OpenBuildingControl

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November 2, 2017

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  See https://github.com/lbl-srg/obc/tree/master/meetings/2017-11-02-team for report
- Updates to CDL (Michael)
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- Upcoming deadlines.
  See https://github.com/lbl-srg/obc/wiki/2017-11-02-team-meeting-agenda#agenda
- Next steps
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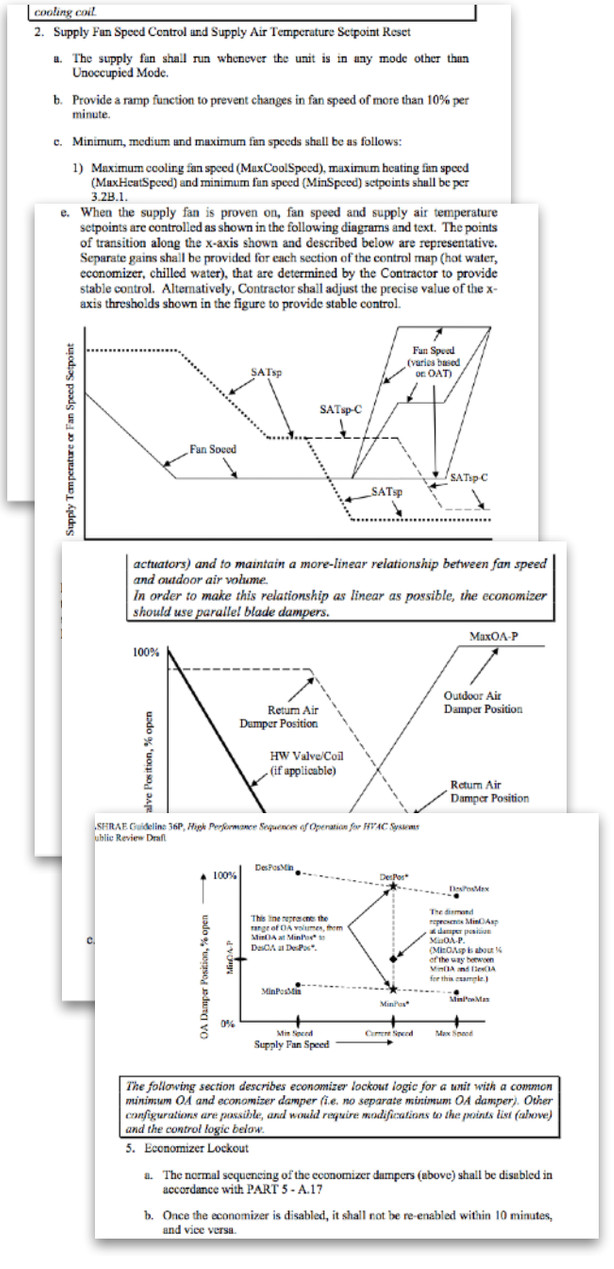
- Other feedback/discussions?

Guideline 36 implementation (Jianjun and Milica)

Implement sequences with CDL

ASHRAE Guideline 36



cooling coil.

2. Supply Fan Speed Control and Supply Air Temperature Setpoint Reset

a. The supply fan shall run whenever the unit is in any mode other than Unoccupied Mode.

b. Provide a ramp function to prevent changes in fan speed of more than 10% per minute.

c. Minimum, medium and maximum fan speeds shall be as follows:

1) Maximum cooling fan speed (MaxCoolSpeed), maximum heating fan speed (MaxHeatSpeed) and minimum fan speed (MinSpeed) setpoints shall be per 3.2B.1.

e. When the supply fan is proven on, fan speed and supply air temperature setpoints are controlled as shown in the following diagrams and text. The points of transition along the x-axis shown and described below are representative. Separate gains shall be provided for each section of the control map (hot water, economizer, chilled water), that are determined by the Contractor to provide stable control. Alternatively, Contractor shall adjust the precise value of the x-axis thresholds shown in the figure to provide stable control.

Supply Temperature or Fan Speed Setpoint
SATsp
Fan Speed (varies based on OAT)
SATsp-C
Fan Speed
SATsp-C
SATsp

actuators) and to maintain a more-linear relationship between fan speed and outdoor air volume.
In order to make this relationship as linear as possible, the economizer should use parallel blade dampers.

100%
MaxOA-P
Return Air Damper Position
Outdoor Air Damper Position
HW Valve/Coil (if applicable)
Return Air Damper Position

The following section describes economizer lockout logic for a unit with a common minimum OA and economizer damper (i.e. no separate minimum OA damper). Other configurations are possible, and would require modifications to the points list (above) and the control logic below.

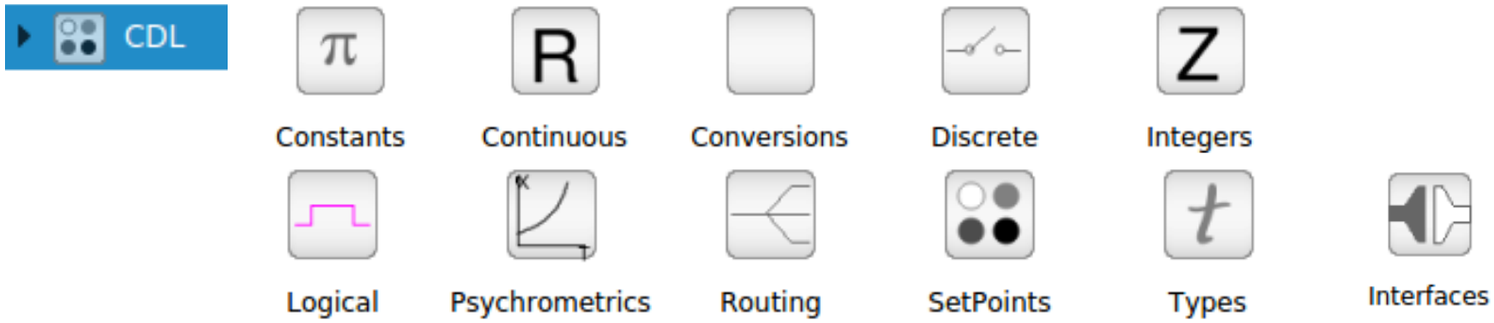
5. Economizer Lockout

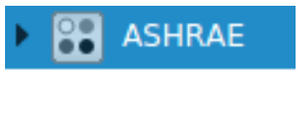
a. The normal sequencing of the economizer dampers (above) shall be disabled in accordance with PART 5 - A.17

b. Once the economizer is disabled, it shall not be re-enabled within 10 minutes, and vice versa.

