This document elaborates the detailed formulation for the reduced order models that mimic the behaviors of studied commercial buildings. In addition, the method we used to train the model and to generate the training dataset are also discussed.

1. **Model Formulation**
   1. Zonal Model

In this study, all the rooms that are served by one air handling unit are considered as one thermal zone, governed by:

|  |  |
| --- | --- |
|  | (1) |

where is the temperature\* of the th thermal zone at the th time step;

is the ambient temperature at the th time step;

is the total transmitted solar radiation rate at the th time step;

is the total internal heat gain rate at the th time step;

,, , and are the zone temperature heating and cooling setpoints, the air flow rate setpoint, and the reheat coil water mass flow rate for the th room in the th thermal zone at the th time step, respectively;

is the temperature of the internal wall between the th thermal zone and the th thermal zone at the th time step;

is the number of the zones in the th thermal zone (m≥1 for conditioned zones);

is the number of the internal walls for the th thermal zone;

is the discretization step;

are the regression coefficients. In total, there are (4m+n+5) coefficients.

For thermal zones with CAV system (constant air flow rate and no reheat):

|  |  |
| --- | --- |
|  | (1) |

is the supply air temperature for the th room in the th thermal zone at the th time step;

For basement with CAV system (constant air flow rate and no reheat):

|  |  |
| --- | --- |
|  | (1) |

* 1. Internal wall Model

Similar to the zonal model the internal wall model basically treats all the partitions as one wall. Thus, the temperature of the internal wall is the average temperature for all the partitions (weighted by the area) and is calculated by:

|  |  |
| --- | --- |
|  | (2) |

where , , and are the regression coefficients.

* 1. Fan Model

In this study, we assume that the static pressure set points for the fans are constant. Thus, the fan power is calculated by

|  |  |
| --- | --- |
|  | (3) |

where is the specific hear for air;

and are the regression coefficients.

* 1. Boiler Model

We assume that efficient of the boilers are constant and calculate the boiler energy consumption by

|  |  |
| --- | --- |
|  | (4) |
|  | (5) |
|  |  |

where is the specific hear for water

is the rated mass flow rate for the th room in the th thermal zone at the th time step, respectively;

and are the supply hot water temperature, and the return hot water temperature at the )th time step, respectively;

is the reciprocal of the boiler efficiency that should be obtained through regression.

* 1. Chiller Model

We assume that efficient of the boilers are constant and calculate the boiler energy consumption by

|  |  |
| --- | --- |
|  | (6) |
|  | (7) |
|  |  |

where is the discharged air temperature at the )th time step;

is the mixed air temperature at the )th time step;

is the reciprocal of the rated coefficient of performance;

is the rate of the latent cooling load to the sensible cooling load;

**,…,**  are the regression coefficients.

1. **Calibration Method**

In this study, we employed the least squares regression (LSR) method to obtain the values for all the regression coefficients. The idea for the LSR is to solve the following unconstrained optimization problem

|  |  |
| --- | --- |
|  | (8) |

where and are the th observation for the inputs and the outputs,

is the parameters whose values need to be calculated

1. **Training Dataset Generation**

A training dataset is the key to the reduced order models. A good dataset shall consider cover the most of the input sets for the models. To achieve that objective, we add excitations to the EnergyPlus model. The excitations are realized by adding random noise to the zone temperature setpoint:

|  |  |
| --- | --- |
|  | (9) |

where is the nominal zone temperature setpoint for the th room in the th thermal zone at the th time step;

is a function that returns a random value between and .

1. **Closed loop calculation example (middle office)**