Detailed Comparison of the Operational Characteristics of Energy-conserving HVAC Systems during the Cooling Season

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Supplementary materials

Figures S1 (a)–S1 (c) compare the input class lists of the HVAC systems in EnergyPlus [72]. The items with different list names and content organizations are marked in red. The items for which the list names are identical but have different content are denoted in green. The items that are identical for each system are marked in blue. Figure S1 (a) shows the differences between the VAV and CAV modeling configurations in EnergyPlus.

The first significant difference between VAV and CAV system modeling is the selection of the air loop’s air handling unit (A). This is because the two systems have different control concepts based on temperature and airflow. Therefore, in the AHU item (A), we set the AHU object type, schedule, the location setting of the inlet/outlet air node, minimum airflow setting, and damper control. In the VAV, the terminal unit (VAV box) was modeled as an “Air Terminal Single Duct: VAV Reheat” while in the CAV, the terminal unit was modeled as an “Air Terminal Single Duct: Constant Volume: Reheat”, where each of the detailed items was set. The second difference is fan modeling (B). In the VAV, fans were modeled as a “Fan: Variable Volume” while in the CAV, fans were modeled as a “Fan: Constant Volume”. In this item, we set the variable speed fan, constant speed fan type, fan efficiency, pressure, motor efficiency, and the location of the inlet/outlet air node. The plant loop, condenser loop, schedule, internal heat generation, equipment sizing design, and output variables were identical. The branch and node lists, which vary due to the differences in the air loop, were composed of branches and nodes that match each system.

Figure S1 (b) shows the differences between the EnergyPlus class lists in the VAV and UFAD. The main difference is related to the most important items, i.e., the “Room model Type” and “Room Air Setting: Underfloor Air Distribution (Interior, Exterior)” (A). Unlike overhead air distribution (OHAD) systems that supply conditioned air via the ceiling, UFAD uses the space under the floor panels in a raised access floor as the space that supplies air. Therefore, during modeling, we must implement thermal stratification, which supplies air from the floor diffusers. In the EnergyPlus, the “Room Air Model” can be used to implement a system in which air is supplied from the floor and diffuses via the ceiling. In the “Room Air modeling type”, several systems other than the UFAD can be modeled, such as low velocity displacement air conditioning systems. In the “Room Air Setting: Underfloor Air Distribution (Interior, Exterior)” item, it is also possible to set the interior/exterior zone settings, floor supply diffuser type and number, diffuser performance curve, and occupied/unoccupied zone height.
Figure S1 (a). Comparison of CAV and VAV modeling in the EnergyPlus class list.
The first significant difference between VAV and CAV system modeling is the selection of the air loop’s air handling unit (A). This is because the two systems have different control concepts based on temperature and airflow. Therefore, in the AHU item (A), we set the AHU object type, schedule, the location setting of the inlet/outlet air node, minimum airflow setting, and damper control. In the VAV, the terminal unit (VAV box) was modeled as an “Air Terminal Single Duct: VAV Reheat” while in the CAV, the terminal unit was modeled as an “Air Terminal Single Duct: Constant Volume: Reheat”, where each of the detailed items was set. The second difference is fan modeling (B). In the VAV, fans were modeled as a “Fan: Variable Volume” while in the CAV, fans were modeled as a “Fan: Constant Volume”. In this item, we set the variable speed fan, constant speed fan type, fan efficiency, pressure, motor efficiency, and the location of the inlet/outlet air node. The plant loop, condenser loop, schedule, internal heat generation, equipment sizing design, and output variables were identical. The branch and node lists, which vary due to the differences in the air loop, were composed of branches and nodes that match each system.

Figure S1 (b) shows the differences between the EnergyPlus class lists in the VAV and UFAD. The main difference is related to the most important items, i.e., the “Room model Type” and “Room Air Setting: Underfloor Air Distribution (Interior, Exterior)” (A). Unlike overhead air distribution (OHAD) systems that supply conditioned air via the ceiling, UFAD uses the space under the floor panels in a raised access floor as the space that supplies air. Therefore, during modeling, we must implement thermal stratification, which supplies air from the floor diffusers. In the EnergyPlus, the “Room Air Model” can be used to implement a system in which air is supplied from the floor and diffuses via the ceiling. In the “Room Air modeling type”, several systems other than the UFAD can be modeled, such as low velocity displacement air conditioning systems. In the “Room Air Setting: Underfloor Air Distribution (Interior, Exterior)” item, it is also possible to set the interior/exterior zone settings, floor supply diffuser type and number, diffuser performance curve, and occupied/unoccupied zone height.

Figure 10 (c) shows the differences between the EnergyPlus class lists for the VAV and active chilled beam with DOAS. The significant differences between the VAV and active chilled beam with DOAS modeling are the introduction of exterior air and the use of chilled beams. In the active chilled beam system, the AHU uses the DOAS to regulate the indoor environment based solely on the use of outdoor air, where the outdoor air supply is separated from the return air and handled independently. The primary side air that has experienced cooling, dehumidification, and heat recovery in the DOAS is used for air conditioning through a chilled beam rather than a normal diffuser. Chilled water, which passes through a cooling coil in the chilled beam, is used to perform cooling. Therefore, when we examined the air loop’s AHU type and configuration (A), we observed that the VAV modeled the terminal unit as an “Air Terminal Single Duct: VAV Reheat” while the active chilled beam with DOAS modeled the terminal unit as an “Air Terminal Single Duct: Cooled Beam”. We added and set each of the detailed items for the beam’s “Coil: Cooling: Water: Detailed Geometry” (B) and “Heat exchanger air to air: Sensible and latent” (C) of the DOAS. In the “Air Terminal Single Duct: Cooled Beam”, we determined the chilled beam system’s type (i.e., either passive chilled beam or active chilled beam), the locations of the inlet/outlet air node and inlet/outlet cold water node, beam dimensions, quantity, performance curve, and supplied airflow. In the “Coil: Cooling: Water: Detailed Geometry”, we set the beam’s pipe dimensions, quantity, flow setting, location of the inlet/outlet cold water node, and pipe material properties. In the “Heat exchanger air to air: Sensible and latent” item, it was possible to set the heat exchange efficiency, minimum outdoor air inflow, location of the inlet/outlet temperature node, heat exchanger type, and schedule.
Figure S1 (b). Comparison of CAV and UFAD modeling in the EnergyPlus class list
Figure S1 (c). Comparison of CAV and Active chilled beam with DOAS modeling in the EnergyPlus class list.
**Figure S2 (a).** Diagram of the CAV system layout in the EnergyPlus simulation (Scalable Vector Graphics (SVG) of the CAV system)
Figure S2 (b). Diagram of the VAV system layout in the EnergyPlus simulation ( Scalable Vector Graphics (SVG) of the VAV system)
Figure S2 (c). Diagram of the UFAD system layout in the EnergyPlus simulation (Scalable Vector Graphics (SVG) of the UFAD system)
Figure S2 (d). Diagram of the ACB with DOAS layout in the EnergyPlus simulation (Scalable Vector Graphics (SVG) of the ACB with DOAS)