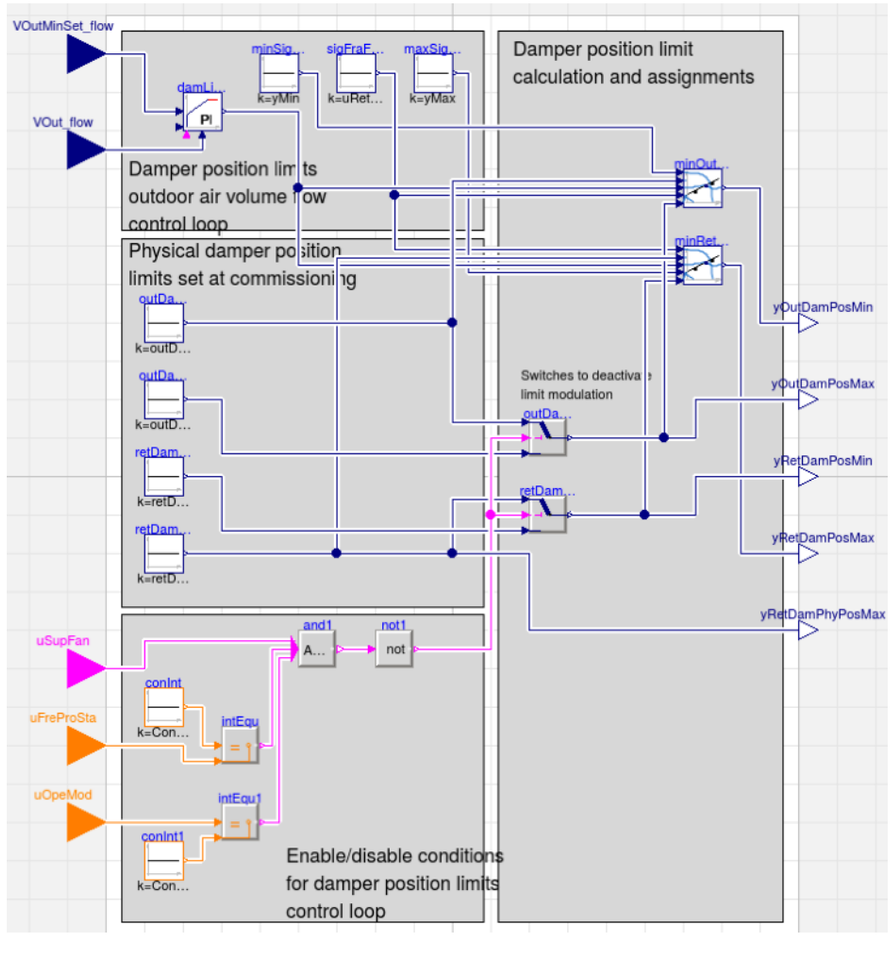
ASHRAE Guideline 36P, High Performance Sequences of Operation for HVAC systems, First Public Review Draft. ASHRAE, June 2016

Implementation using CDL





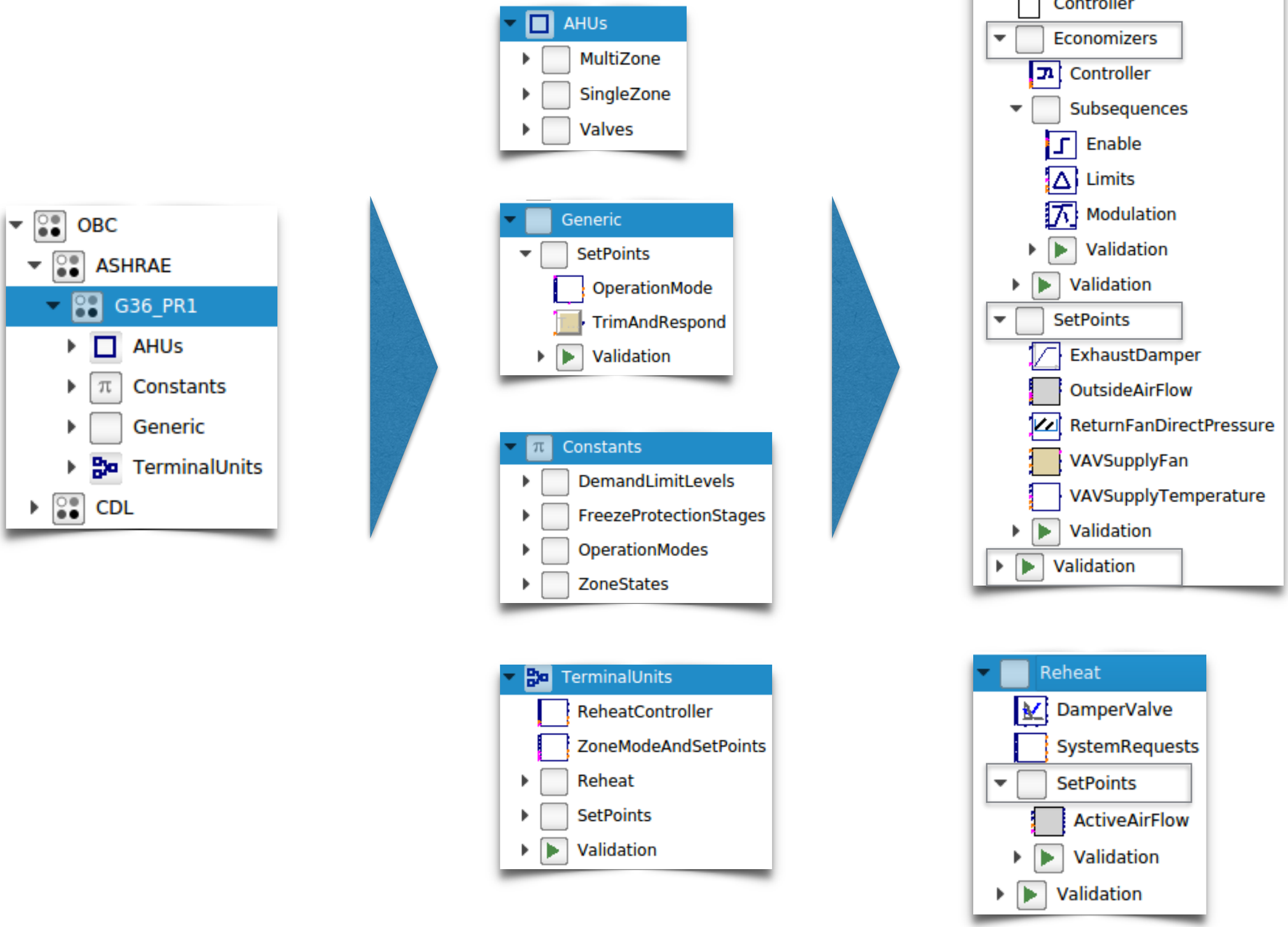

```
Buildings.Controls.OBC.CDL.Interfaces.RealInput VOut_f
  final unit="m3/s",
  final quantity="VolumeFlowRate")
  "Measured outdoor volumetric airflow rate"
  ;
Buildings.Controls.OBC.CDL.Interfaces.RealInput VOutMi
  final unit="m3/s",
  final quantity="VolumeFlowRate")
  "Minimum outdoor volumetric airflow rate setpoint"
  ;
Buildings.Controls.OBC.CDL.Interfaces.IntegerInput uOp
  "AHU operation mode status signal"
  ;
Buildings.Controls.OBC.CDL.Interfaces.IntegerInput uFr
  "Freeze protection status signal"
  ;
Buildings.Controls.OBC.CDL.Interfaces.BooleanInput uSu
  "Supply fan status signal"
  ;

Buildings.Controls.OBC.CDL.Interfaces.RealOutput yOutD
  final min=outDamPhyPosMin,
  final max=outDamPhyPosMax,
  final unit="1")
  "Minimum outdoor air damper position limit"
  ;
```



