OpenBuildingControl
—
Team Meeting

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Presentation Contents

- Progress update
- Primary sequences implementation
- Case study
- Control Sequence Selection and Configuration Tool (part of linkage.js)
- CDL translation to product line
- Commercialization plan
- Next steps

Milestone and progress

Task 2.3: By Q7, release a version of the control library for primary systems, facade and lighting.
— Primary system is ongoing, facade is completed, lighting perceived as not important by TAG.

Task 2: By Q7, coordinate with NREL to architect the control design tool as part of the OpenStudio framework.
— Completed.

Task 2: By Q10, release English language export program on github.
— On target for end of August.

Task 4: By Q8, write case study report as above, but for primary HVAC system.
— Delayed, data collected, implementation of control ongoing; expect completion in fall.

Task 5: By Q8, write first version of commercialization and market transformation plan.
— Completed.

Task 5: By Q12, write final version of commercialization and market transformation plan.
— Ongoing (due to DOE/CEC on 11/27/19).

Task 5: By Q9, hold an ASHRAE seminar or forum about controls design and verification to aid dissemination and get feedback from the ASHRAE community.

- Seminar at BS'19, Haystack Connect.
- Presentation given to ASHRAE Guideline 36 Committee in Jan. 2019 and June 2019.

Other organizational activities:

1. Request for changes in scope still under review by CEC.
2. Phase II proposal for Oct. 2019 to Sep. 2022 in review by DOE.

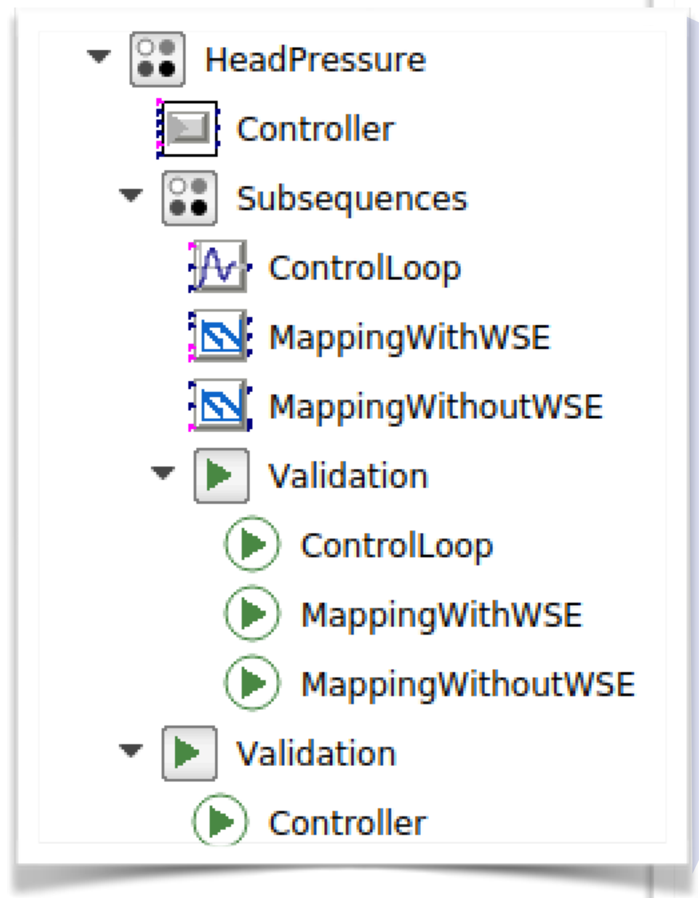
Primary sequence implementation

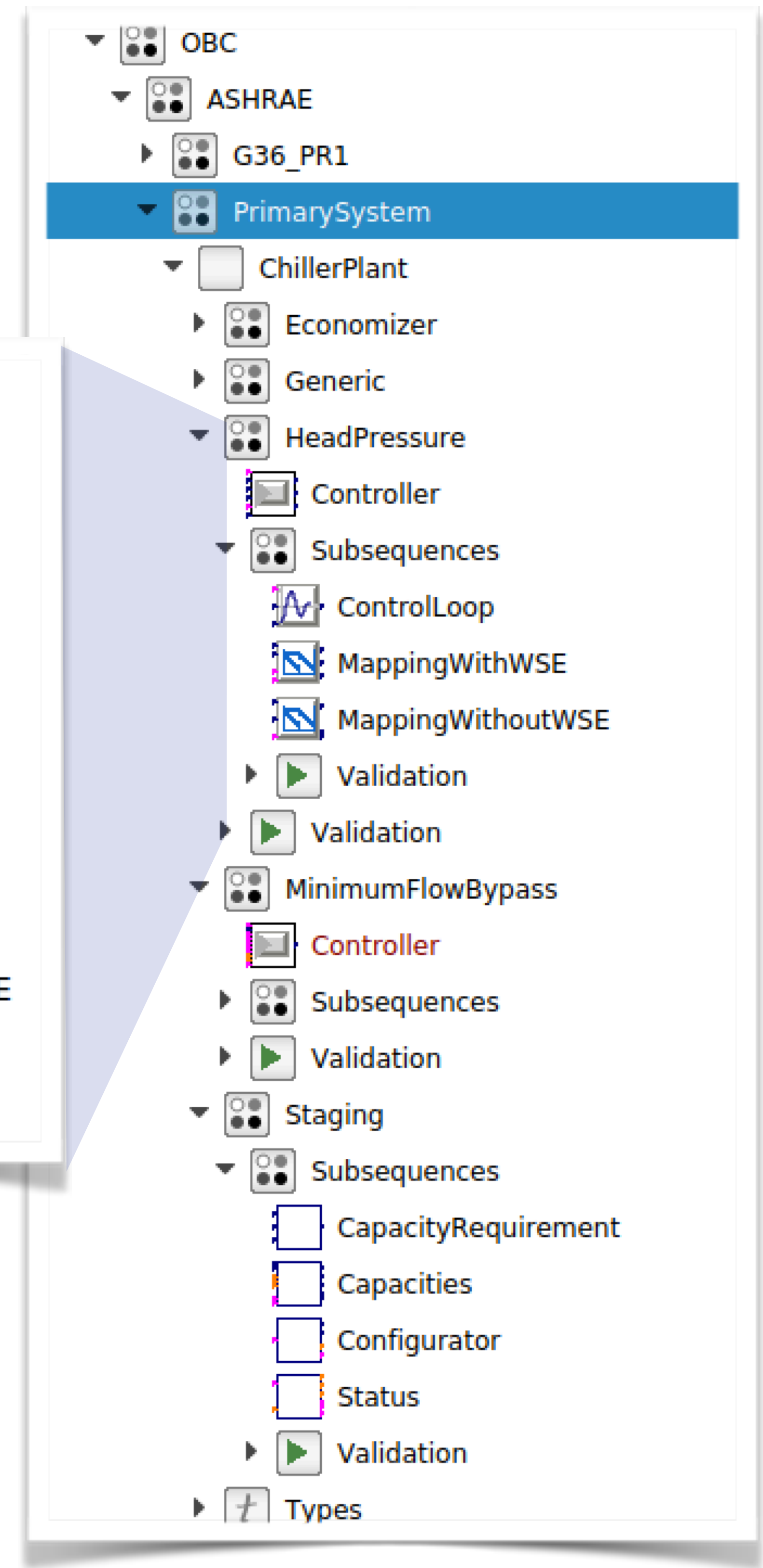
Ongoing development according to ASHRAE RP-1711:

- Draft 4, 01/07/2019,
- Some clarifications based on draft 5, 03/26/2019
- Expecting a new version in the following weeks

Implementation approach:

- **Modular**, with top level controllers
- **Generalized**, to account for any number of devices
- Validation tests at all levels





Implemented on a staging branch (`issue1378_staging_primarySequence`)

Primary sequence implementation - Modularization

Example subsequence based on a single article in 1711: **CapacityRequirement**

Info section for the subsequence

Cooling capacity requirement

Information

Calculates cooling capacity requirement based on the measured chilled water return temperature (CHWRT), `TChiWatRet`, calculated chilled water supply temperature setpoint (CHWST setpoint), `TChiWatSupSet`, and the measured chilled water flow, `VChiWat_flow`.

