## Enable Optimal Start/Stop

### Author

* Danny Studer, NREL (design)
* Brian Ball, NREL (measure coding)

### Description

This energy efficiency measure (EEM) queries the outdoor air temperature to determine if the HVAC system can be shut off (up to one hour) early. Additionally, this measure modifies the HVAC system start time, optimizing energy savings by delaying startup as long as possible, while still ensuring that the building will be a comfortable temperature when occupants arrive.

### Modeler Description

This EEM adds EMS logic to the model that actuates the infiltration, HVAC operation, cooling set point, and heating set point schedules. The measure first identifies the schedule HVAC stopping point by day of week (Saturday, Sunday, and Weekdays). Early HVAC system shutoff is determined entirely by the outdoor air temperature (OAT). If the OAT is ≤2°C or ≥18°C, then no action is taken. The HVAC system is shut off one hour early when the OAT is between 12°C and 18°C. The HVAC system shut off time varies linearly with OAT from one hour to zero hours between 12°C and 2°C, and between 18°C and 28°C.

AvailabilityManager:OptimumStart objects are inserted for each HVAC system in the model and use the AdaptiveASHRAE algorithm to dynamically adjust HVAC startup time each day.

### Use Case Types

Retrofit, New Construction

### 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} applicable AirLoopHVAC systems for which this measure is applicable.

### Final Condition Message

Optimal start/stop logic was applied to {X} air loops in the model. Air loops affected were {AirLoopHVAC name 1}, {AirLoopHVAC name 2}, etc.

### Not Applicable Messages

* No AirLoopHVAC objects found. EEM not applied.
* No AirLoopHVAC systems shut down at night. EEM not applied.

### Warning Messages

* No heating temperature setback found for the {AirLoopHVAC Name} system.
* No cooling temperature setback found for the {AirLoopHVAC Name} system.
* No infiltration rate change found for the {AirLoopHVAC Name} system.
* No change in minimum OA requirements found for the {AirLoopHVAC Name} system.

### Information Messages

N/A

Did something to object 2. Etc.

### Error Messages

N/A

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

* Loop through the model and identify each AirLoopHVAC object.
* For each AirLoopHVAC object, check to see if the system is ever shut down, by examining the HVAC availability schedule for that system. This is available as an OpeNStudio parameter, but not as an EnergyPlus parameter. If that schedule is always >0, then the HVAC system runs constantly, and this measure will NOT apply to that air loop.
* For each applicable AirLoopHVAC object, identify the time at which the HVAC system is shut down, by day of week (Saturday, Sunday, and Weekdays). This can be done by examining the OS Availability Schedule parameter for each AirLoopHVAC object (by examining the E+ Schedule:Day:Interval and associated Schedule:Week:Daily objects created by the availability manager for each AirLoopHVAC object).
* For each applicable AirLoopHVAC object, identify the unoccupied OA schedule value. This schedule is referenced in the corresponding Controller:OutdoorAir object, in the Minimum Outdoor Air Schedule Name parameter.
* Loop through the model and create a list of which zones are assigned to which air loop.
* For each zone, identify the heating set back temperature. Then, make a list of zones that reference unique thermostat schedules. For example, if two thermostat schedules are used, but each schedule is referenced by five different zones, make a list that contains two zone names and their corresponding thermostat schedule names, such that each thermostat schedule name is included in the list. Ignore the remaining eight zones since their thermostat schedules are included in the already created list.)
* For each zone, identify the cooling set back temperature. Then make a list of zones that reference unique thermostat schedules.
* For each zone, identify the infiltration schedule value when the HVAC system is off. Then, make a list of zones that reference unique infiltration schedules. Infiltration schedule names and their assigned zone can be found in ZoneInfiltration:DesignFlowRate, ZoneInfiltration:EffectiveLeakageArea, or ZoneInfiltration:FlowCoefficient objects.

**Add this:**

EnergyManagementSystem:Sensor,

OAT, !- Name

\*, !- Output:Variable or Output:Meter Index Key Name

Site Outdoor Air Drybulb Temperature; !- Output:Variable or Output:Meter Name

**For each applicable AirLoopHVAC and/or Zone, insert the following:**

EnergyManagementSystem:ProgramCallingManager,

{Air Loop Name}\_Optimal\_Stop\_Control, !- Name

AfterPredictorBeforeHVACManagers, !- EnergyPlus Model Calling Point

{Air Loop Name}\_Optimal\_Stop; !- Program Name 1

EnergyManagementSystem:Program,

{Air Loop Name}\_Optimal\_Stop, !- Name

! Identify when the HVAC system is scheduled to turn off, and account for DST

SET SaturdayHVACEnd = {End of Sat. HVAC Operation Time} - DaylightSavings, !- Program Line 1

SET SundayHVACEnd = {End of Sun. HVAC Operation Time} - DaylightSavings, !- Program Line 1

SET WeekdayHVACEnd = {End of Weekday HVAC Operation Time} - DaylightSavings, !- Program Line 2

! Set the earliest you are willing to stop the HVAC system (1 hour in this case)

SET MinimumEarlyStop = 1, !- A4

! Set the earliest time for the HVAC system to shut off depending on the day of the week