Buildings.Controls.OBC.ASHRAE.G36_PR1.AHUs.MultiZone.Economizers.Subsequences.Limits

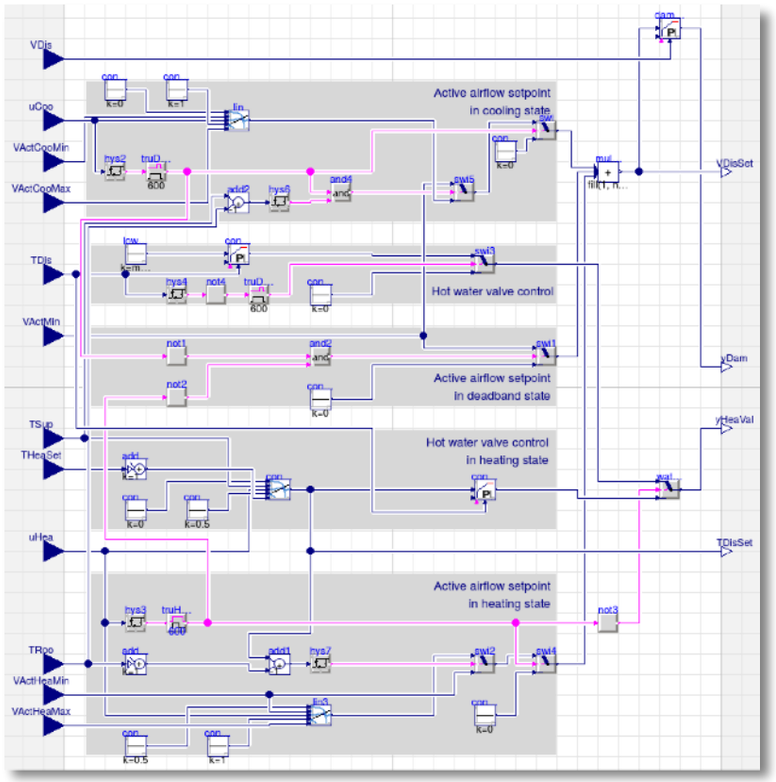
Implement sequences with CDL

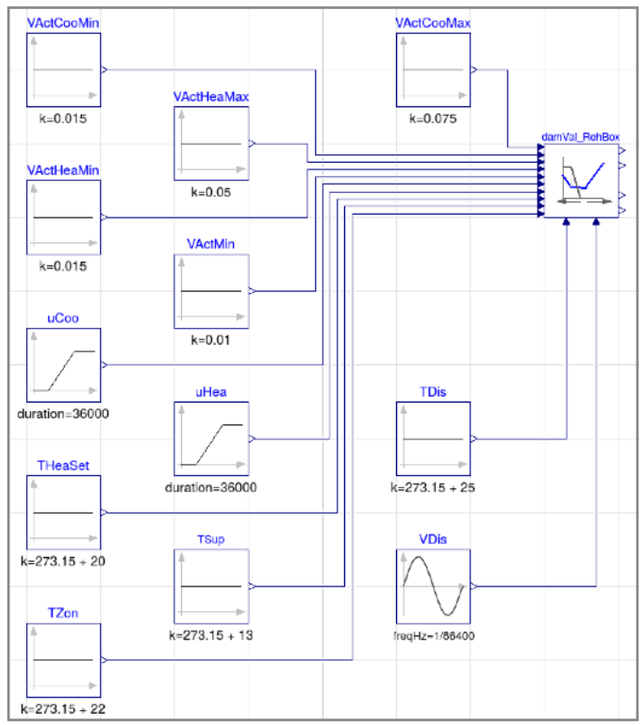
Organize sequences package according to Guideline 36 structure

