdoor air, i.e. the heat source, to the cooling system, i.e. the heat sink. Heat pump uses electric power to provide a mechanical work necessary to transfer the heat from the heat source to the heat sink, which is herein described by

$$P_{el}^{HP} = \frac{|P_t^{HP}|}{COP}, \quad (1)$$

where COP is the coefficient of performance factor, $P_t^{HP}[W]$ is the transferred heat power on the heat pump and $P_{el}^{HP}[W]$ is the consumed electric power. The transferred heat power is given by

$$P_t^{HP} = c_s q_s (T_s - T_r), \quad (2)$$

where q_s is the mass flow of the medium, T_s [°C] is the temperature of the supply medium and T_r [°C] is the temperature of the medium entering the heat pump. Note: the medium temperature T_s is the controlled and bounded variable, such that $T_s \in [7, 11]$. The medium temperature reference T_s is sampled with the discretisation interval of 15 minutes. It is synchronized with the fan coils on-off state controls in a way that its sampling instants coincide in time with a sampling instant for fan coils control. It is considered that medium temperature at the output of the heat pump towards the building follows the medium temperature reference instantaneously, and thus the same annotation T_s is used for both.

Coefficient of performance is expressed by employing the temperatures of the cooling medium in the system

$$COP = \gamma \frac{T_s + T_r - 2\Delta T + 2 \cdot 273.15}{2T_{env} - T_s - T_r + 4\Delta T}, \quad (3)$$

where γ is the constant parameter describing the efficiency of the heat pump Carnot cycle, T_{env} [°C] is the air temperature in the environment outside the building and ΔT [°C] is the constant parameter characterizing the heat pump. Parameters of the heat pump model are defined within the MATLAB file *model_init.m*.

Schematic diagram of the presented heat pump model is depicted in Fig. 2.

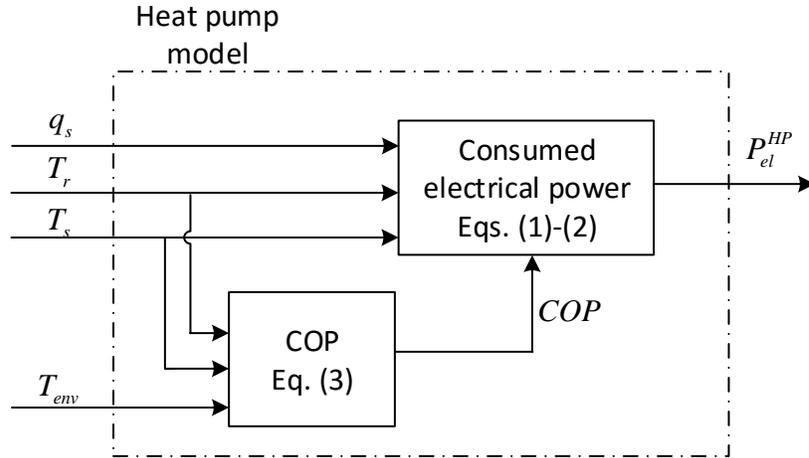


Figure 2. Schematic diagram of the heat pump model.

2.2 Hydraulic pump model

Note: hydraulic pump in the considered case study operates each day from 06:00 to 18:00. The medium flow in the system equals $q_s = 0.3$ kg/s while the pump is operating and otherwise the flow is $q_s = 0$ [kg/s].

Hydraulic pump model describes the consumed electric power with respect to the realized medium flow and the pressure difference at the pump. Its model is given by

$$P_{el}^P = \begin{cases} 4 \text{ W} & \text{for } q_s = 0.3 \text{ [kg/s]}, \\ 0 \text{ W} & \text{for } q_s = 0 \text{ [kg/s]}, \end{cases} \quad (4)$$

where P_{el}^P [W] is the electric power consumption of the pump. The hydraulic pump model is provided in the Simulink model.

2.3 Pipework model

The pipework model provides the medium mass flows and medium temperatures in the different segments of the pipework. Also transport delay is accounted for the medium temperature from the chiller to the fan coils and from the fan coils back to the chiller.

i) Hydraulic model

Since the fan coils are employed as the cooling units, hydraulic conditions in the system can be considered constant. Herein provided hydraulic model consists of the flow shares model

$$q_w = C_q q_s, \quad (5)$$

where $C_q \in \mathbb{R}^{3 \times 1}$ is the vector of constant parameters and $q_w = [q_{w,1} \quad q_{w,2} \quad q_{w,3}]^T$ is a vector of mass flows in the zones.

