



Open-loop Validation - Review

Chiller Plant Sequences

Milica Grahovac, Jianjun Hu, Michael Wetter

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Lawrence Berkeley National Laboratory

Agenda

- Get familiarized with the chiller plant sequences in CDL
 - Package vs 1711 structure
- Dive into each validation package
 - OBC team to demo open-loop validation tests
 - Discuss output and models
 - Discuss questions related to 1711
 - Get familiar with the info sections
 - models fully reflecting the 1711 specification
 - models to generalize the controller

The following slides are added as an intro to the demo content that will be presented in the meetings.

Updated for May 22: Equipment rotation, Sec. 5.1.2

leaLag in Buildings.Controls.OBC.ASHRAE.PrimarySystem.ChillerPlant.Generic.EquipmentRotation.Validation.ControllerTwo

General Advanced Add modifiers Attributes

Component

Name leaLag
Comment Lead/lag rotation

Model

Path Buildings.Controls.OBC.ASHRAE.PrimarySystem.ChillerPlant.Generic.EquipmentRotation.ControllerTwo
Comment Lead/lag or lead/standby equipment rotation controller for two devices or two groups of devices

Icon

Parameters

lag true true = lead/lag; false = lead/standby
continuous false Continuous lead device operation
minLim false Utilize minimum runtime period for a current lead device before rotation may occur
minLeaRuntime 12 h Minimum cumulative runtime period for a current lead device before rotation may occur

Scheduler

simTimSta true Measure rotation time from the simulation start
weelnt true Rotation is scheduled in: true = weekly intervals; false = daily intervals
rotationPeriod 336 h Rotation time period measured from simulation start
houOfDay 2 Rotation hour of the day: 0 = midnight; 23 = 11pm
weeCou 1 Number of weeks
weekday 1 Rotation weekday, 1 = Monday, 7 = Sunday
dayCou 1 Number of days

Calendar

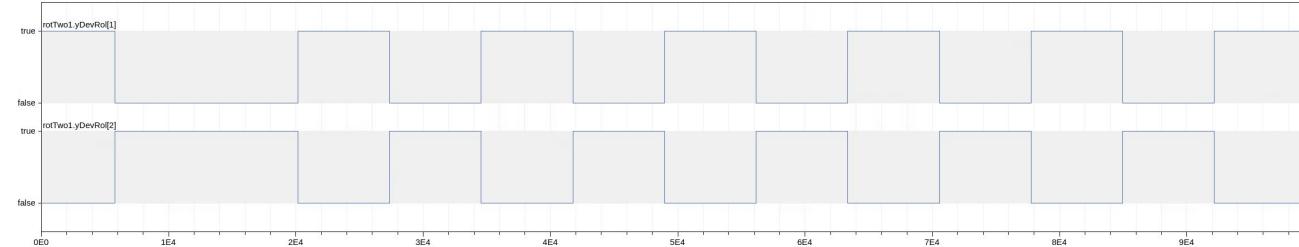
offset 0 s Offset that is added to 'time', may be used for computing time in a different time zone
zerTim Building Enumeration for choosing how reference time (time = 0) should be defined
yearRef 2019 Year when time = 0, used if zerTim=Custom

Info Cancel OK

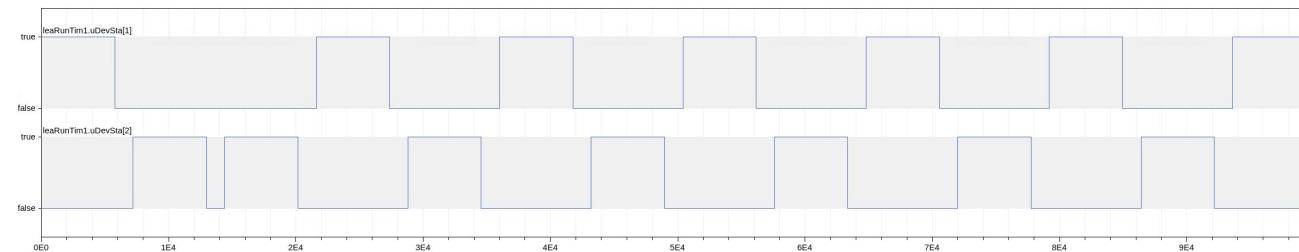
Currently implemented for two devices and groups of devices.