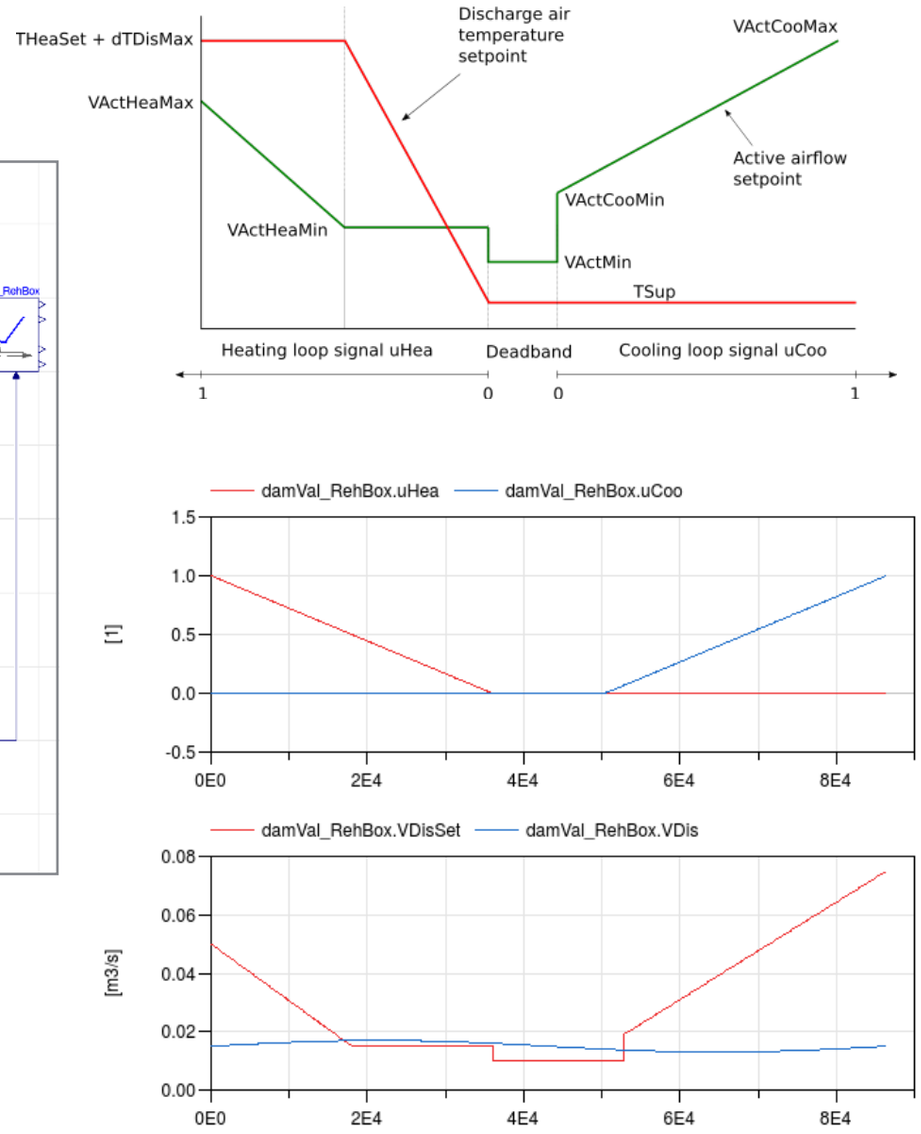


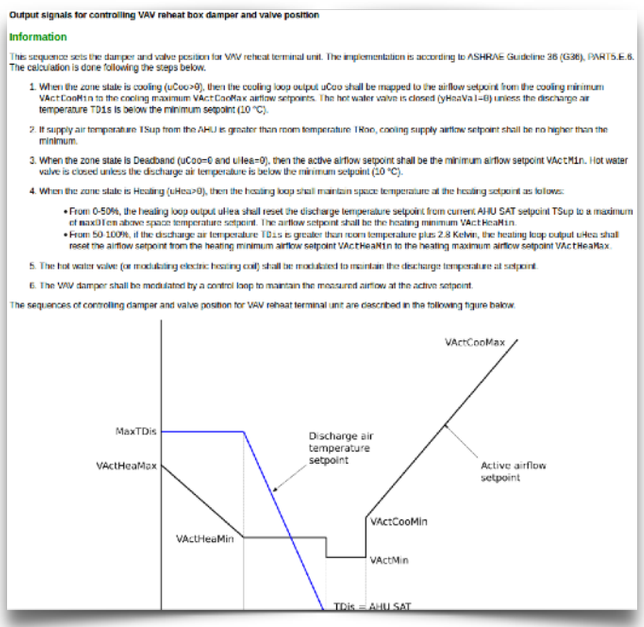
Implement sequences with CDL

Documented and validated sequences









Output signals for controlling VAV reheat box damper and valve position

Information

This sequence sets the damper and valve position for VAV reheat terminal unit. The implementation is according to ASHRAE Guideline 36 (G36), PART5.E.6. The calculation is done following the steps below.

1. When the zone state is cooling (uCoo>0), then the cooling loop output uCoo shall be mapped to the airflow setpoint from the cooling minimum VActCooMin to the cooling maximum VActCooMax airflow setpoints. The hot water valve is closed (yHeaVal=0) unless the discharge air temperature TDis is below the minimum setpoint (10 °C).
2. If supply air temperature TSup from the AHU is greater than room temperature TRoo, cooling supply airflow setpoint shall be no higher than the minimum.
3. When the zone state is Deadband (uCoo=0 and uHea=0), then the active airflow setpoint shall be the minimum airflow setpoint VActMin. Hot water valve is closed unless the discharge air temperature is below the minimum setpoint (10 °C).
4. When the zone state is Heating (uHea>0), then the heating loop shall maintain space temperature at the heating setpoint as follows:
   - From 0-50%, the heating loop output uHea shall reset the discharge temperature setpoint from current AHU SAT setpoint TSup to a maximum of maxDTem above space temperature setpoint. The airflow setpoint shall be the heating minimum VActHeaMin.
   - From 50-100%, if the discharge air temperature TDis is greater than room temperature plus 2.8 Kelvin, the heating loop output uHea shall reset the airflow setpoint from the heating minimum airflow setpoint VActHeaMin to the heating maximum airflow setpoint VActHeaMax.
5. The hot water valve (or modulating electric heating coil) shall be modulated to maintain the discharge temperature at setpoint.
6. The VAV damper shall be modulated by a control loop to maintain the measured airflow at the active setpoint.

The sequences of controlling damper and valve position for VAV reheat terminal unit are described in the following figure below.