ii) Temperature model

Flow of the cooling medium through the pipework which is surrounded by a material of different temperature results with thermal losses. All thermal losses are considered to be non-contributing to zones cooling. Temperature model is used to describe the consequent change of the medium temperature through the pipework, and the thermal losses in the zones can be neglected. Thus, the temperature model is herein given for the supply and the return pipe,

$$T_w^{\text{in}}(t + 15 \text{ min}) = \begin{cases} C_{T,s} [T_s(t) & q_s(t)^2 & q_s(t) & 1]^T & \text{for } q_s(t) > 0, \\ I_{3 \times 3} T_a(t) & & & & \text{for } q_s(t) = 0, \end{cases} \quad (6)$$

$$T_r(t + 15 \text{ min}) = C_{T,r} [C_q T_w^{\text{out}}(t) \quad q_s(t)^2 \quad q_s(t) \quad 1]^T, \quad (7)$$

where $T_a = [T_{a,1} \quad T_{a,2} \quad T_{a,3}]^T$ is the vector of air temperatures in the zones, $T_w^{\text{in}} = [T_{w,1}^{\text{in}} \quad T_{w,2}^{\text{in}} \quad T_{w,3}^{\text{in}}]^T$ and $T_w^{\text{out}} = [T_{w,1}^{\text{out}} \quad T_{w,2}^{\text{out}} \quad T_{w,3}^{\text{out}}]^T$ denote medium temperatures at the inlet and the outlet of the fan coils in zones, respectively, $C_{T,s} \in \mathbb{R}^{3 \times 4}$ and $C_{T,r} \in \mathbb{R}^{1 \times 4}$ are the temperature model parameters, $I_{3 \times 3}$ is the identity matrix of denoted dimensions, $C_q T_w^{\text{out}}$ models the mixing of the medium at the segment where pipelines join together in the return pipe.

The outlet temperatures T_w^{out} depend on the inlet temperatures and the generated thermal power flow on the fan coil units.

According to the presented temperature and hydraulic model of the pipework follows the model of induced thermal losses

$$\begin{aligned} P_t^{PW,s} &= c_w q_s (T_s - C_q T_w^{\text{in}}), \\ P_t^{PW,r} &= c_w q_s (C_q T_w^{\text{out}} - T_r), \end{aligned} \quad (8)$$

where $P_t^{PW,s}$ [W] and $P_t^{PW,r}$ [W] are the thermal power losses in the supply and return piping, respectively. It is considered that pipework thermal losses do not contribute in any part to rooms cooling. Parameters of the pipework model are included within the MATLAB file `model_init.m`.

Schematic diagram of the presented pipework model is depicted in Fig. 3.

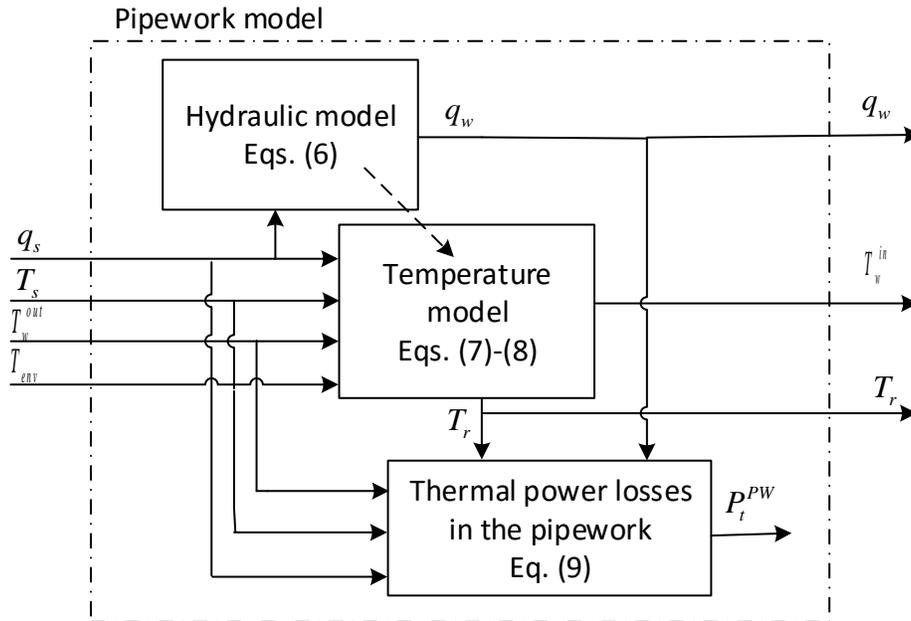


Figure 3. Schematic diagram of the pipework model.