When `continuous` is true the default setting is to rotate at `rotationPeriod` after the start of the simulation/operation

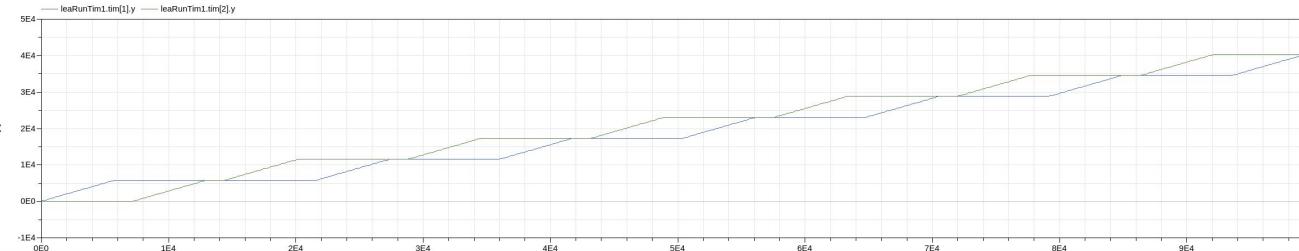
Updated for May 22: Equipment rotation - lead/standby case, default settings



$yDevRole[i]$ - device i role,
true is lead, false is lag



$yDevStat[i]$ - device i status



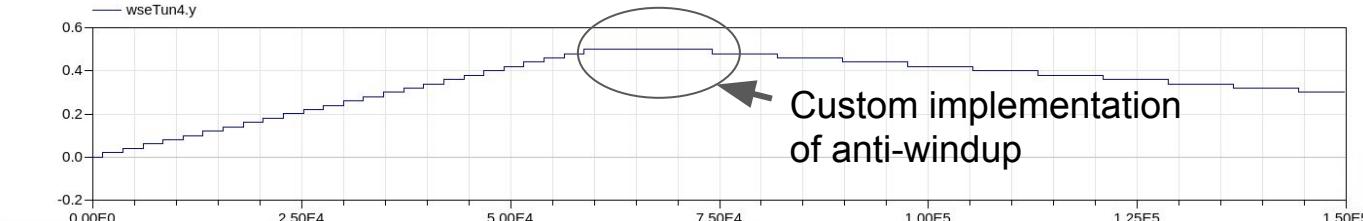
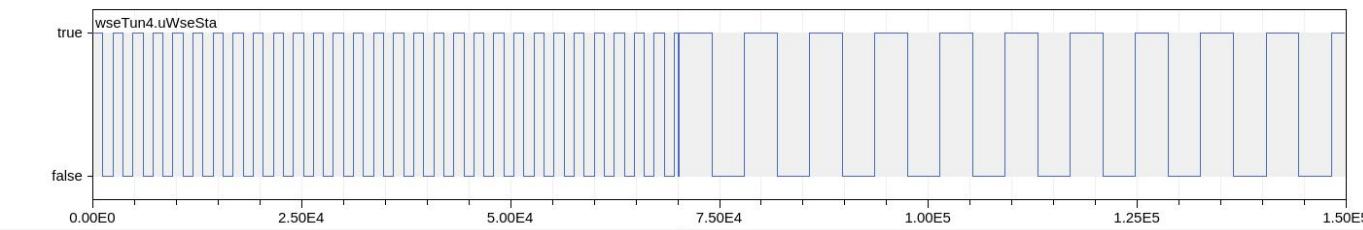
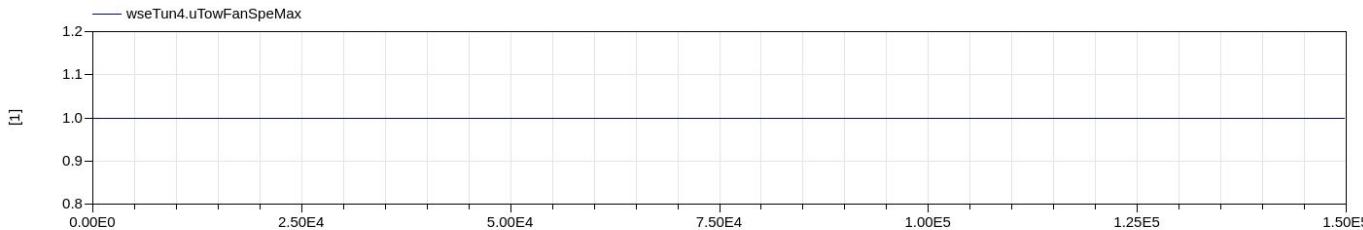
Runtime counters for each
device/group of devices