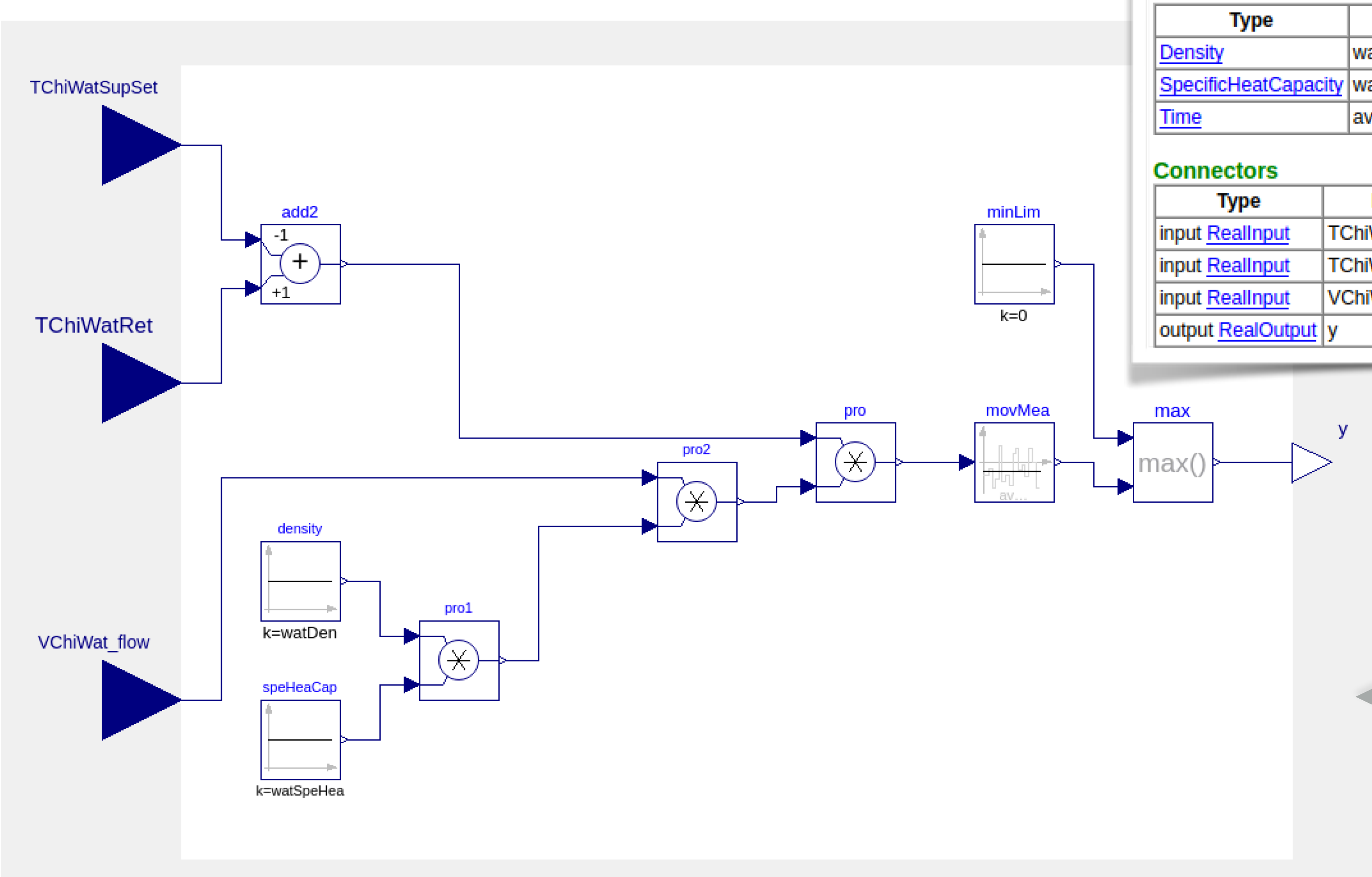
The calculation is according to Draft 4, section 5.2.4.3.

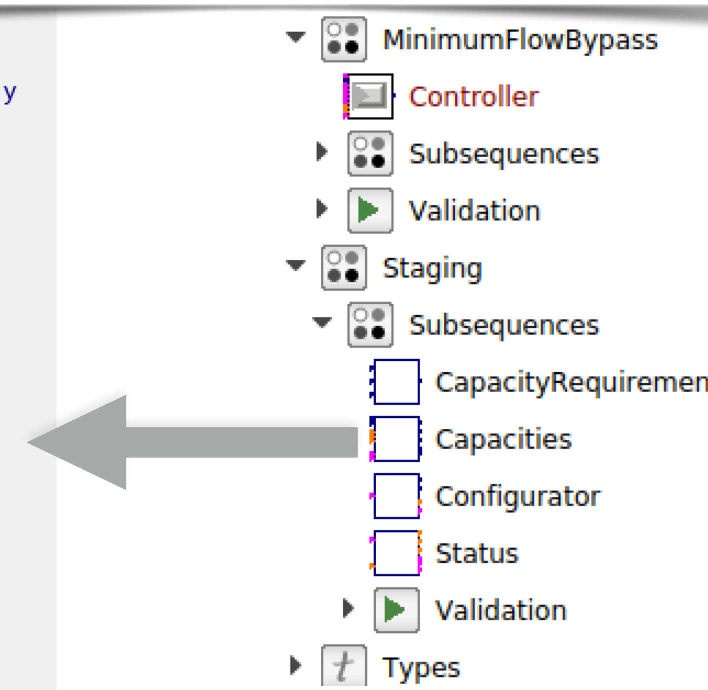
Parameters

Type	Name	Default	Description
Density	watDen	1000	Water density [kg/m3]
SpecificHeatCapacity	watSpeHea	4184	Specific heat capacity of water [J/(kg.K)]
Time	avePer	300	Period for the rolling average [s]