2.4 Fan coil units

Fan coils are one of the most common heating/cooling elements found in office buildings. Due to their improved performance over classic radiators, they are widely used for localized heating and cooling. Heat transfer within a fan coil consists of three parts: convection of the heating/cooling medium, heat conduction through the heat exchanger and convection of air to be heated or cooled. Dynamics of the fan coil unit is described with the following differential equation for each fan coil $i = 1,2,3$:

$$m_{w,i} c_w \dot{T}_{w,i}^{\text{out}} = q_{w,i} c_w (T_{w,i}^{\text{in}} - T_{w,i}^{\text{out}}) - U_{o,i} (\bar{T}_{w,i} - T_{a,i}^{\text{in}}), \quad (9)$$

where $T_{w,i}^{\text{out}}$ [°C] is water outlet temperature, $T_{w,i}^{\text{in}}$ [°C] is water inlet temperature, $T_{a,i}^{\text{in}}$ [°C] is the air intake temperature assumed to be equal to zone temperature $T_{a,i}$, mean water temperature inside the unit, $\bar{T}_{w,i}$, is the average of water inlet temperature and water outlet temperature, i.e. $\bar{T}_{w,i} = 0.5(T_{w,i}^{\text{out}} + T_{w,i}^{\text{in}})$, $q_{w,i}$ [kg/s] is the medium mass flow through the unit, $c_w = 4180$ [J/(kg°C)] and $U_{o,i} = f(FS_i, q_{w,i})$ [W/°C] are the specific heat capacity of water and the heat transfer coefficient, respectively. Parameter $m_{w,i}$ [kg] is the mass of water inside the i^{th} fan coil, while parameter FS_i denotes the fan state (*on* or *off*) of the i^{th} fan coil. Note: The fan commands *on* and *off*, correspond to 1 and 0 commands used in the Simulink model, respectively. The thermal power transferred from the fan coil to the zone air $P_{\text{FCU},i}$ is defined as:

$$P_{\text{FCU},i} = U_{o,i} (\bar{T}_{w,i} - T_{a,i}^{\text{in}}), \quad (10)$$

with overall heat transfer coefficient $U_{o,i}$ defined as:

$$U_{o,i} = \begin{cases} \frac{201.80}{1 + 5.40 \cdot 10^{-3} \cdot q_{w,i}^{-1.86}} & \text{for } FS_i = on \quad \text{and} \quad q_{w,i} > 0, \\ 5.30 & \text{for } FS_i = off \quad \text{and} \quad q_{w,i} > 0, \\ 0 & \text{for } q_{w,i} = 0. \end{cases} \quad (11)$$

The electric power of the fan $P_{el,i}$ [W] is equal to 50 W when fan is *on* and equal to zero when fan is *off*.

$$P_{el,i}(FS) = \begin{cases} 50 & \text{for } FS_i = on, \\ 0 & \text{for } FS_i = off. \end{cases} \quad (12)$$

The schematic diagram of the fan coil model is shown in Fig. 4.

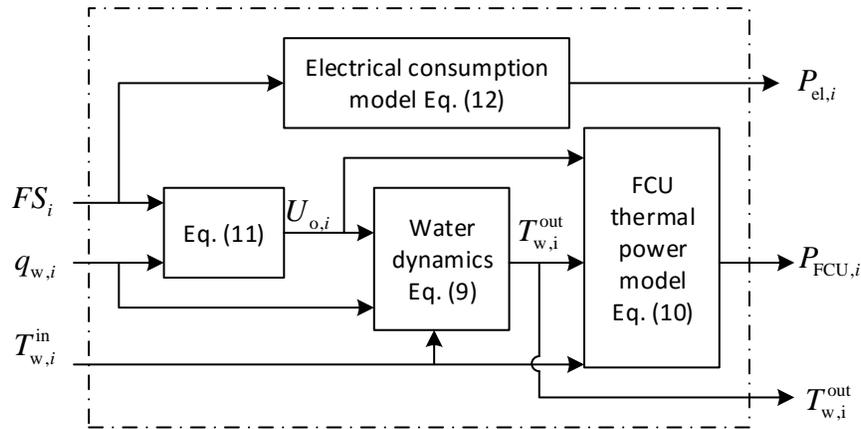


Figure 4: Schematic diagram of the fan coil model.