Waterside economizer - Tuning parameter simulation

Section 5.2.3.3 March draft

| Type | Name | Description |
|--------------------|---------------|---|
| input BooleanInput | uWseSta | WSE enable disable status |
| input RealInput | uTowFanSpeMax | Maximum cooling tower fan speed signal [1] |
| output RealOutput | y | Tuning parameter for the waterside economizer outlet temperature prediction |

wseTun4 - instance name of the tuning parameter model

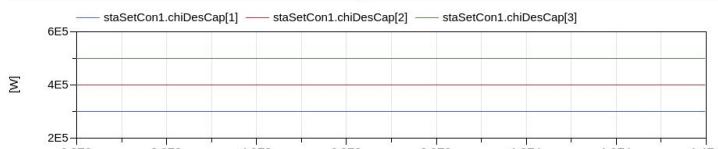
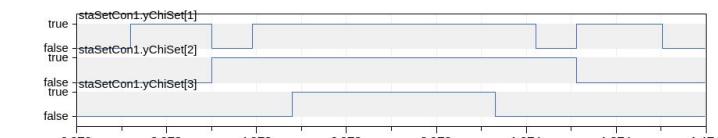
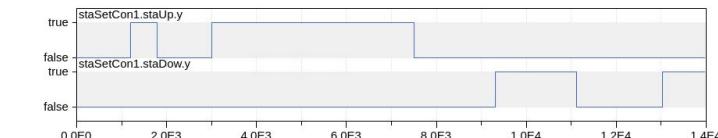
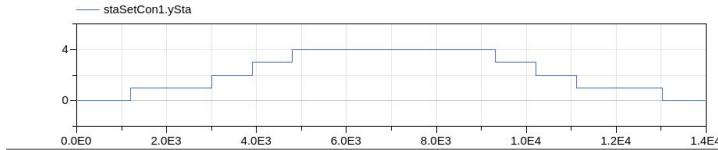


WSE status controller calls for a maximum tower fan speed input (5.2.2.3) - is that the fan speed output of the tower controller (asking based on the reference to the tower sequences)?

Yes, answered May 15

Chiller staging setpoints

Sections from 5.2.4.1 +
OBC generalization



staSetCon1 - an instance of the staging setpoint controller
ySta - chiller stage setpoint to send to staging processes

cap.yDes - design capacity of a given stage
capReq.y - capacity requirement based on load