Buildings.Controls.OBC.ASHRAE.G36_PR1.TerminalUnits.Reheat.DamperValve

Updates to CDL (Michael)

CDL changes compared to last meeting

CDL language changes

Now allow calculations in parameter assignments: E.g.,

```
parameter Real pRel(unit="Pa") = 50
     "Static pressure difference at damper";
CDL.Logical.Hysteresis hys(
uLow  = pRel-25,
uHigh = pRel+25) "Hysteresis for fan control";
```

Now allow conditional removal of blocks and connectors:

```
parameter Boolean use_enthalpy = true
     "Set to true to use outdoor air enthalpy";

CDL.Interfaces.RealInput hOut if use_enthalpy
     "Outdoor air enthalpy";
```

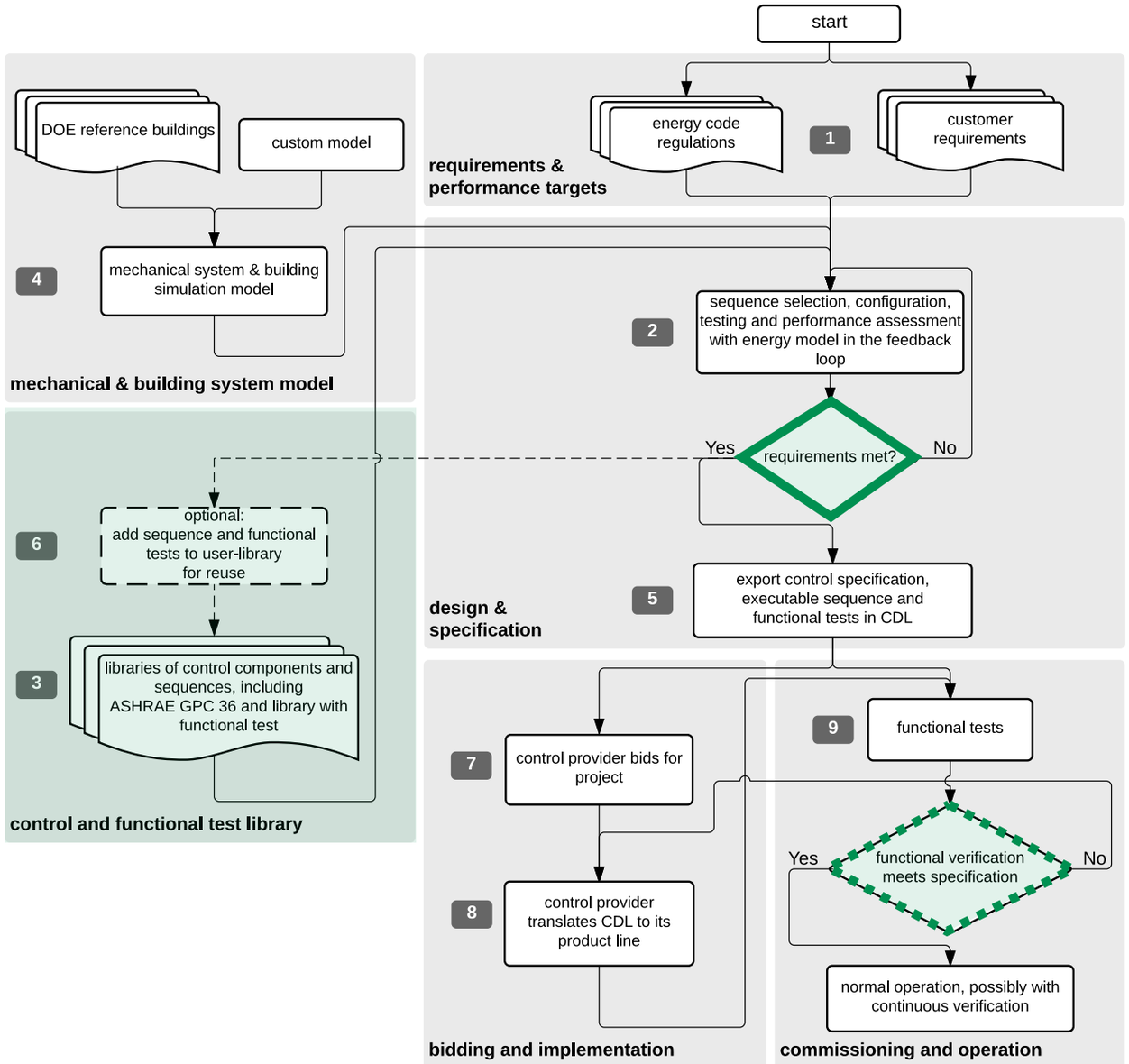
CDL library additions (which were required during the implementation of guideline 36):

- conversion to/from integer
- truncation of signals
- addition of 3 signals (real, integer)
- integer comparison

Requirements verification (Michael)

Goal is to (semi-)automatically test requirements during design and commissioning, and possibly also during continuous operation

- M3.1 By Q5, demonstrate with an *emulated control response* that the controls verification can signal satisfied, undecided, and violated test results.
- M3.2 By Q6, demonstrate with an *actual measured control response* that the controls verification can signal satisfied, undecided, and violated test results.



81.2 % of Guideline36 requirements are satisfied at time = 1.8144e+07 s

Requirements violated (3 of 16)

Observation	Requirement	First violation at	Description
VAV terminal box	conVAVEas.reqTRooCoo	1.74868e+07 s	Room air temperature maintains cooling setpoint
VAV terminal box	conVAVSou.reqTRooCoo	1.75913e+07 s	Room air temperature maintains cooling setpoint
VAV terminal box	conVAVWes.reqTRooCoo	1.77736e+07 s	Room air temperature maintains cooling setpoint

Requirements untested (0 of 16)

None

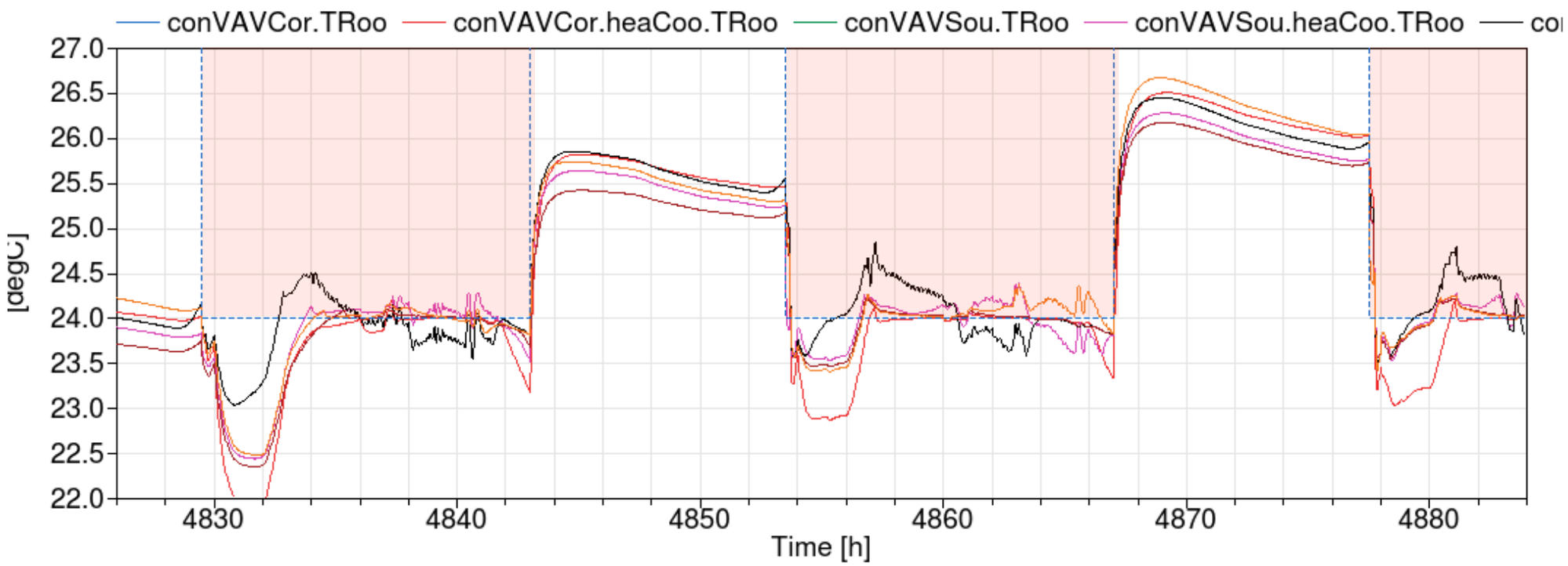
Requirements satisfied (13 of 16)