2.5 Building model

The building consists of three south-oriented zones. Every zone has only one external wall with a large glazing area. Each zone is equipped with one fan coil unit. Additionally, every zone $i = 1,2,3$ is affected with additional disturbance heat flux $P_{D,i}$ which represents the equivalent impact of all unmodeled heat sources, e.g. electronic equipment, lighting, occupants, etc. The zone thermodynamics is approximated with two thermal masses: fast dynamics with lower thermal capacity related to the air temperature inside the i^{th} zone $T_{a,i}$ and slow dynamics with a higher thermal capacity related to the temperature of solid zone parts, e.g. walls and furniture, $T_{\text{wall},i}$. Building dynamics is described with the following state space representation:

$$\begin{aligned} \dot{x} &= Ax + Bu, \\ y &= Cx + Du, \end{aligned} \quad (13)$$

where state vector $x \in \mathbb{R}^{6 \times 1}$ consists of three $T_{a,i}$ and three $T_{\text{wall},i}$ temperatures. The notation $T_{a,i}$ and $T_{\text{wall},i}$ represents the air and slow dynamics mass temperatures of the i^{th} zone, respectively.

$$x = [T_{a,1} \quad T_{a,2} \quad T_{a,3} \quad T_{\text{wall},1} \quad T_{\text{wall},2} \quad T_{\text{wall},3}]^T. \quad (14)$$

The input vector $u \in \mathbb{R}^{9 \times 1}$ consists of environmental (outdoor) air temperature T_{env} , direct solar irradiance incident on the southern building facade $I_{\text{dir}}^{\text{S}}$, diffuse solar irradiance incident on the southern building facade $I_{\text{diff}}^{\text{S}}$, actuator thermal powers $P_{\text{FCU},i}$ and additional heat disturbance flux $P_{\text{D},i}$ affecting the corresponding zones.

$$u = [T_{\text{env}} \quad I_{\text{dir}}^{\text{S}} \quad I_{\text{diff}}^{\text{S}} \quad P_{\text{FCU},1} \quad P_{\text{FCU},2} \quad P_{\text{FCU},3} \quad P_{\text{D},1} \quad P_{\text{D},2} \quad P_{\text{D},3}]^T. \quad (15)$$

The actual external weather conditions acting on the building are:

$$T_{\text{env}}(t) = T_{\text{env}}^{\text{P}}(k|k) + w_{\text{env}}(k) + \left(\frac{(T_{\text{env}}^{\text{P}}(k+1|k+1) + w_{\text{env}}(k+1)) - (T_{\text{env}}^{\text{P}}(k|k) + w_{\text{env}}(k))}{3600} \right) (t - 3600 \cdot k), \quad (16)$$

$$I_{\text{dir}}^{\text{S}}(t) = I_{\text{dir}}^{\text{S,P}}(k|k) + w_{\text{dir}}(k) + \left(\frac{(I_{\text{dir}}^{\text{S,P}}(k+1|k+1) + w_{\text{dir}}(k+1)) - (I_{\text{dir}}^{\text{S,P}}(k|k) + w_{\text{dir}}(k))}{3600} \right) (t - 3600 \cdot k), \quad (17)$$

$$I_{\text{diff}}^{\text{S}}(t) = I_{\text{diff}}^{\text{S,P}}(k|k) + w_{\text{diff}}(k) + \left(\frac{(I_{\text{diff}}^{\text{S,P}}(k+1|k+1) + w_{\text{diff}}(k+1)) - (I_{\text{diff}}^{\text{S,P}}(k|k) + w_{\text{diff}}(k))}{3600} \right) (t - 3600 \cdot k),$$

where $3600k \leq t < 3600(k+1)$, $T_{\text{env}}^{\text{P}}(k|k)$, $I_{\text{dir}}^{\text{S,P}}(k|k)$ and $I_{\text{diff}}^{\text{S,P}}(k|k)$ denote the first element of prediction of the corresponding weather conditions vector at time $t = 3600k$ s and w denotes the prediction error. Prediction error is modeled with Gaussian distribution such that $w_{\text{env}} \sim \mathcal{N}(0, 0.25)$ and:

$$w_{\text{dir}}(k) = \begin{cases} \mathcal{N}(0, 1000), & \text{for } I_{\text{dir}}^{\text{S,P}}(k|k) > 0, \\ 0, & \text{otherwise,} \end{cases} \quad (18)$$

$$w_{\text{diff}}(k) = \begin{cases} \mathcal{N}(0, 1000), & \text{for } I_{\text{diff}}^{\text{S,P}}(k|k) > 0, \\ 0, & \text{otherwise.} \end{cases}$$

With $\mathcal{N}(\cdot, \cdot)$ Gaussian random variable distribution is denoted with the corresponding mean and variance (square of standard deviation), respectively. Both direct and diffuse solar irradiances $I_{\text{dir}}^{\text{S}}(t)$ and $I_{\text{diff}}^{\text{S}}(t)$ are saturated to be strictly greater or equal to zero. The predicted values of the outdoor temperature and solar irradiances are provided as MATLAB variables saved within the file Weather_data.mat as variables Enviroment_temperature, Diffuse_irradiance and Direct_irradiance. Each variable consists of 24 predictions valid for the time period from $t = 3600k$ s up to $t = 3600(k+24)$ s. The provided weather sequence data are exemplary, and different weather sequences may be used in evaluation, as described more in detail in the section related to challenge rules and deadlines.