Connectors

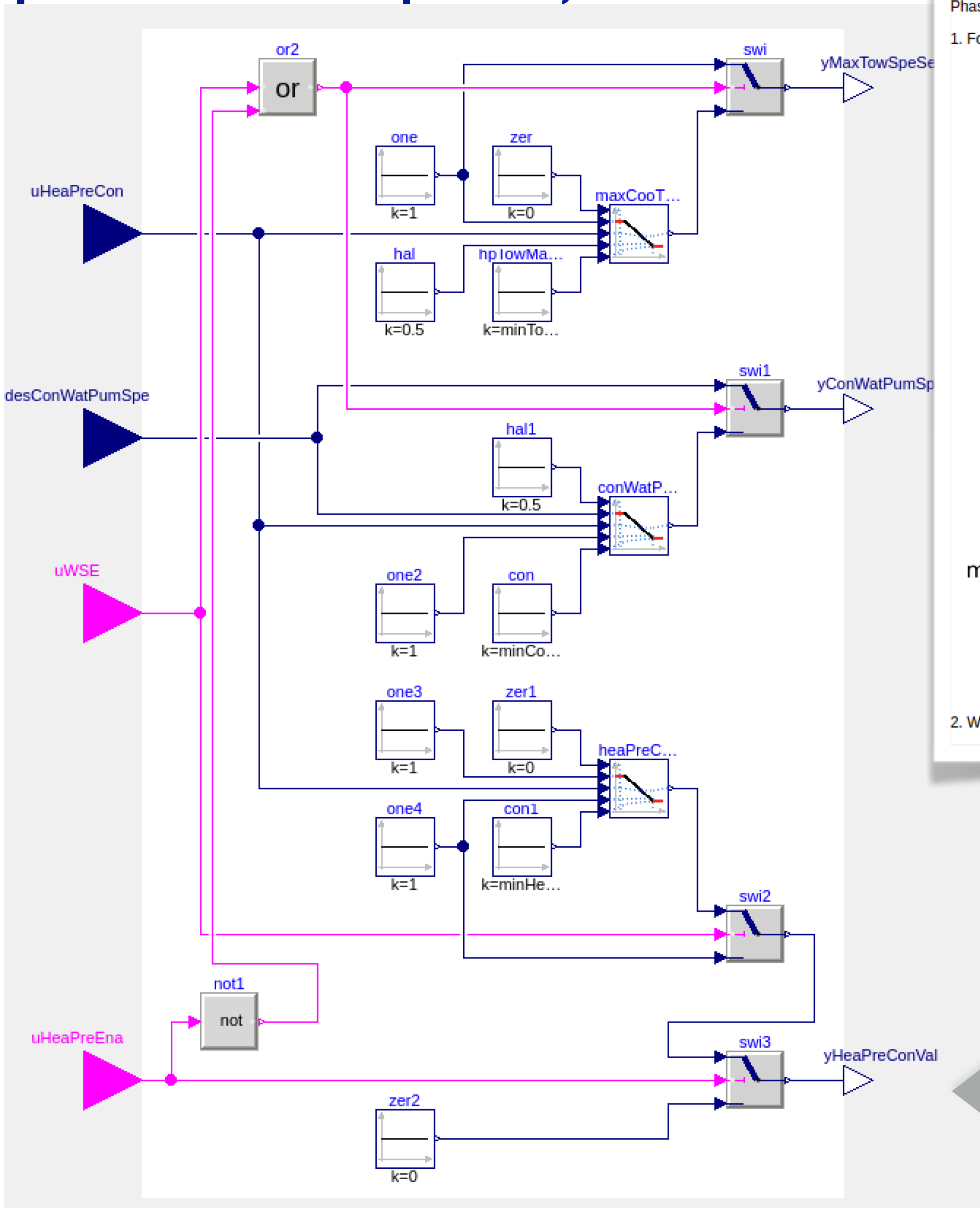
Type	Name	Description
input RealInput	TChiWatSupSet	Chilled water supply temperature setpoint [K]
input RealInput	TChiWatRet	Chilled water return temperature [K]
input RealInput	VChiWat_flow	Measured chilled water flow rate [m3/s]
output RealOutput	y	Chilled water cooling capacity requirement [W]





Primary sequence implementation - Modularization

Example subsequence based on multiple articles in 1711: **Head pressure subsequence, w WSE**



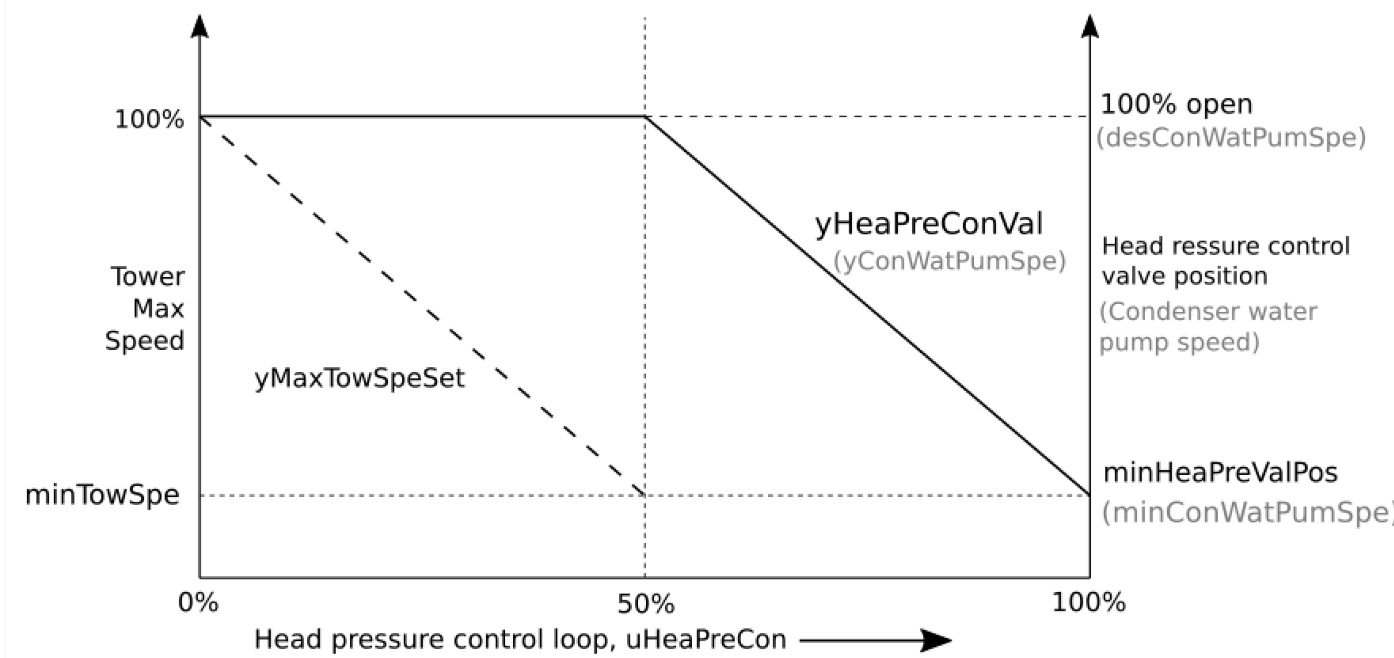
Equipment setpoints when chiller head pressure control is enabled, for plants without waterside economizer

Information

Block that resets maximum cooling tower speed setpoint `yMaxTowSpeSet`, controls head pressure control valve position `yHeaPreConVal` or condenser water pump speed `yConWatPumSpe` for plants without water side economizers. The development follows ASHRAE RP-1711 Advanced Sequences of Operation for HVAC Systems Phase II – Central Plants and Hydronic Systems (Draft 4 on January 7, 2019), section 5.2.10 Head pressure control, part 5.2.10.3 and 5.2.10.6.

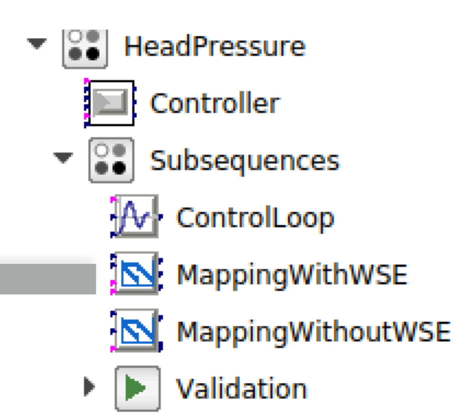
1. For each chiller, map chiller head pressure control loop signal `uHeaPreCon` as follows:

- When `uHeaPreCon` changes from 0 to 50%, reset maximum cooling tower speed setpoint `yMaxTowSpeSet` from 100% to minimum speed `minTowSpe`.
- If the plant has fixed speed condenser water pumps (`fixSpePum`=true), then: when `uHeaPreCon` changes from 50% to 100%, reset head pressure control valve position `yHeaPreConVal` from 100% open to `minHeaPreValPos`.
- If the plant has variable speed condenser water pumps (`fixSpePum`=false), then: when `uHeaPreCon` changes from 50% to 100%, reset condenser water pump speed `yConWatPumSpe` from design speed for the stage `desConWatPumSpe` to minimum speed `minConWatPumSpe`. When the pumps are dedicated, speed reset shall be independent for each chiller.