IF DayOfWeek == 1 || Holiday == 1, !- A9

SET MinimumStop = SundayHVACEnd - MinimumEarlyStop, !- A10

ELSEIF DayOfWeek == 7, !- A11

SET MinimumStop = SaturdayHVACEnd - MinimumEarlyStop, !- A12

ELSE, !- A13

SET MinimumStop = WeekdayHVACEnd - MinimumEarlyStop, !- A14

ENDIF, !- A15

! Initialize variables

SET {Air Loop Name}\_HVAC\_OP = Null, !- A16

SET {Zone Name X}\_HSet = null,

SET {Zone Name X}\_CSet = null,

SET {Zone Name X}\_Infil = null,

SET {Air Loop Name}\_MinOA = null,

! Use OAT and the current time to determine if the HVAC system should be shut off

IF CurrentTime **>**= MinimumStop,

IF OAT <= 2 || OAT > 28, !- A19

SET HourPlus = MinimumEarlyStop, !- A20

ELSEIF OAT <= 12, !- A21

SET HourPlus = MinimumEarlyStop \* (12 - OAT)/10, !- A22

ELSEIF OAT <= 18, !- A23

SET HourPlus = 0, !- A24

ELSE, !- A25

SET HourPlus = MinimumEarlyStop \* (OAT - 18)/10, !- A26

ENDIF, !- A27

IF CurrentTime > MinimumStop + HourPlus, !- A28

SET {Air Loop Name}\_HVAC\_OP = 0, !- A33

SET {Zone Name X}\_HSet = {Zone Name X Unoccupied Heating Set Point},

SET {Zone Name X}\_CSet = {Zone Name X Unoccupied Cooling Set Point},

SET {Zone Name X}\_Infil = {Zone Name X Unoccupied Infiltration Schedule Value},

SET {Air Loop Name}\_MinOA = {Air Loop Name Unoccupied OA Value},

ENDIF, !- A36

ENDIF; !- A37

EnergyManagementSystem:Actuator,

{Air Loop Name}\_MinOA,

{Corresponding Minimum Outdoor Air Schedule Name},

Schedule:Year,

Schedule Value;

EnergyManagementSystem:Actuator,

{Zone Name X}\_Infil,

{Corresponding Zone Infiltration Schedule Name},

Schedule:Compact,

Schedule Value;

EnergyManagementSystem:Actuator,

{Air Loop Name}\_HVAC\_OP, !- Name

{Corresponding HVAC Operation Schedule}, !- Actuated Component Unique Name

Schedule:Year, !- Actuated Component Type

Schedule Value; !- Actuated Component Control Type

EnergyManagementSystem:Actuator,

{Zone Name X}\_HSet, !- Name

{Corresponding Heating Set Point Schedule}, !- Actuated Component Unique Name

Schedule:Year, !- Actuated Component Type

Schedule Value; !- Actuated Component Control Type

EnergyManagementSystem:Actuator,

{Zone Name X}\_CSet, !- Name

{Corresponding Cooling Set Point Schedule }, !- Actuated Component Unique Name

Schedule:Year, !- Actuated Component Type

Schedule Value; !- Actuated Component Control Type

* For each applicable AirLoopHVAC object, identify the associated “Availability Manager List Name.” Search for an AvailabilityManagerAssignmentList object with that name. For each, append the following. Note that we will need to replace the semicolon that currently ends the object with a comma. Take the {Name} from the AvailabilityManagerAssignmentList name.

**Add this:**

AvailabilityManager:OptimumStart,

{Air Loop Name} Optimal Start;

**So that this:**

AvailabilityManagerAssignmentList,

{Something} Availability Manager List,

AvailabilityManager:NightCycle,

{Something} Availability Manager;

**Becomes this:**

AvailabilityManagerAssignmentList,

{Something} Availability Manager List,

AvailabilityManager:NightCycle,

{Something} Availability Manager,

AvailabilityManager:OptimumStart,

{Air Loop Name} Optimal Start;

* Then add in the AvailabilityManager:OptimumStart objects, one for each applicable AirLoopHVAC object found:

**Add this:**

AvailabilityManager:OptimumStart,

{Air Loop Name} Optimal Start, !- Name

{Insert an Always\_On Schedule Here}, !- Applicability Schedule Name

{Corresponding HVAC Availability Schedule Schedule}, !- Fan Schedule Name

MaximumofZoneList, !- Control Type

, !- Control Zone Name

{Air Loop} Zone List, !- Zone List Name

3, !- Maximum Value for Optimum Start Time {hr}

AdaptiveASHRAE; !- Control Algorithm

* Then add a ZoneList object for applicable AirLoopHVAC object. The zones in the list should be all the zones served by that Air Loop.

**Add this:**

ZoneList,

{Air Loop} Zone List, !- Name

{Zone X}, !- Zone 1 Name

{Zone Y}; !- Zone 2 Name

### Tests

**This measure applies to:**

1. Small Office
2. Medium Office
3. Large Office
4. Primary School
5. Secondary School
6. Stand-Alone Retail
7. Strip Mall
8. Supermarket
9. Quick Service Restaurant
10. Full Service Restaurant
11. Small Hotel
12. Large Hotel
13. Outpatient Healthcare
14. Hospital
15. Warehouse
16. Midrise Apartment

**This measure does not apply to:**

### References

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