Thermal powers affecting the zones $P_{\text{FCU},i}$ are generated with fan coil model (Fig. 4), while disturbance heat fluxes $P_{\text{D},i}$ [W] affect the zone temperatures according to the fixed schedule defined as:

$$P_{\text{D},i} = \begin{cases} k_i + w_{\text{D},i} & \text{for } 8:00 \leq h \leq 18:00, \\ w_{\text{D},i} & \text{otherwise,} \end{cases} \quad (19)$$

where h denotes the hour in a day, $w_{\text{D},i} \sim \mathcal{N}(0, 1000)$ is Gaussian discrete noise modeling unmeasurable stochastic heat sources affecting the zones and k_i defines the intensity of the measurable deterministic heat flux affecting the i^{th} zone defined as:

$$k_i = \begin{cases} 100 & \text{for } i = 1, \\ 120 & \text{for } i = 2, \\ 150 & \text{for } i = 3. \end{cases} \quad (20)$$

Note: All Gaussian processes are modeled as discrete processes with sampling time 3600 s.

Output vector $y \in \mathbb{R}^{3 \times 1}$ consists of the zone air temperatures:

$$y = [T_{a,1} \quad T_{a,2} \quad T_{a,3}]^T. \quad (21)$$

System matrix A , input matrix B , output matrix C and direct feedthrough matrix D are matrices of appropriate sizes provided as a MATLAB state-space structure in the file *Building_ss_model.mat*.

2.6 Forecast data

The use of weather forecast for management of building thermal processes can significantly improve the overall performance of the system and reduce the operational costs. The following meteorological forecasts are available:

- i) Forecast of environment (outdoor) air temperature and solar irradiance incident with the south building facade – every full hour new forecast is available, the forecast consists of 24 hourly sampled values where k denotes the moment $t = 3600k$ s.

$$\begin{aligned} T_{\text{env}}^P(k) &= [T_{\text{env}}(k|k) \quad T_{\text{env}}(k+1|k) \quad \dots \quad T_{\text{env}}(k+23|k)]^T. \\ I_{\text{dir}}^{S,P}(k) &= [I_{\text{dir}}^S(k|k) \quad I_{\text{dir}}^S(k+1|k) \quad \dots \quad I_{\text{dir}}^S(k+23|k)]^T. \\ I_{\text{diff}}^{S,P}(k) &= [I_{\text{diff}}^S(k|k) \quad I_{\text{diff}}^S(k+1|k) \quad \dots \quad I_{\text{diff}}^S(k+23|k)]^T. \end{aligned} \quad (22)$$

The notation $(k+n|k)$ denotes the prediction for time $(k+n)$ provided at the timestamp k .

- ii) Setpoint prediction – the setpoint in zone i changes deterministically according to the following rule:

$$L_b \leq SP_i \leq U_b, \quad (23)$$

$$\begin{aligned} L_b &= \begin{cases} 24 & \text{for } 8:00 \leq h \leq 18:00, \\ 0 & \text{otherwise,} \end{cases} \\ U_b &= \begin{cases} 24 & \text{for } 8:00 \leq h \leq 18:00, \\ 100 & \text{otherwise,} \end{cases} \end{aligned} \quad (24)$$

where h is the current hour, L_b is lower temperature bound and U_b is upper temperature bound. Outside the interval $8:00 \leq h \leq 18:00$ zone temperature can be any value between lower and upper bound since temperature deviation outside this interval is not included into the penalization cost (for more details please see Chapter 3) and medium mass flow is set to

zero outside the interval $6:00 \leq h \leq 18:00$ (please refer to Section 2.2). Please note that the cooling is available 2 hours before the occupants set their comfort demands to 24°C , which enables implementation of the precooling functionality. The new hourly sampled prediction of the setpoint bounds over the next 24 hours is available every full hour as an output from the provided Simulink model.

- iii) Electricity prices prediction – c_{el}^P is available in hourly resolution 24 hours ahead.

$$c_{\text{el}}^P(k) = [c_{\text{el}}(k|k) \quad c_{\text{el}}(k+1|k) \quad \dots \quad c_{\text{el}}(k+23|k)]^T. \quad (25)$$

Electricity price forecast $c_{\text{el}}^P(k)$ related to time instant $t = 3600k$ s is given as output of the provided Simulink model. The price $c_{\text{el}}^P(k|k)$ is valid for the period between $3600k$ s and $3600(k+1)$ s, i.e. $c_{\text{el}}^P(k) = c_{\text{el}}^P(k|k)$ for $3600k \leq t < 3600(k+1)$. Described prediction data is available in the file *Electricity_cost.mat*.

