## Advanced RTU Controls

### Author

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### Description

This energy efficiency measure (EEM) adds a variable speed drive (VSD) to existing constant-speed, single-stage cooling rooftop units (RTUs). The VSD reduces the fan speed when the RTU is in economizer or ventilation mode, saving energy compared to a constant-speed fan baseline where the fan is run at 100% flow regardless of need.

### Modeler Description

This EEM adds EMS logic to the model for each AirLoopHVAC:Unitary:HeatPump:AirToAir or CoilCoolingDXSingleSpeed objects found. The added logic first defines fan speed modifier values based on the unit mode (0.9 for heating, 0.9 for cooling, 0.75 for economizing, 0.4 for ventilation) and a fan power exponent (2.2). The code then checks the heating and cooling runtime fractions and the outdoor air (OA) mass flow rate at each time step. The runtime fractions and OA mass flow rate values are used to determine the percentage of the time step that the unit spends in each mode (heating, cooling, economizing, or ventilation). The mode percentages are then used with the fan speed modifiers and fan power exponent value to calculate a weighted average fan pressure rise for the entire time step. Note that this will affect the fan power for the time step, but does not change the fan flow rate and thus will not affect zone thermal or comfort performance.

The measure is run using the BeginTimestepBeforePredictor calling point. As such, fan pressure rise lags changes in the cooling and heating runtime fractions by a time step. Changing the calling point was observed to affect the energy savings associated with this measure (up to 0.5% of total building energy use), but did not remedy the lag issue.

### Use Case Types

Retrofit

### Arguments

“run\_measure” is a choice argument that determines whether or not the Measure is applied during a given run.

### Initial Condition Message

The initial model contained {X} single-zone, constant air volume units for which this measure is applicable.

### Final Condition Message

VSDs and associated controls were applied to {X} single-zone, constant air volume units in the model. Airloops affected were {airloop\_name}, etc.

### Not Applicable Messages

* No AirLoopHVAC:Unitary:HeatPump:AirToAir or CoilCoolingDXSingleSpeed objects found. EEM not applied.
* EMS control logic modifying fan pressure rise already exists in the model. EEM not applied.

### Warning Messages

### No minimum outdoor air schedule found.

### No minimum fraction of outdoor air schedule name found.

### Information Messages

N/A

### Error Messages

N/A

### Code Outline

Modeling strategy taken from “Energy Savings Modeling of Standard Commercial Building Retuning Measures: Large Office Buildings” (1).

Applies to AirLoopHVAC:UnitaryHeatPump:AirToAir objects with Coil:Cooling:DX:SingleSpeed OR a Coil:Cooling:DX:SingleSpeed directly on the airloop.

If any eligible Coil:Cooling:DX:SingleSpeed object is found, and there is only one fan, insert the following EMS code:

EnergyManagementSystem:GlobalVariable,

FanPwrExp, ! Exponent used in fan power law

Stage1Speed, ! Fan speed in cooling mode

HeatSpeed, ! Fan speed in heating mode

VenSpeed, ! Fan speed in ventilation mode

EcoSpeed; ! Fan speed in economizer mode

EnergyManagementSystem:Program,

Set\_FanCtl\_Par1,

SET FanPwrExp = 2.2,

SET HeatSpeed = 0.9,

SET VenSpeed = 0.4,

SET Stage1Speed = 0.9,

SET EcoSpeed = 0.75;

SET PSZ{#}\_OADesignMass = PSZ{#}\_DesignOAFlowMass,

{…}

SET PSZ{n}\_OADesignMass = PSZ{n}\_DesignOAFlowMass;

EnergyManagementSystem:ProgramCallingManager,

Fan\_Parameter\_manager, !- Name

BeginNewEnvironment, !- EnergyPlus Model Calling Point

Set\_FanCtl\_Par1, !- Program Name 1

EnergyManagementSystem:InternalVariable,

PSZ{#}\_DesignFlowMass, !- Name

{Corresponding Controller:OutdoorAir Object Name}, !- Internal Data Index Key Name

Outdoor Air Controller Minimum Mass Flow Rate; !- Internal Data Type

{…}

EnergyManagementSystem:InternalVariable,

PSZ{n}\_DesignOAFlowMass, !- Name

{Corresponding Controller:OutdoorAir Object Name}, !- Internal Data Index Key Name