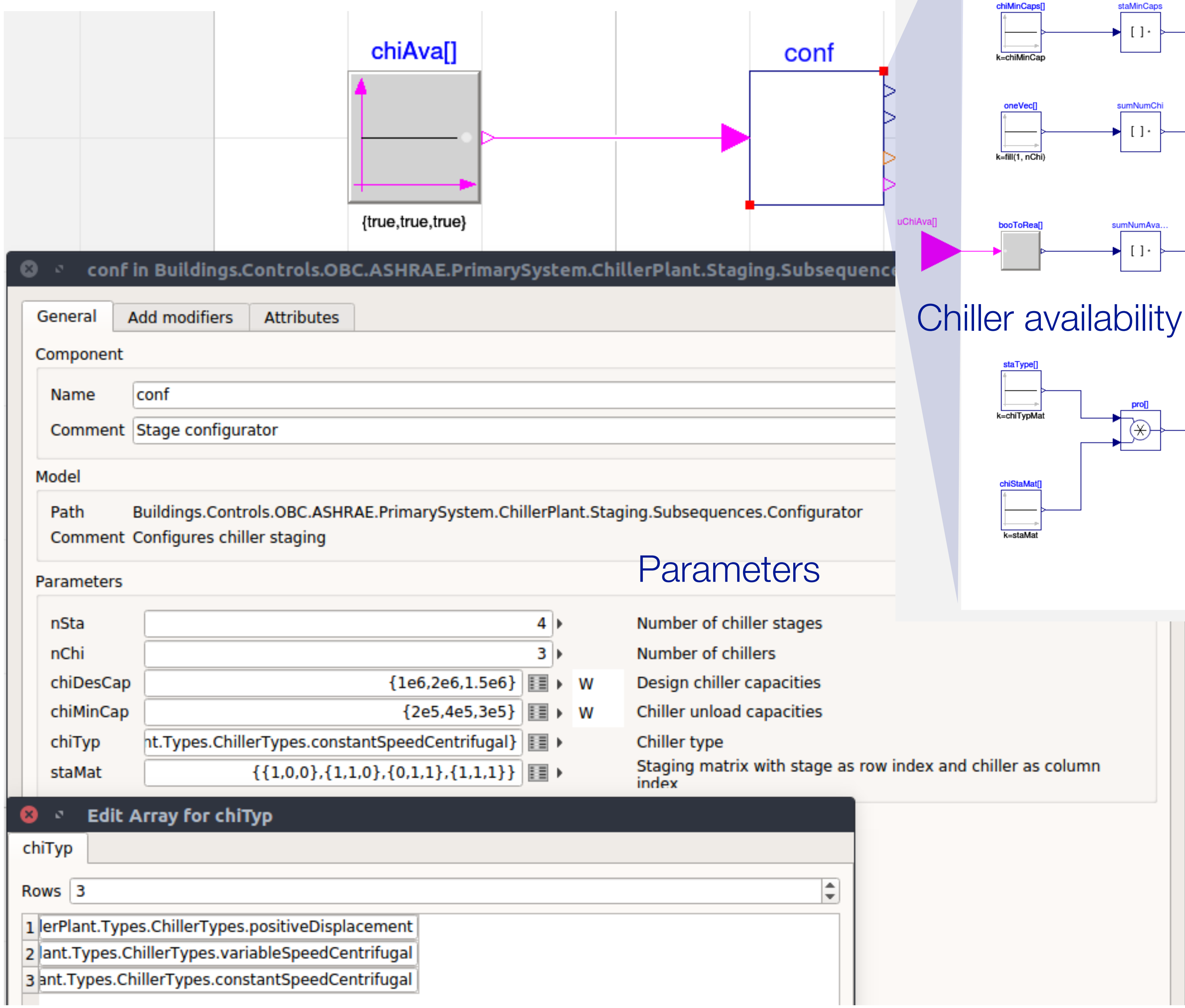


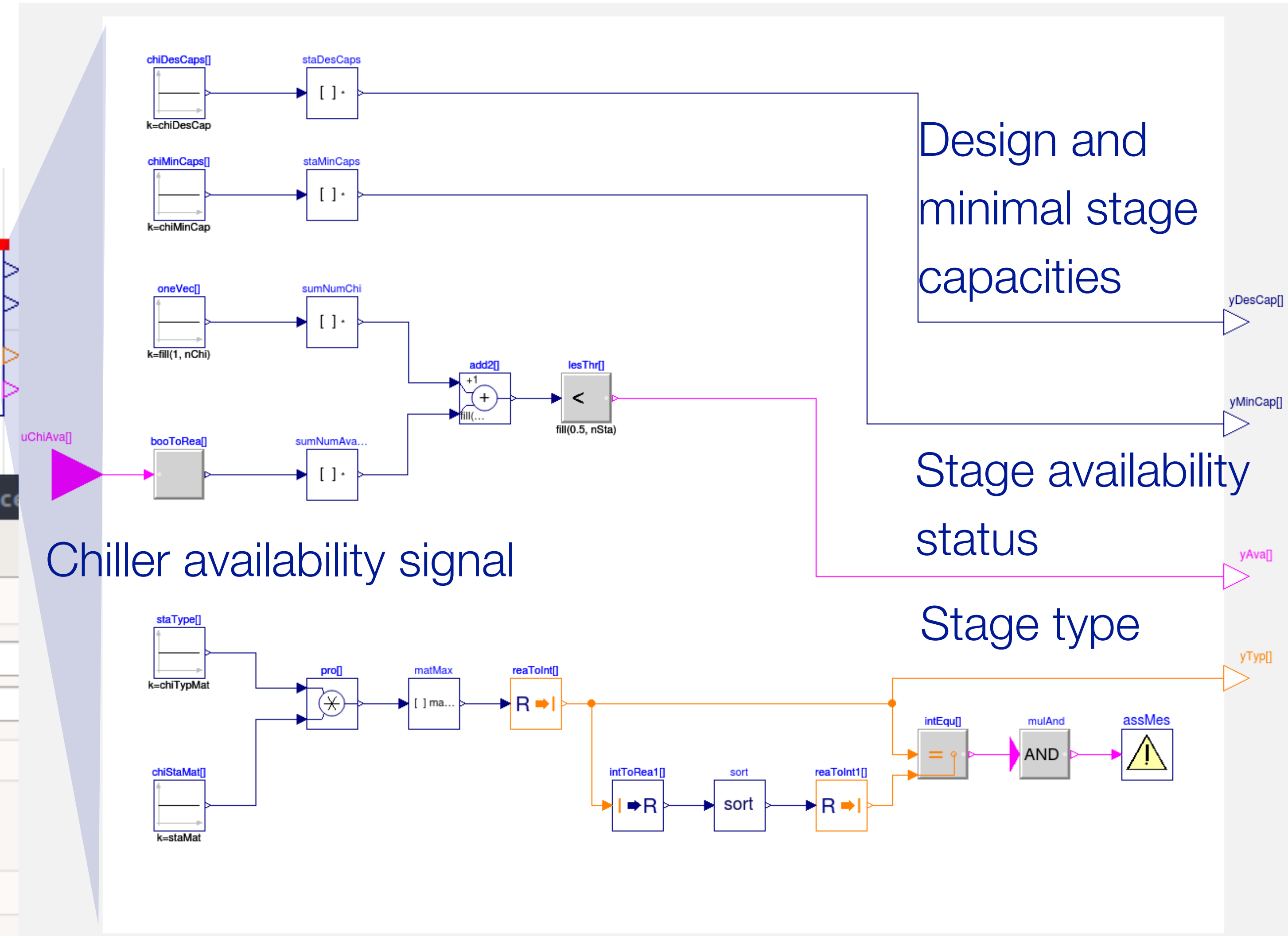
2. When the head pressure control loop is disabled (`uHeaPreEna` = false), the head pressure control valve shall be closed, or the pump should be disabled.