Observation	Requirement	Description
VAV terminal box	conVAVCor.reqTRooCoo	Room air temperature maintains cooling setpoint
VAV terminal box	conVAVCor.reqTRooHea	Room air temperature maintains heating setpoint
VAV terminal box	conVAVCor.reqYDam	VAV damper signal stable
VAV terminal box	conVAVEas.reqTRooHea	Room air temperature maintains heating setpoint
VAV terminal box	conVAVEas.reqYDam	VAV damper signal stable
VAV terminal box	conVAVNor.reqTRooCoo	Room air temperature maintains cooling setpoint
VAV terminal box	conVAVNor.reqTRooHea	Room air temperature maintains heating setpoint
VAV terminal box	conVAVNor.reqYDam	VAV damper signal stable
VAV terminal box	conVAVSou.reqTRooHea	Room air temperature maintains heating setpoint
VAV terminal box	conVAVSou.reqYDam	VAV damper signal stable
VAV terminal box	conVAVWes.reqTRooHea	Room air temperature maintains heating setpoint
VAV terminal box	conVAVWes.reqYDam	VAV damper signal stable
AHU	reqTFre	Mixed air temperature above freezing

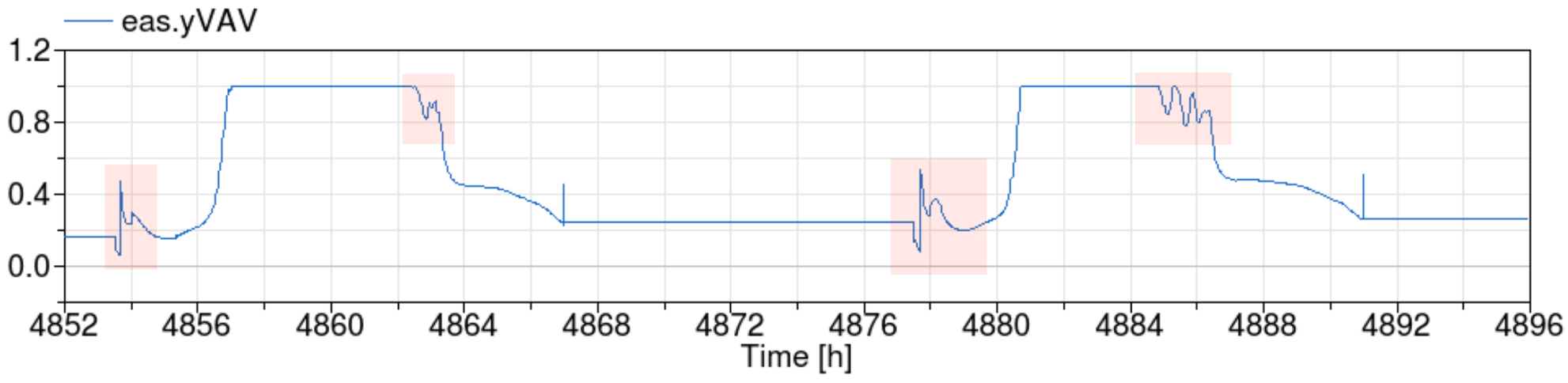
Example output

Problem: How do we verify 100s to 1000s of trajectories, and identify which one(s) cause (first) a problem?

Are these room temperatures satisfactory?