- iv) Heat disturbance prediction – heat disturbance changes over time as described in (19) and (20). The disturbance prediction is not given as an output from the MATLAB case study model and for the use in the control algorithm it should be anticipated according to the definition given in (19) and (20).

3 Challenge assignment and validation criteria

The challenge assignment is to design an algorithm for the described cooling system control that will be operating on a target Siemens PLC. Sampling time of the control system should be devised by the designer but should not be less than 1 min for the fan coils fan control and less than 15 min for the supply medium temperature control. Control inputs of the system are the medium temperature T_s and the fan coil commands FS_1, FS_2 and FS_3 . The controller should be designed to minimize the cost of consumed electrical energy of the system in the market of time-varying prices while satisfying the setpoint temperatures in the zones in the presence of disturbances. Moreover, the designed control system should operate in a way to reduce the noise of the fan coils, associated to the number of times when the fan coils are turned on.

The criteria that will be used to validate and rank the submitted solutions are as follows. Measure of performance is used to quantify the cost of operation in euros associated to the designed controller. Respective performance index is given by the sum of three cost functions:

$$J = J_1 + J_2 + J_3. \quad (26)$$

J_1 is the cost of consumed electrical energy for the system operation:

$$J_1 = \int_{\tau=0}^{T_{\text{sim}}} \frac{c_{el}(\tau)}{3.6 \cdot 10^6} \left(P_{el}^P(\tau) + P_{el}^{HP}(\tau) + \sum_{i=1}^3 P_{FCU,i}(\tau) \right) d\tau, \quad (27)$$

where c_{el} [EUR/kWh] is the cost of electricity and T_{sim} [s] is the simulation time of the provided Simulink model. Cost J_2 quantifies the setpoint temperature SP^i tracking cost in the zones,

$$J_2 = \int_{\tau=0}^{T_{\text{sim}}} \varphi(t) \frac{c_{el}(\tau)}{3.6 \cdot 10^6} \sum_{i=1}^3 Q_i (T_{a,i}(\tau) - SP_i(\tau))^2 d\tau, \quad (28)$$

where $Q_i \in \mathbb{R}^1$ is the weight coefficient for penalization of the temperature deviation from the user selected value and normalization to electrical power saving proportional to temperature deviation above the setpoint, and $\varphi(t)$ is the weighting function such that the setpoint tracking error is considered in the working hours only,

$$\varphi(t) = \begin{cases} 1 & \text{for } 8:00 \leq h \leq 18:00, \\ 0 & \text{otherwise.} \end{cases} \quad (29)$$

Since $L_b = U_b$ during the occupied hours ($8:00 \leq h \leq 18:00$), setpoint value is chosen to be $SP_i = L_b = U_b$. Finally, cost J_3 is used to quantify the acoustic comfort in the zones,

$$J_3 = c_{ON} \sum_{j=0}^{N_{\text{sim}}} \sum_{i=1}^3 \delta_i(j), \quad (30)$$

$$\delta_i(j) = \begin{cases} 1 & \text{if } FS_i(j) = on \text{ and } FS_i(j-1) = off, \\ 0 & \text{otherwise,} \end{cases}$$

where c_{ON} is the cost of switching the fan coils to *on* state, j is used to denote 1-minute discrete time instants and N_{sim} is the overall number of respective time instants in the simulation. It is considered at the beginning of the simulation that $FS_i(-1) = off$ for all $i = 1,2,3$.

The simulation time for evaluation of the criterion is 6 days ($T_{sim} = 6 \text{ days}$, $N_{sim} = 6 \cdot 24 \cdot 60 - 1$).

To optimize the operation of the designed control system candidates can employ the available 24 hours ahead predictions of the electricity prices, setpoint profiles and the weather condition predictions. Respective predictions are for the considered simulation scenario available within the supplementary materials. As stipulated in the rules and deadlines section, these are test-sequences that may be set differently for the evaluation of challenge solutions submitted by the competitors.

The schematic diagram depicting the case study system and the controller performance measure is given in Fig. 5. The controllable variables, fan speeds and supply temperature, are marked with red squares. The implementation of the system is available in the provided MATLAB files.

The Process automation challenge candidates should design and validate their solution within the MATLAB environment. Only input and output variables of the main (root) block of the provided MATLAB Simulink model can be used and any other variable from the Simulink block of the process cannot be used. PLC coder within MATLAB allows one to generate a PLC code for the custom algorithm designed in Simulink. Thus, candidates are encouraged to use the PLC coder and design their controllers such that the implementation is viable on a real PLC hardware. The operation of the migrated PLC codes will be validated in TIA Portal IDE. TIA Portal will be also used to deploy the submitted solutions to the real Siemens PLC target.