Info section for the subsequence



Primary sequence implementation - Generalization



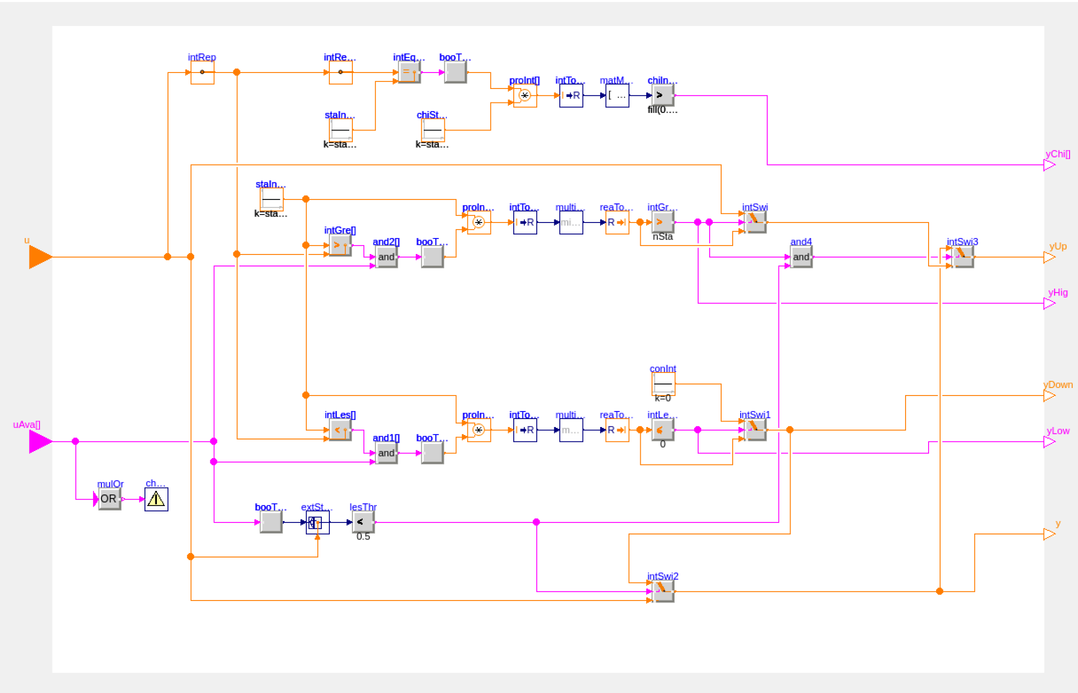


Stage type enumeration

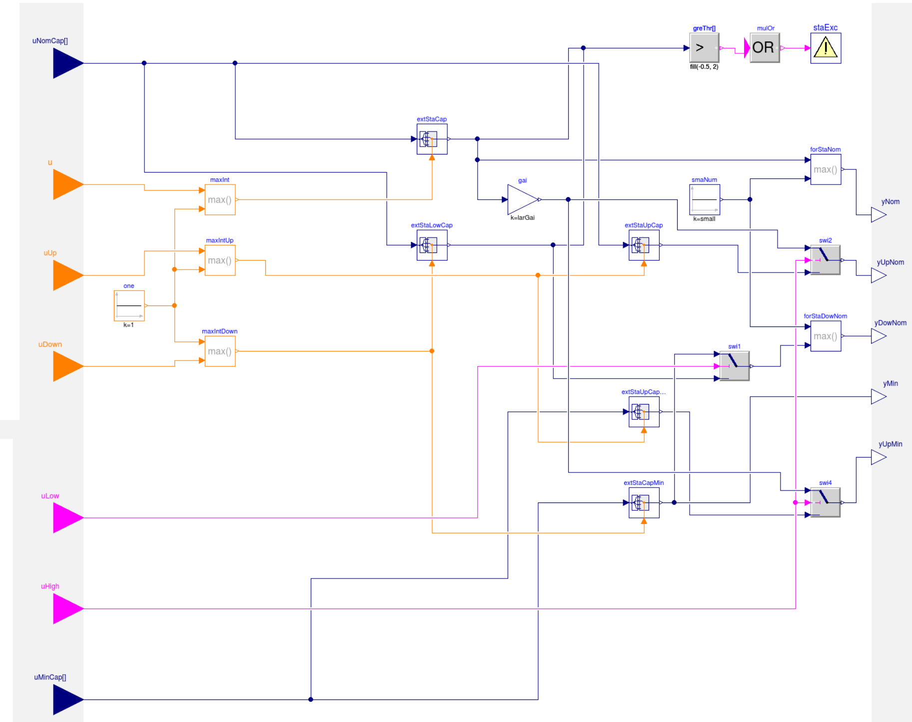
Stage **Configurator** calculates design and minimal stage capacities, stage availability and stage type

Outputs of this subsequence are inputs to downstream chiller staging subsequences

Primary sequence implementation - Generalization

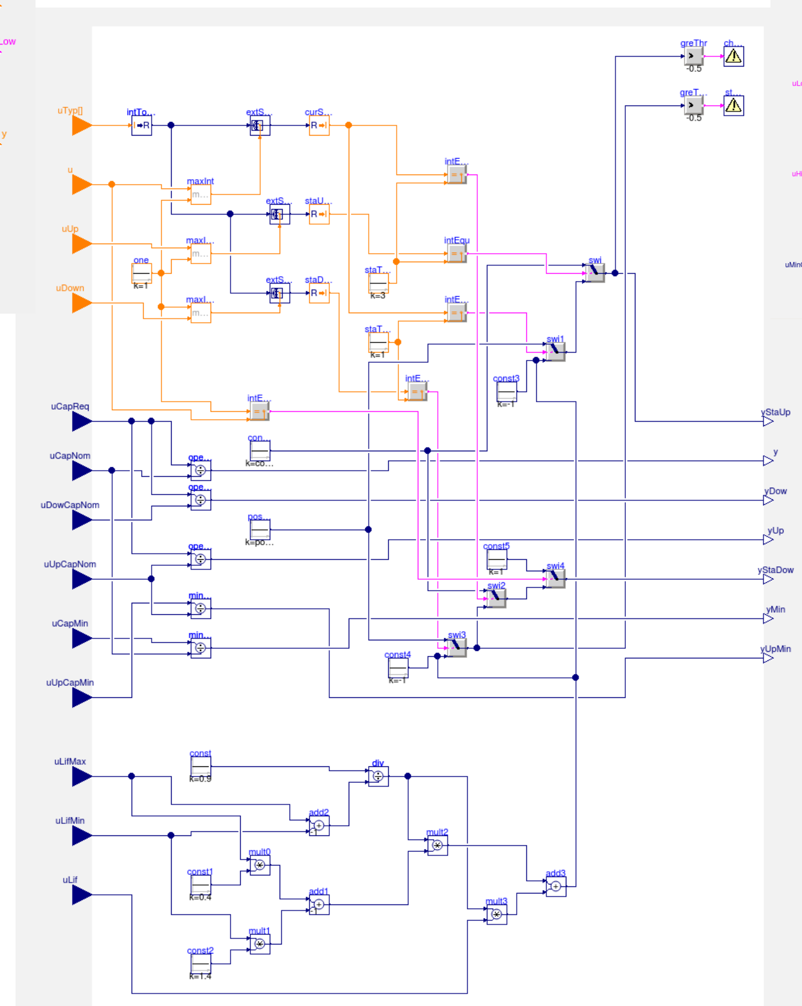


Stage status sequence provides inputs to other staging subsequences such as **Capacities** and **PartLoadRatios**



Based on the current stage index and the stage availability vector, stage **Status** sequence is able to:

- Determine the next available stage up and down
- Figure out whether the current stage is the lowest and/or the highest available stage
- Handle events when the current stage becomes unavailable