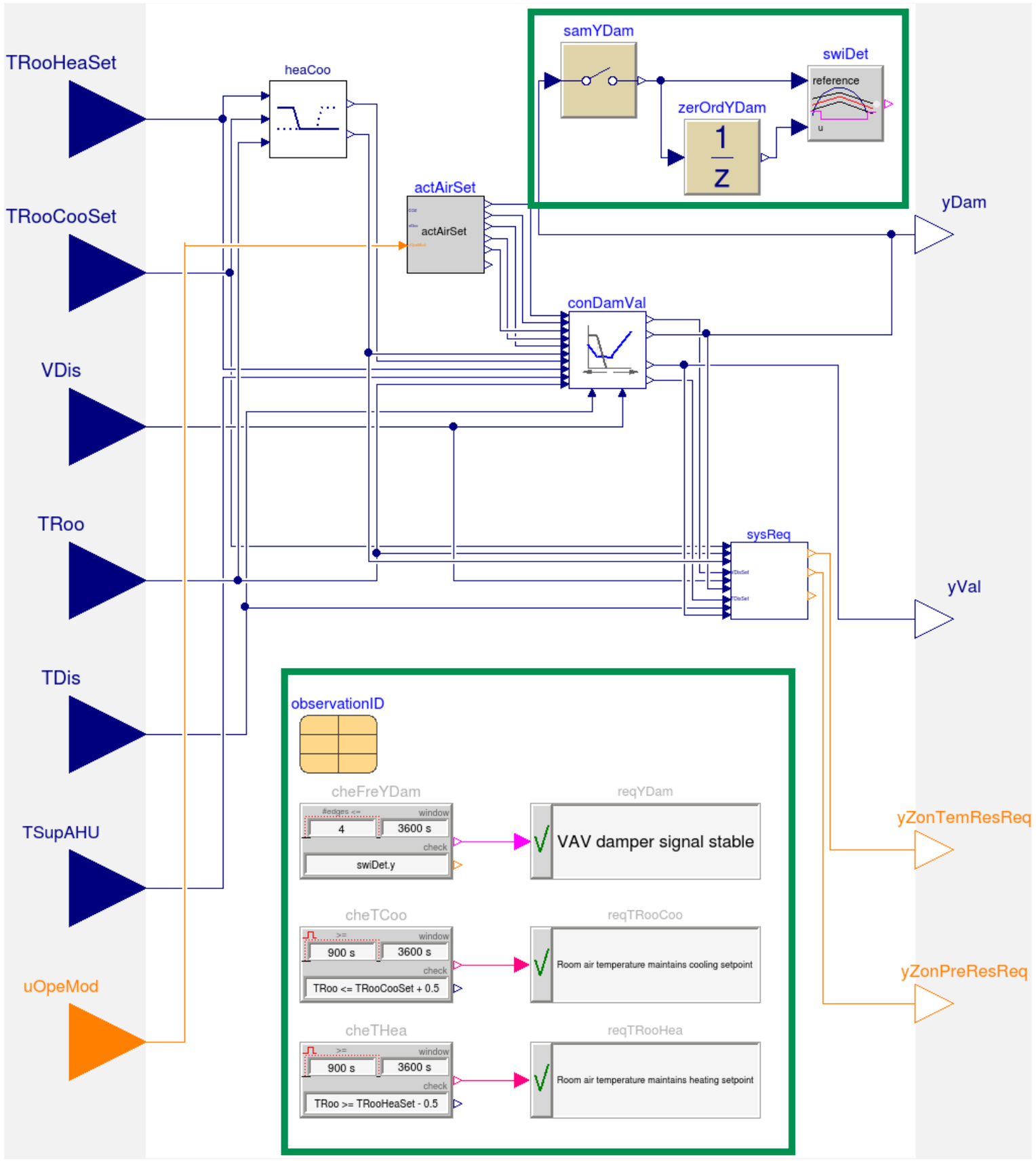


Is this damper control signal stable?



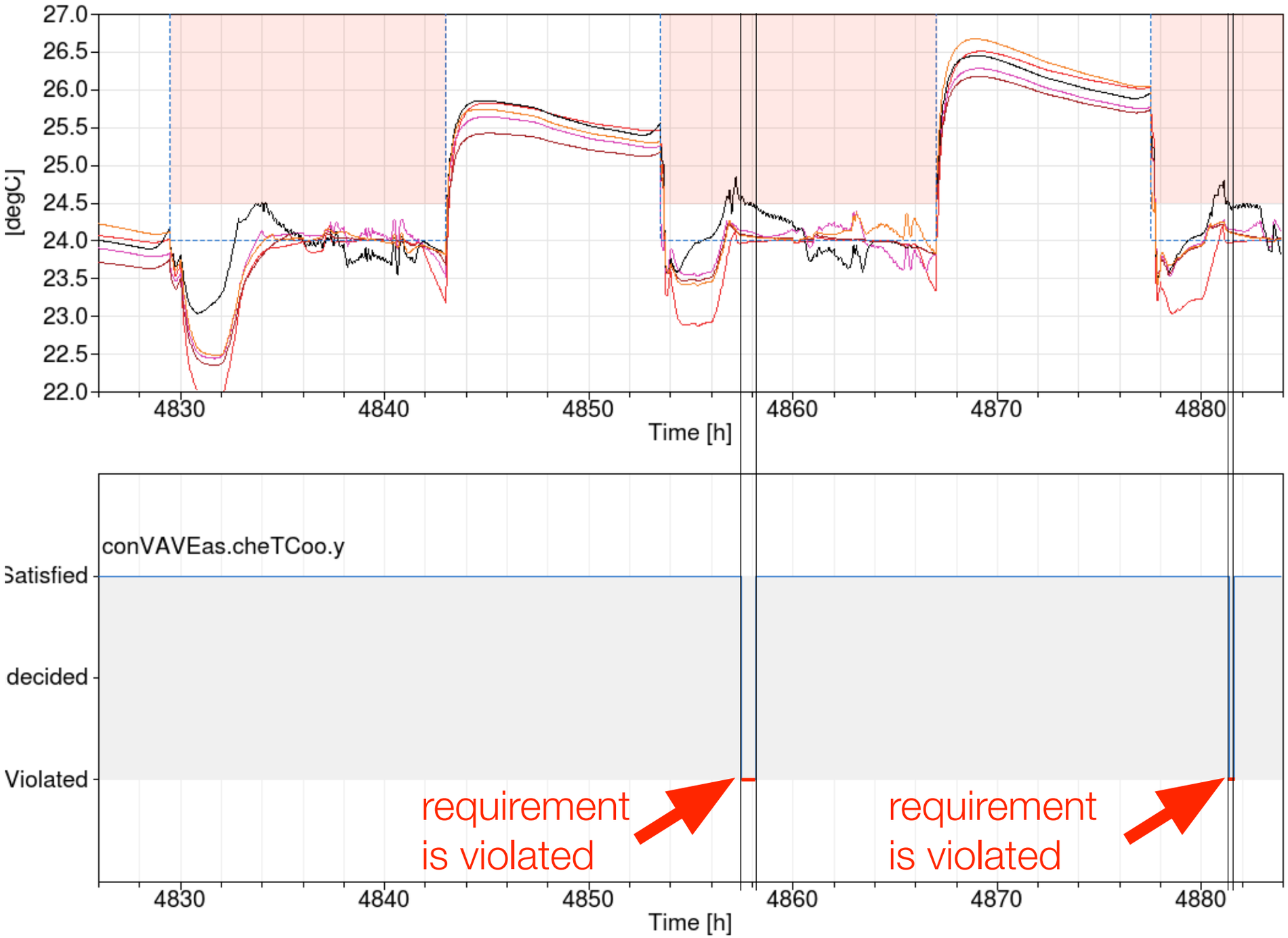
Simulations based on branch issue846_verification, commit 454cc7521

Approach: Instrument the control with verification tests



Verification of room air temperature of east zone

Requirement: Room air temperature shall be within (TSet + 0.5 K) for at least 45 min within each 60 min window.