Outdoor Air Controller Minimum Mass Flow Rate; !- Internal Data Type

* For each eligible Coil:Cooling:DX:SingleSpeed object found, insert the following EMS code:

EnergyManagementSystem:InternalVariable,

PSZ{#}\_FanDesignPressure, !- Name

{Supply Fan Name from corresponding Controller:OutdoorAir Object}, !- Internal Data Index Key Name

Fan Nominal Pressure Rise; !- Internal Data Type

EnergyManagementSystem:InternalVariable,

PSZ{#}\_DesignFlowMass, !- Name

{Corresponding Controller:OutdoorAir Object Name}, !- Internal Data Index Key Name

Outdoor Air Controller Maximum Mass Flow Rate; !- Internal Data Type

EnergyManagementSystem:Sensor,

PSZ{#}\_OASch,

{Minimum Outdoor Air Schedule Name from corresponding Controller:OutdoorAir object},

Schedule Value;

EnergyManagementSystem:Sensor,

PSZ{#}\_OAFracSch,

{Minimum Fraction of Outdoor Air Schedule Name from corresponding Controller:OutdoorAir object},

Schedule Value;

EnergyManagementSystem:Sensor,

PSZ{#}\_OAFlowMass,

{Actuator Node Name from corresponding Controller:OutdoorAir object},

System Node Mass Flow Rate;

EnergyManagementSystem:Sensor,

PSZ{#}\_HtgRTF,

{Name of corresponding Coil:Heating:Gas, Coil:Heating:Electric or Coil:Heating:DX:SingleSpeed object},

Heating Coil Runtime Fraction;

EnergyManagementSystem:Sensor,

PSZ{#}\_ClgRTF,

{Name of corresponding Coil:Cooling:DX:SingleSpeed object},

Cooling Coil Runtime Fraction;

EnergyManagementSystem:Actuator,

PSZ{#}\_FanPressure, ! Name

{Name of corresponding Fan:OnOff or Fan:ConstantVolume object}, ! Actuated Component Unique Name

Fan, ! Actuated Component Type

Fan Pressure Rise; ! Actuated Component Control Type

EnergyManagementSystem:Program,

PSZ{#}\_FanControl, !- Name

IF PSZ{#}\_HtgRTF > 0,

SET PSZ{#}\_Htg = PSZ{#}\_HtgRTF, ! Percent of time in heating mode

SET PSZ{#}\_Ven = 1 - PSZ{#}\_HtgRTF, ! Percent of time in ventilation mode

SET PSZ{#}\_Eco = 0, ! Percent of time in economizer mode

SET PSZ{#}\_Stage1 = 0, ! Percent of time in DX cooling

ELSE,

SET PSZ{#}\_Htg = 0,

SET PSZ{#}\_MinOA1 = PSZ{#}\_OADesignMass \* PSZ{#}\_OASch,

SET PSZ{#}\_MinOA2 = PSZ{#}\_DesignFlowMass \* PSZ{#}\_OAFracSch,

SET PSZ{#}\_MinOA = @Max PSZ{#}\_MinOA1 PSZ{#}\_MinOA2,

IF PSZ{#}\_ClgRTF > 0, ! Mechanical cooling is on

SET PSZ{#}\_Stage1 = PSZ{#}\_ClgRTF,

IF PSZ{#}\_OAFlowMass > PSZ{#}\_MinOA, ! Integrated Economzing mode

SET PSZ{#}\_Eco = 1-PSZ{#}\_ClgRTF,

SET PSZ{#}\_Ven = 0,

ELSE,

SET PSZ{#}\_Eco = 0,

SET PSZ{#}\_Ven = 1-PSZ{#}\_ClgRTF,

ENDIF,

ELSE, ! Mechanical cooling is off

SET PSZ{#}\_Stage1 = 0,

IF PSZ{#}\_OAFlowMass > PSZ{#}\_MinOA, ! Economizer mode

SET PSZ{#}\_Eco = 1.0,

SET PSZ{#}\_Ven = 0,

ELSE,

SET PSZ{#}\_Eco = 0,

SET PSZ{#}\_Ven = 1.0,

ENDIF,

ENDIF,

ENDIF,

! For each mode, (percent time in mode) \* (fanSpeed^PwrExp) is the contribution to weighted fan power over time step