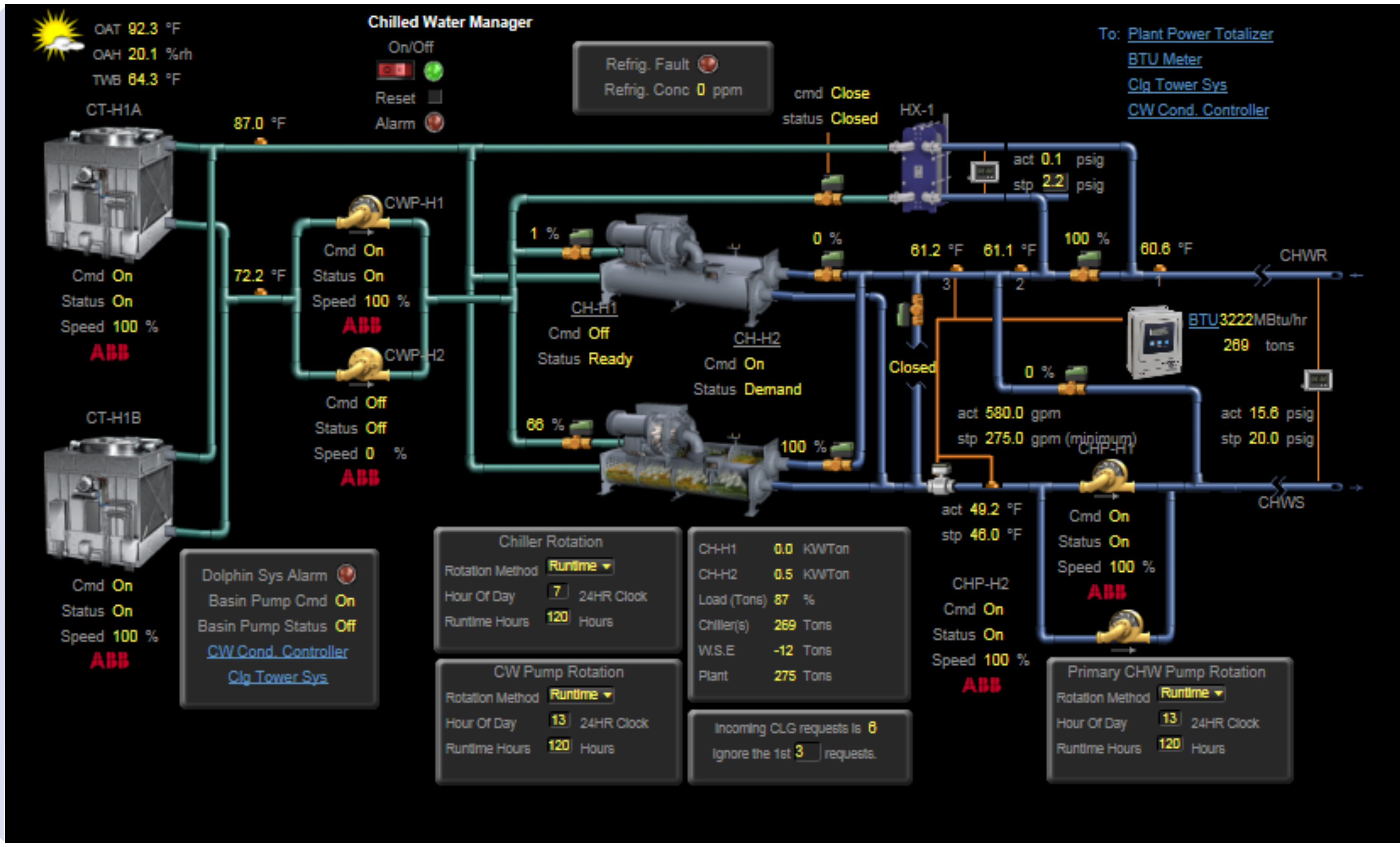


Capacities subsequence calculates nominal and/or minimal capacities for current, next available stage up and down as required by downstream subsequences

PartLoadRatios subsequence calculates operating and staging part load ratios used in the downstream subsequences

Case study primary plant

- Plant installed in a commercial office building in Hacienda Business Park in Pleasanton, California
- Control design by Taylor Engineering
- Plant consists of:
  - 2 x 310 ton screw chillers
  - 2 x CWP, CHP
  - 2 x CT
  - 1 x WS economizer HEWeb-based and local use
- Trend data specs
  - ~50 data points
  - 1 minute interval data for Jun 22 - July 10 2018
  - 5 minute interval data for Mar 11 - Jun 2 2018
  - multiple operation stages



Eikon equipment view

Update: On hold as it requires the chiller sequences that are now being implemented. Expected completion in fall 2019.

Make CDL an ANSI/ISO Standard via ASHRAE

Title: CDL - A Control Description Language that enables a Digital Control Delivery Process

Purpose: To standardize a declarative programming language for digitizing the control delivery process, using a human and machine readable format suitable for

- Closed loop performance simulation of the control sequences
- Process to develop and specify sequences
- Machine-to-machine translation, or native use of the sequences for control platforms
- Verification of the correct implementation of the control sequences

Scope: This standard applies to control sequences for mechanical systems, active facades, and lighting systems.

Note: Out of scope is water treatment, security, transportation.

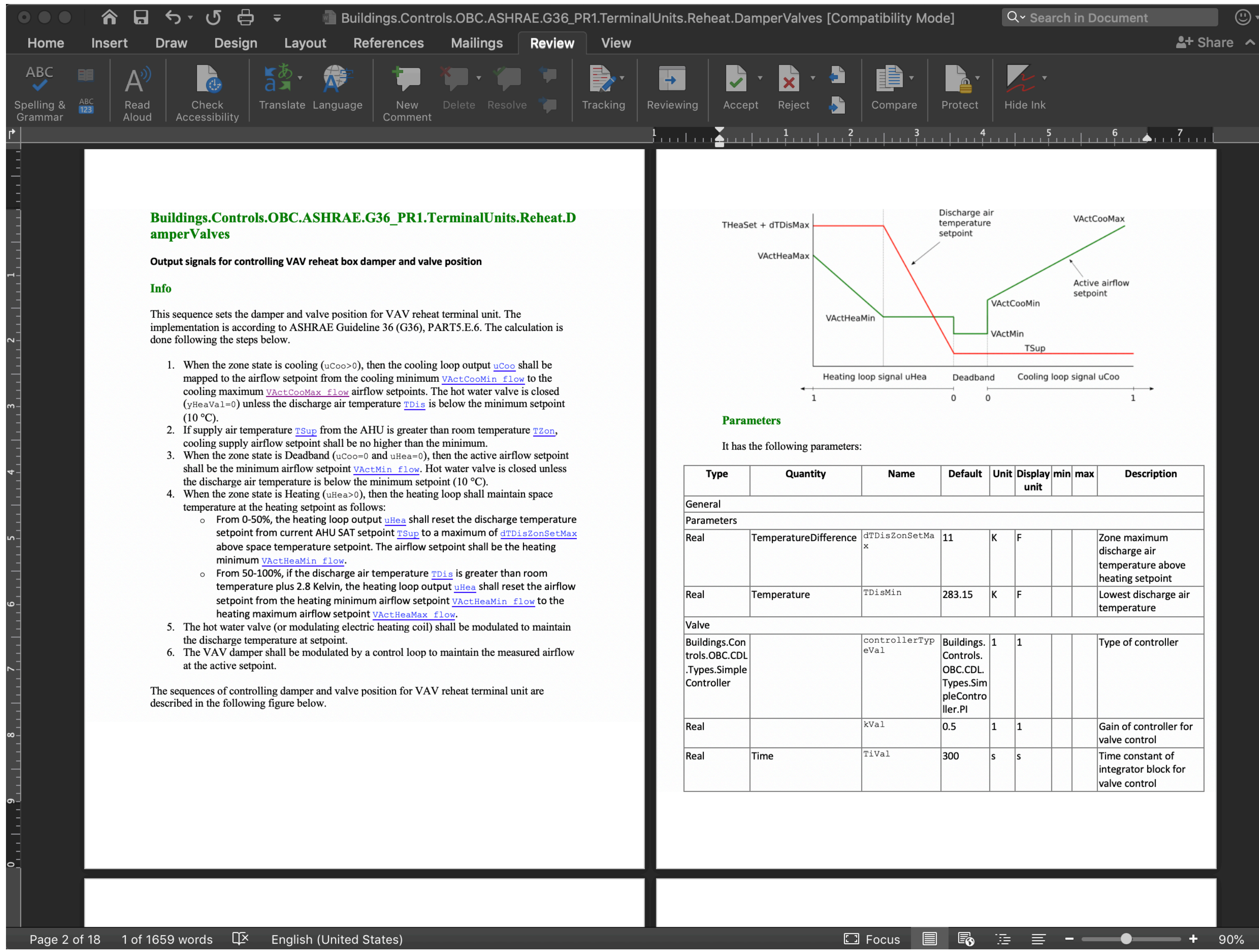
Guideline 36 Reference Implementation in CDL

Future versions of Guideline 36

- should contain a reference implementation in CDL, or
- contain sequence descriptions generated from their CDL implementation.