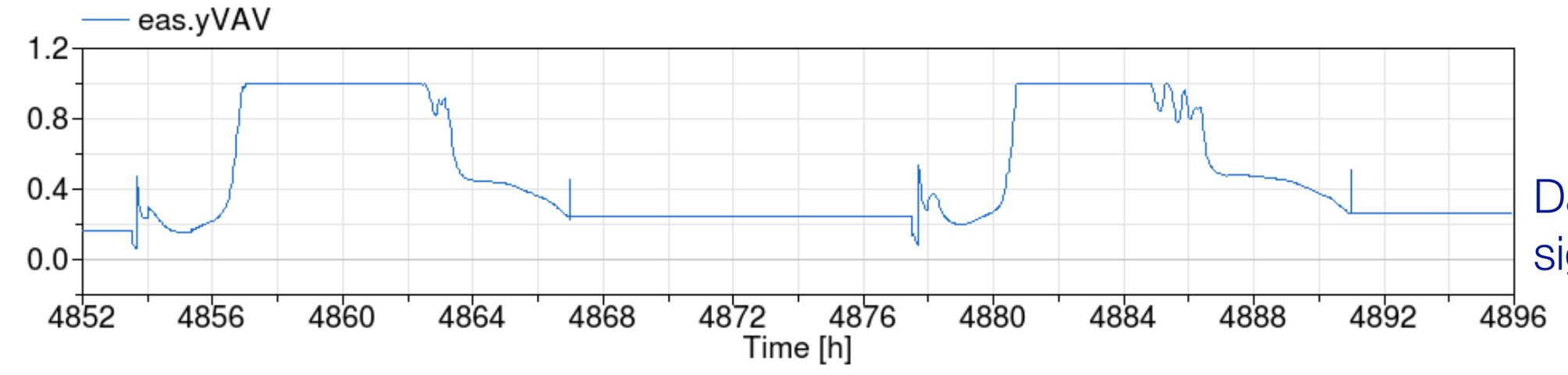


dashed:
cooling set point

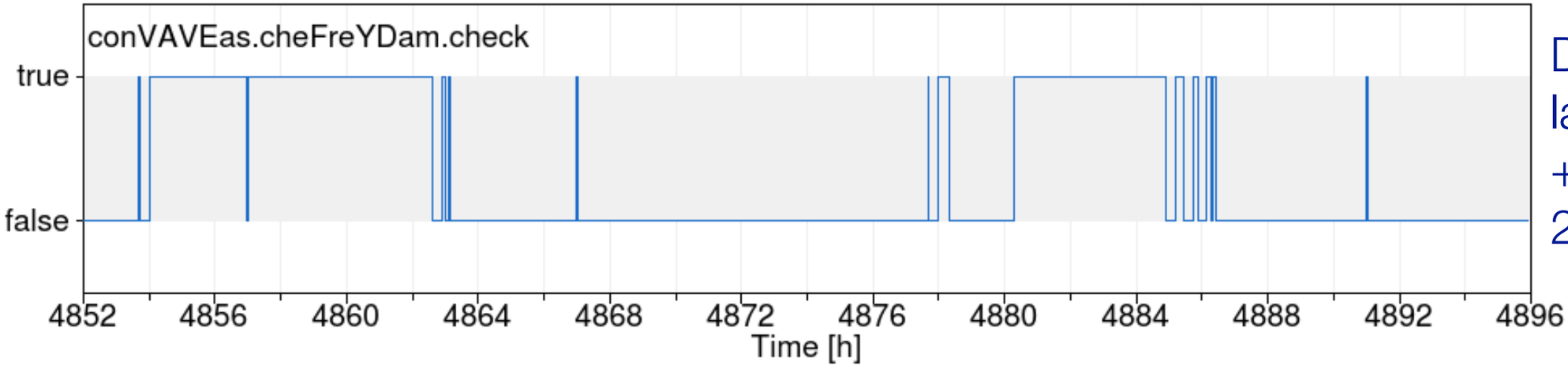
black:
east room
air temperature

Verification of east zone damper signal

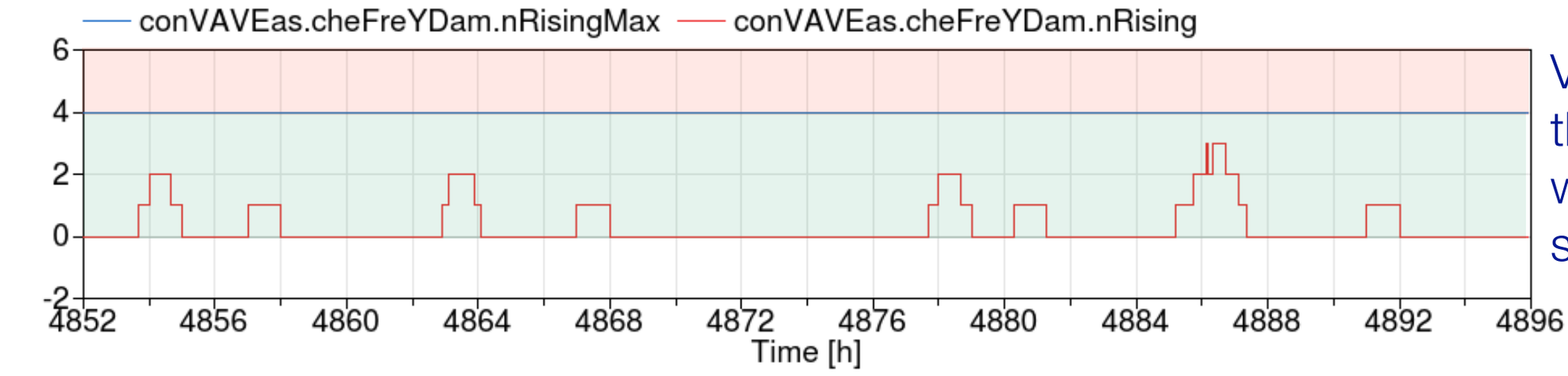
Requirement: Damper signal shall not oscillate more than 4 times per hour between +/- 0.025 (for a 2 minute sample period)



Damper control signal



Detect changes larger than +/- 0.025 between 2 minute samples



Verify no more than 4 changes within 1 hour sliding window

Verification tests

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- M3.2 By Q6, demonstrate with an *actual measured control response* that the controls verification can signal satisfied, undecided, and violated test results.

Need input from team for what requirements shall be verified. For example

- how well shall set points be tracked?
- when shall cycling equipment be flagged?
- when shall control signals be flagged as oscillatory?
- …

Then, can build a requirements library for use in projects.

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