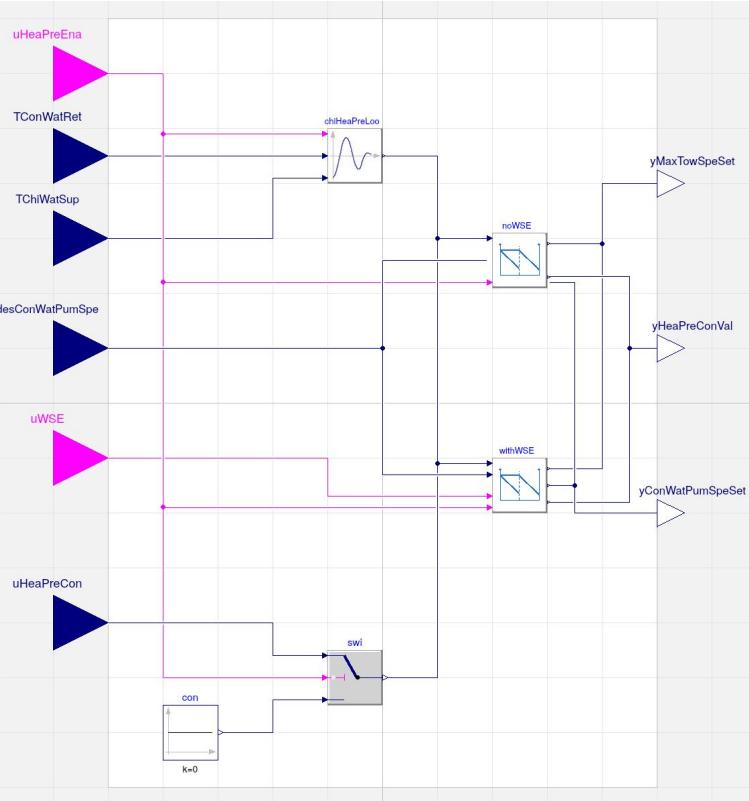
cap.yDes - design capacity of a given stage
capReq.y - capacity requirement based on load

cap.yChiSet[i] - Chiller i enabling status (status setpoint as opposed to proven on status)

cap.chiTyp[i] - Chiller i type

cap.chiDesCap[i] - Chiller i design capacity

Head pressure control (Sec. 5.2.10)



Parameters

| Type | Name | Default | Description |
|-----------------------|-----------------|---------------------------------|--|
| Real | minTowSpe | 0.1 | Minimum cooling tower fan speed |
| Real | minConWatPumSpe | 0.1 | Minimum condenser water pump speed |
| Real | minHeaPreValPos | 0.1 | Minimum head pressure control valve position |
| Plant | | | |
| Boolean | hasHeaPreConSig | false | Flag indicating if there is head pressure control signal from chiller controller |
| Boolean | hasWSE | true | Flag indicating if the plant has waterside economizer |
| Boolean | fixSpePum | true | Flag indicating if the plant has fixed speed condenser water pumps |
| Loop signal | | | |
| TemperatureDifference | minChiLif | 10 | Minimum allowable lift at minimum load for chiller [K] |
| PID controller | | | |
| SimpleController | controllerType | Buildings.Controls.OBC.CDL.T... | Type of controller |
| Real | k | 1 | Gain of controller |
| Time | Ti | 0.5 | Time constant of integrator block [s] |