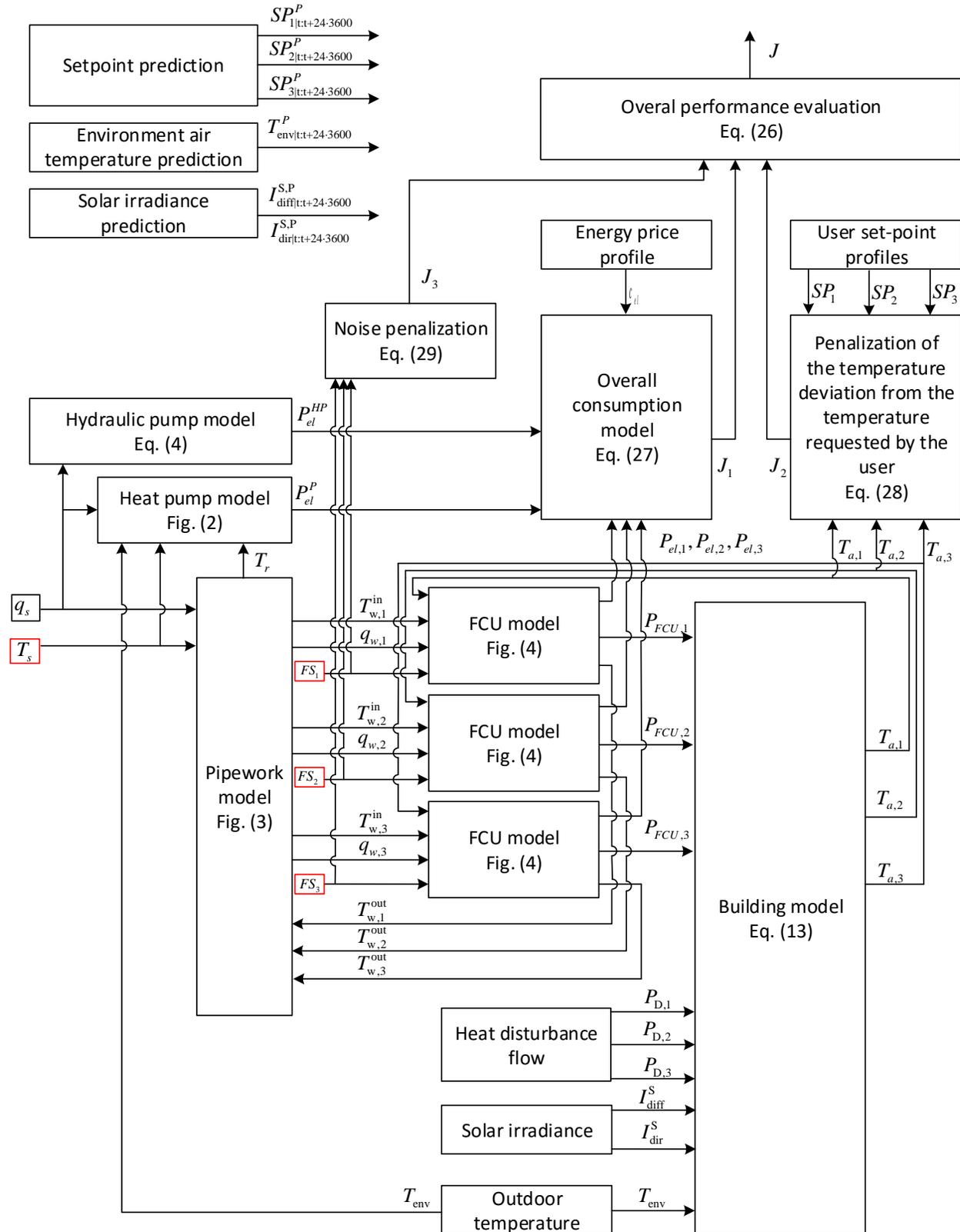


Figure 5. Schematic diagram of the provided Simulink model.

4 Process automation challenge rules and deadlines

Eligible for competition on this challenge are only teams of exclusively students with a verifiable student status on a higher education institution. The number of students in the team is not limited, and students can be enrolled on all levels – B.Sc. studies level, M.Sc. studies level and Ph.D. studies level.

The challenge is organized to select the finalists teams in a two-stage procedure, and then the finals are held during the MED conference in Zadar to finally select the challenge winning team.

Each student team that would like to participate needs to register on the registration link provided for the challenge during the first stage of the challenge procedure. In that way it will be assigned the verification code with which it can access the MATLAB model simulation files prepared for the challenge.