Needs:

- Structure sequences in encapsulated blocks with defined inputs, outputs, and parameters.
- Implement sequences in CDL.
- Ensure licensing is compatible for our funders (incorporated in DOE-sponsored software for use at no cost to users)



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

Output signals for controlling VAV reheat box damper and valve position

Info

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_flow to the cooling maximum VActCooMax_flow 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 TZon, 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_flow. 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 dTDisZonSetMax above space temperature setpoint. The airflow setpoint shall be the heating minimum VActHeaMin_flow.
   - 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_flow to the heating maximum airflow setpoint VActHeaMax_flow.
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.

Parameters

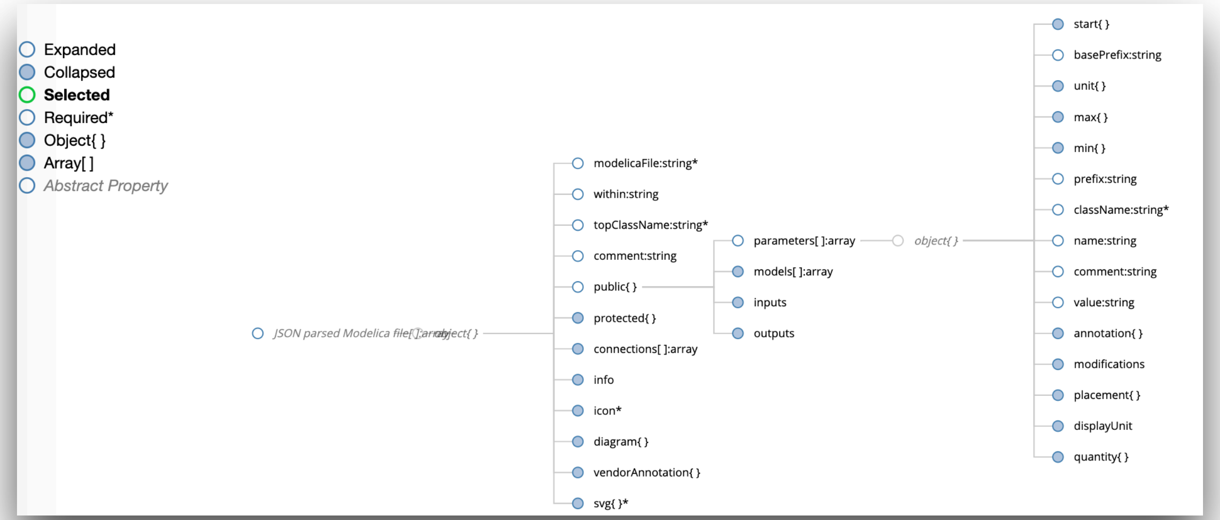
It has the following parameters:

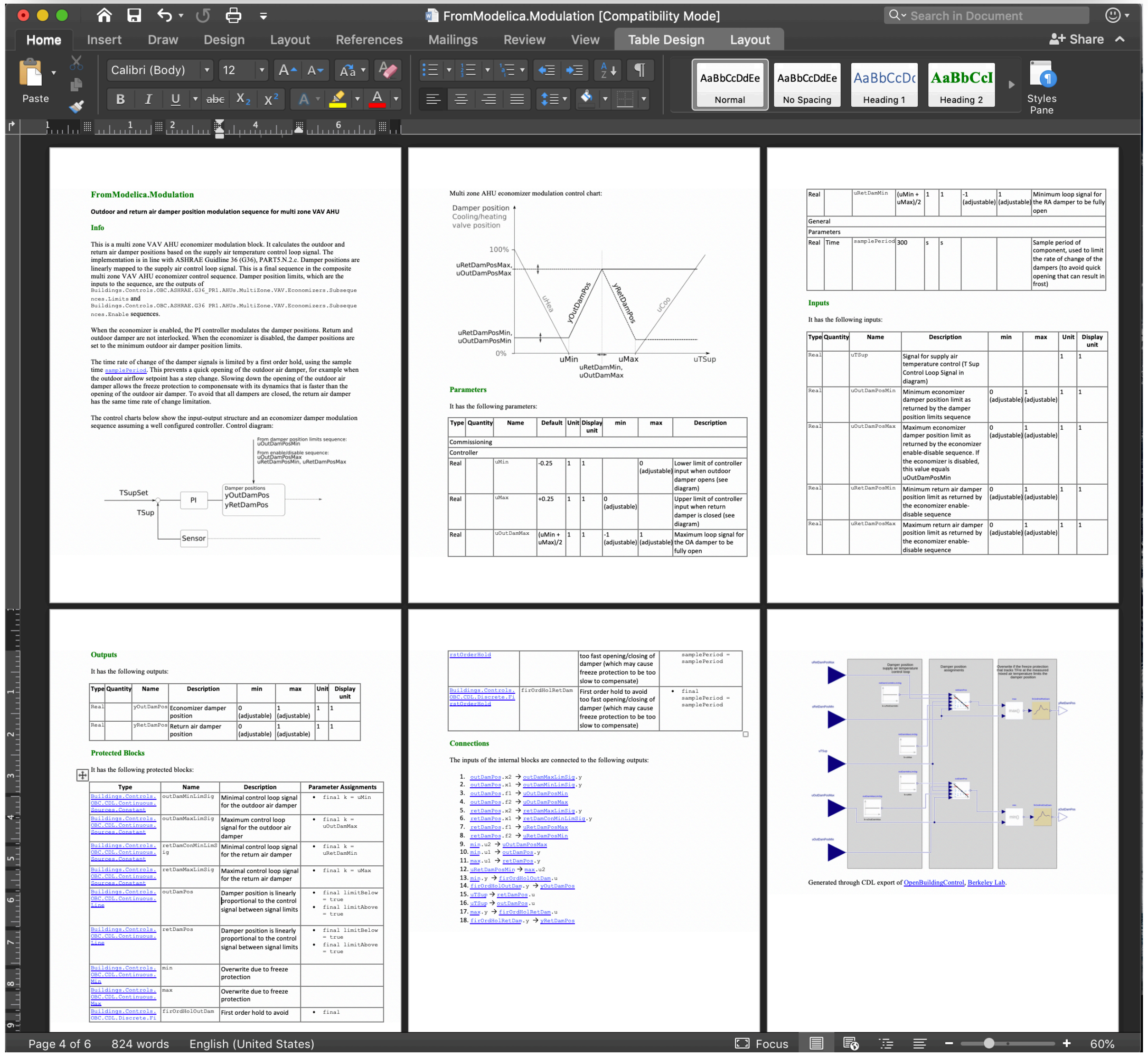
Type	Quantity	Name	Default	Unit	Display unit	min	max	Description
General								
Parameters								
Real	TemperatureDifference	dTDisZonSetMax	11	K	F			Zone maximum discharge air temperature above heating setpoint
Real	Temperature	TDisMin	283.15	K	F			Lowest discharge air temperature
Valve								
Buildings.Controls.OBC.CDL.Types.SimpleController		controllerTypeVal	Buildings.Controls.OBC.CDL.Types.SimpleController.PI	1	1			Type of controller
Real		kVal	0.5	1	1			Gain of controller for valve control
Real	Time	TiVal	300	s	s			Time constant of integrator block for valve control