SET PSZ{#}\_FPR = PSZ{#}\_Ven \* (VenSpeed ^ FanPwrExp),

SET PSZ{#}\_FPR = PSZ{#}\_FPR + PSZ{#}\_Eco \* (EcoSpeed ^ FanPwrExp),

SET PSZ{#}\_FPR1 = PSZ{#}\_Stage1 \* (Stage1Speed ^ FanPwrExp),

SET PSZ{#}\_FPR = PSZ{#}\_FPR + PSZ{#}\_FPR1,

SET PSZ{#}\_FPR3 = PSZ{#}\_Htg \* (HeatSpeed ^ FanPwrExp),

SET PSZ{#}\_FanPwrRatio = PSZ{#}\_FPR + PSZ{#}\_FPR3,

! System fan power is directly proportional to static pressure, so this change linearly adjusts fan energy for speed control

SET PSZ{#}\_FanPressure = PSZ{#}\_FanDesignPressure \* PSZ{#}\_FanPwrRatio;

EnergyManagementSystem:ProgramCallingManager,

PSZ{#}\_Fan\_Manager, !- Name

BeginTimestepBeforePredictor, !- EnergyPlus Model Calling Point

PSZ{#}\_FanControl; !- Program Name 1

### Tests

**This measure applies to:**

1. Small Office
2. Stand-Alone Retail
3. Strip Mall
4. Quick Service Restaurant
5. Full Service Restaurant
6. Small Hotel
7. Warehouse
8. Midrise Apartment

**This measure does not apply to:**

1. Medium Office
2. Large Office
3. Primary School
4. Secondary School
5. Supermarket
6. Large Hotel
7. Hospital
8. Outpatient Healthcare

**Test results:**

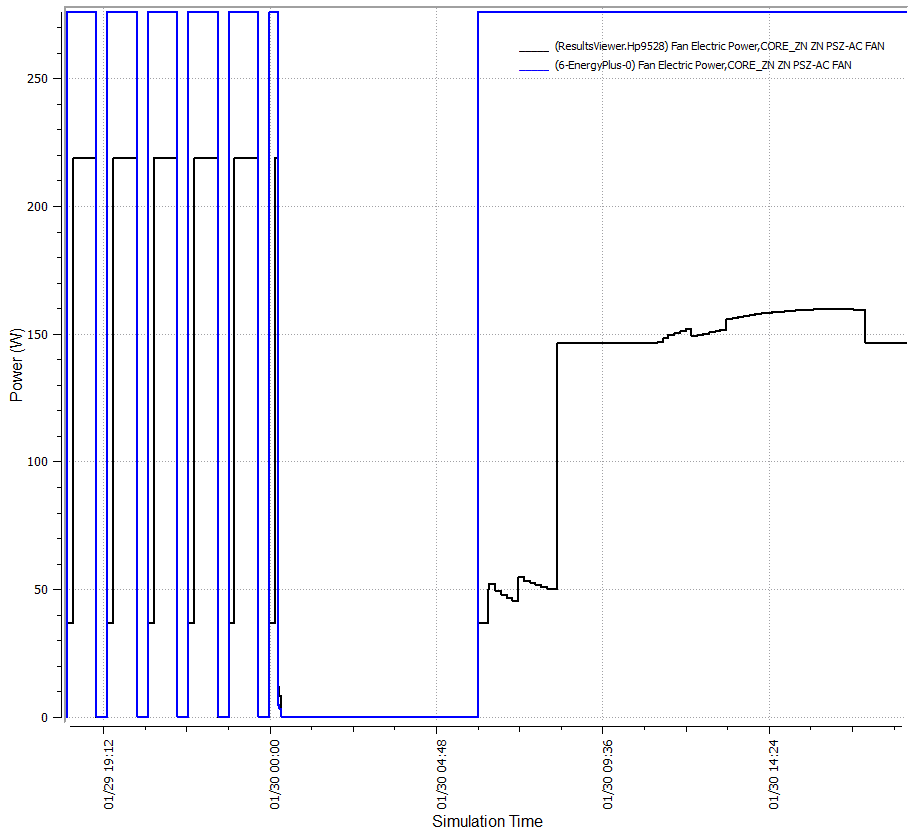
Annual results without EMS (Houston):