In the first stage the students should work on their controller solution in MATLAB/Simulink environment; all controller solutions starting from very simple industry standard ones like hysteresis controllers for fan coils and pre-defined temperature curves for the cooling medium are acceptable. By the submission deadline for the first stage the students need to submit their MATLAB solution in the form of a controller block in a Simulink scheme and, if applicable, a necessary initialization script. The block needs to be readily attachable to the official Simulink model simulation files provided. No change on the control algorithm after the deadline can be done. All the solutions will be evaluated by determining the value of the overall cost J on the same test-sequence of weather and electricity pricing data that differs from the one provided in simulation blocks and which will not be known to competitors prior to the submission deadline for the first stage. All teams will be informed about the test-sequence and about their score and ranking according to the evaluation criterion. All members of the teams within the first submission need to provide also student status proofs issued by their higher education institution. Best 30 eligible teams will be selected to advance to the second stage. In case of solutions of different teams with exactly the same evaluation criterion, the ranking will be decided based on solution submission time such that prior submissions will achieve higher ranking.

In the second stage all 30 teams that pass the first stage will be provided with the additional necessary tools from Mathworks and Siemens – MATLAB/Simulink with needed toolboxes and TIA portal with trial licenses covering the period of the challenge duration – to be able to smoothly design a PLC code block from the controller and then also test its operation in TIA portal via simulation of the block in PLCSim tool in different operation conditions. More to it, Siemens will ensure the TIA portal license that lasts for one year from the activation date which can be thus used also after the challenge, but strictly for educational purposes. For transition of the controller from Simulink to PLC code Mathworks toolbox Simulink PLC coder will be available as part of the MATLAB/Simulink installation. The task of the second stage is to enhance the initially developed algorithm and create also a PLC code block which implements the same algorithm as the enhanced MATLAB/Simulink block. In the second stage each team submits before the announced deadline the designed MATLAB/Simulink controller and the TIA portal automation project that contains the equivalent block. The exact required format for submission will be announced after the first stage is closed and also the target Siemens PLC will be announced. As in the first stage, no change after the deadline can be done. All the solutions will be evaluated by determining the value of the overall cost J on the same test-sequence of weather and electricity pricing data that differs from the one provided initially at the beginning of the first stage. It will not be known to competitors prior to the submission deadline for the second stage. All teams will be informed about the test-sequence and about their score

and ranking according to the evaluation criterion. The evaluation team will also test the compliance of the results between MATLAB/Simulink and the PLC controller block on test-data not known to the competitors in advance. Non-compliance on the selected test-data will eliminate the team from the further competition. Best 3 teams will be selected to advance to the finals. In case of solutions of different teams with exactly the same evaluation criterion, the ranking will be decided based on solution submission time such that prior submissions will achieve higher ranking.

The challenge finals will occur during the MED 2018 conference in Zadar. All travel and accommodation costs will be covered for up to 2 members of each of the 3 finalist teams and they will need to confirm their presence on the final event. For the three finalists teams there will be three elements of evaluation: 1) prior to the conference event performance of the Siemens PLC connected with the emulated building process in MATLAB via OPC toolbox will be tested by the evaluation team on the same test-sequence of weather and electricity pricing data that differs from the one provided initially at the beginning of the first stage and is not known to competitors before the deadline of the second stage, and each team will be informed on their score evaluated according to the criterion J and the corresponding responses data logs, 2) on the conference event there will be a small change of the assignment and the teams will be asked to perform according to it the necessary adaptations of the controller which will be evaluated in MATLAB environment, 3) the selected 1-hour window of the test-scenario will be evaluated via a real PLC connected via MATLAB OPC toolbox to the Simulink scheme where the building process is simulated in real time and the performance will be evaluated according to the same criterion J . Weights for the three evaluation elements in the finals are 0.5, 0.25 and 0.25, respectively. The challenge winner team will be promoted on the conference gala dinner and each of the two representatives of the winning team will be awarded with an Industrial IOT device Simatic IOT 2040.

Deadlines for the stages are as follows:

1. First stage deadline: 19 March 2018 15:00 CEST, publication of results in one week time
2. Second stage deadline: 30 April 2018 15:00 CEST, publication of results in two weeks time
3. Finals within one day of the conference event, according to the conference programme

INFO:

During the challenge questions can be posted in the forum on the following link: http://www.lares.fer.hr/lares/med2018process_automation_challenge. All answers will be provided solely through that forum.

The case study process is motivated by problems of integrated management of buildings and distribution grids tackled within the project [Smart Building – Smart Grid – Smart City](#) (acronym: 3Smart) funded through Interreg Danube Transnational Programme.