Sequence description generated from CDL in Word format.
For more sample output, see https://github.com/lbl-srg/obc/blob/master/meetings/2019-07-12-team/cdl_parser_output.zip

CDL Translation

- modelica-json now parses modelica and CDL in **3 formats**:
  - ➡ **JSON** : a JSON schema has been implemented to check the data structure. The parser automatically checks the compliance of the generated json file to the schema. The schema can also be used in stand-alone to check an external json file.
  - ➡ **HTML:** A documentation including hyperlinks and schemas is automatically generated from a Modelica or CDL file.
  - ➡ **Docx:** In order to be used in bidding documents or operator manual.
- Documentation available at https://lbl-srg.github.io/modelica-json/ and includes :
  - Step by step installation and help
  - How to use the parser
  - JSON Schemas use and links to 2 graphical viewers for:
    - [CDL Schema viewer](#) (watch with Chrome, and refresh once in the page)
    - [Modelica Schema viewer](#) (watch with Chrome, and refresh once in the page)





https://github.com/lbl-srg/modelica-json

CDL Translation

- On-going:
  - update sequences implementation
    - specify point-type: AI/AO (analog input/output), DI/DO (digital input/output). *any other types, like string?*
    - enable selection point connection type: hardwired point, software point, network point?
  - update modelica-json parser to generate point-list

```
……
    parameter Buildings.Controls.OBC.CDL.Types.PointType leaChiOnPoint =
    Buildings.Controls.OBC.CDL.Types.PointType.BHI "Specify point type of signal: lead chiller status";
……
    Buildings.Controls.OBC.CDL.Interfaces.BooleanInput uLeaChiOn
    "Lead chiller status"
    annotation (__cdl(pointType=leaChiOnPoint),Placement(transformation(extent={{-140,-40},{-100,0}}),
      iconTransformation(extent={{-140,-20},{-100,20}})));
……
```

```
type PointType = enumeration(
    BHI "Binary hardwired input",
    BHO "Binary hardwired output",
    AHI "Analog hardwired input",
    AHO "Analog hardwired output",
    BNI "Binary network input",
    BNO "Binary network output",
    ……)
```

Prototype translator CDL to Eikon of Automated Logic Control (ALC)

Note: This is funded through DOE BOPTEST project.

Signed contract with Dave Robin (now with BSC Softworks).

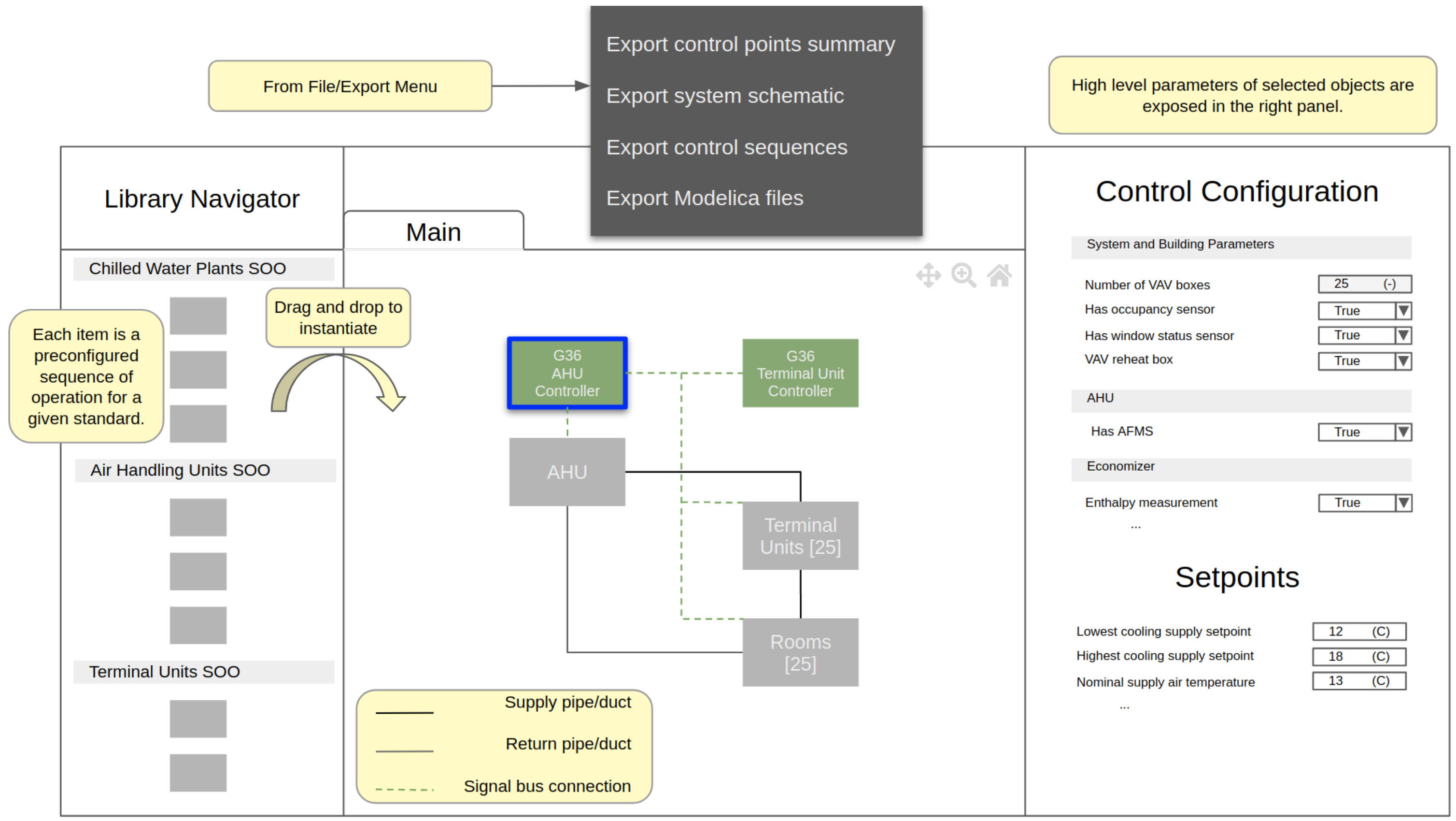
- Dave Robin
  - prototyped graphic programming for ALC in 1990
  - led first 10 years of commercialization of ALC's WebCTRL
  - retired from ALC in 2019 to start BSC Softworks
- ALC will support Dave Robin with ALC in-kind contributions.

Target dates:

- August 2019: Prototype translator.
- September 2019: Turn-over of first translator.
- December 2019: Final delivery and training for LBL. Work with LBL to identify future directions.

Control Sequence Selection and Configuration Tool

- To be completed in OBC Phase II, specification has started
- Web-based and local use
- Automated Logic has offered use of their Control Spec Builder
- Target audience:
  Mechanical designers and energy modelers
- ASHRAE benefit:
  Provides an easy way for designers to select and customize sequences from Guideline 36
- Challenge:
  The tool will provide a free online way to design and customize sequences. DOE funding requires that it work without license fee or restriction. **We need to verify that this does not violate the ASHRAE copyright for the Guideline 36 document**.



Control Sequence Selection and Configuration Tool

Design engineer

- Specifies the equipment layout and the control sequences
- Is assisted in the process by preconfigured templates

- Control points summary
- System schematic
- Description of control sequences in English language and CDL

Energy modeler

- Updates the model with equipment characteristics
- Couples a thermal zone model

- Modelica files ready to simulate

Control provider

- Is provided with high quality and standard specifications
- Translates CDL to actual building automation systems

Commissioning agent

- Is provided with an executable “digital twin” of the control sequences to verify correct implementation

Operator

- Is provided with comprehensively documented control sequences
- Is provided with a “digital twin” that can assist in troubleshooting

Commercialization Plan
(see separate slides)

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Next Steps