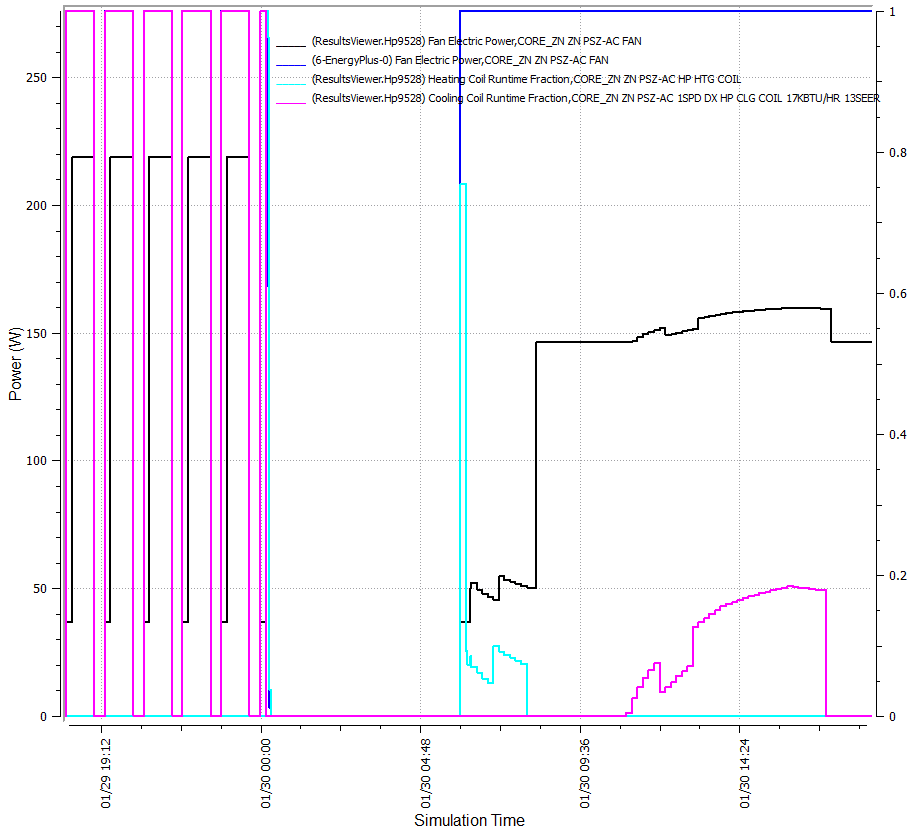
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Electricity [GJ] | Natural Gas [GJ] | Additional Fuel [GJ] | District Cooling [GJ] | District Heating [GJ] | Water [m3] |
| Heating | 1.43 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cooling | 57.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Lighting | 56.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Lighting | 7.56 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Equipment | 47.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Equipment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fans | 28.57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pumps | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Rejection | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Humidification | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Recovery | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water Systems | 18.01 | 0.00 | 0.00 | 0.00 | 0.00 | 30.01 |
| Refrigeration | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Generators | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
|  |  |  |  |  |  |  |
| Total End Uses | 217.32 | 0.17 | 0.00 | 0.00 | 0.00 | 30.01 |

Annual results with EMS (Houston):

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Electricity [GJ] | Natural Gas [GJ] | Additional Fuel [GJ] | District Cooling [GJ] | District Heating [GJ] | Water [m3] |
| Heating | 1.79 | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cooling | 56.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Lighting | 56.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Lighting | 7.56 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interior Equipment | 47.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exterior Equipment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fans | 17.39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pumps | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Rejection | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Humidification | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Heat Recovery | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water Systems | 18.01 | 0.00 | 0.00 | 0.00 | 0.00 | 30.01 |
| Refrigeration | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Generators | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
|  |  |  |  |  |  |  |
| Total End Uses | 205.35 | 0.18 | 0.00 | 0.00 | 0.00 | 30.01 |

Graph of fan power before (blue) and after (black) measure was applied.





### References

1. <http://buildingretuning.pnnl.gov/documents/pnnl_21569.pdf>