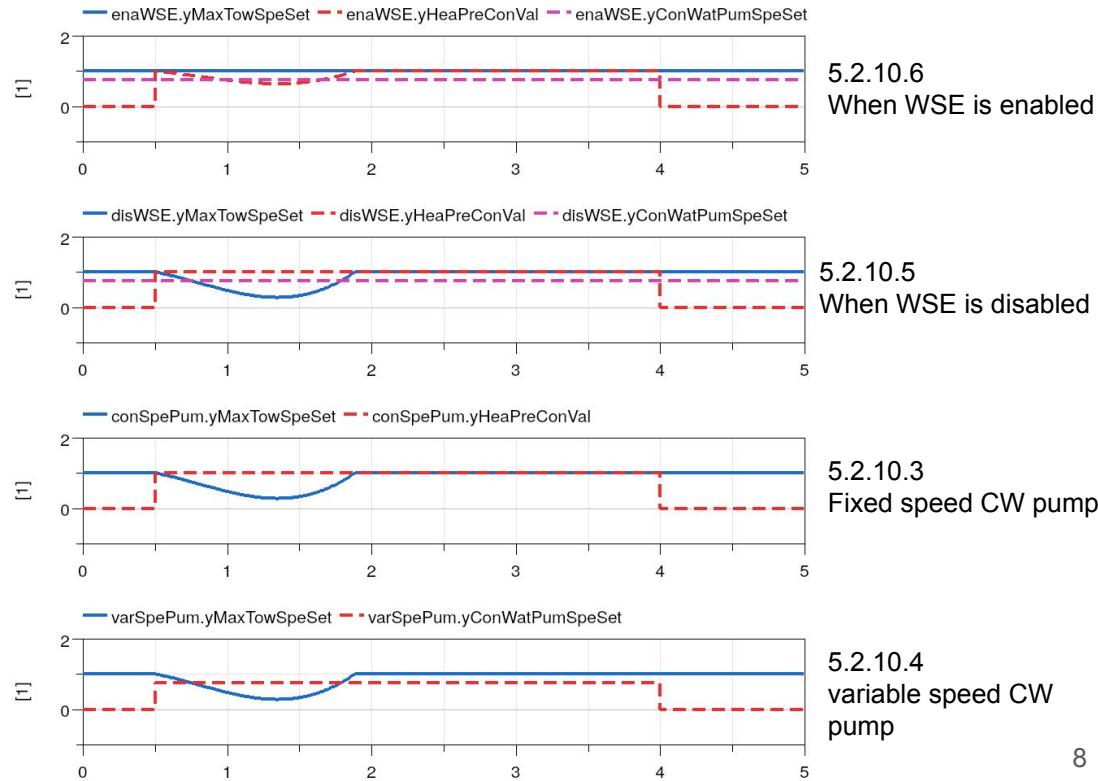
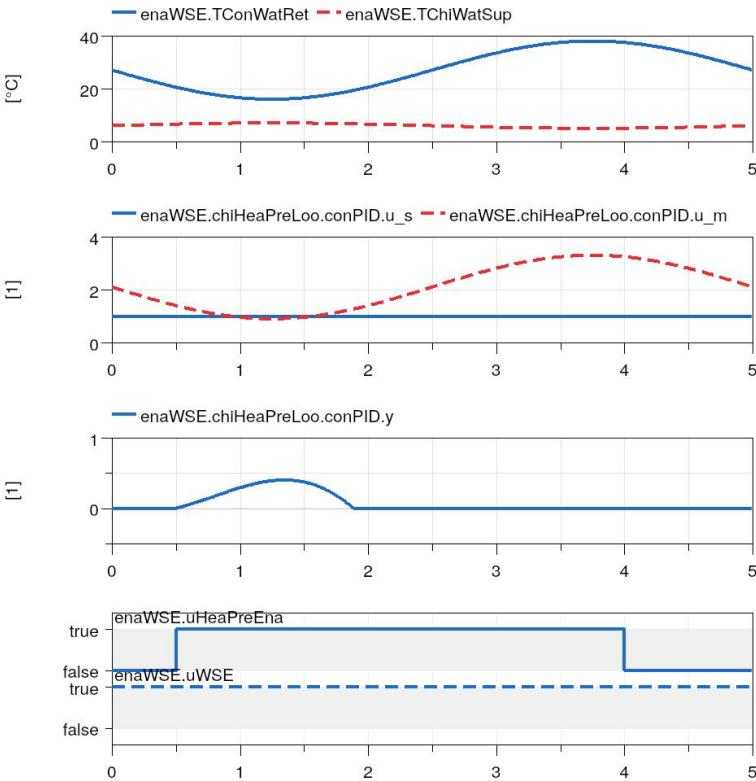
Connectors

| Type | Name | Description |
|--------------------|-------------------------|---|
| input BooleanInput | <i>uHeaPreEna</i> | Status of head pressure control: true = ON, false = OFF |
| input RealInput | <i>TConWatRet</i> | Measured condenser water return temperature [K] |
| input RealInput | <i>TChiWatSup</i> | Measured chilled water supply temperature [K] |
| input RealInput | <i>desConWatPumSpe</i> | Design condenser water pump speed for current stage [1] |
| input BooleanInput | <i>uWSE</i> | Status of water side economizer: true = ON, false = OFF |
| input RealInput | <i>uHeaPreCon</i> | Chiller head pressure control loop signal from chiller controller [1] |
| output RealOutput | <i>yMaxTowSpeSet</i> | Maximum cooling tower speed setpoint [1] |
| output RealOutput | <i>yHeaPreConVal</i> | Head pressure control valve position [1] |
| output RealOutput | <i>yConWatPumSpeSet</i> | Condenser water pump speed setpoint [1] |

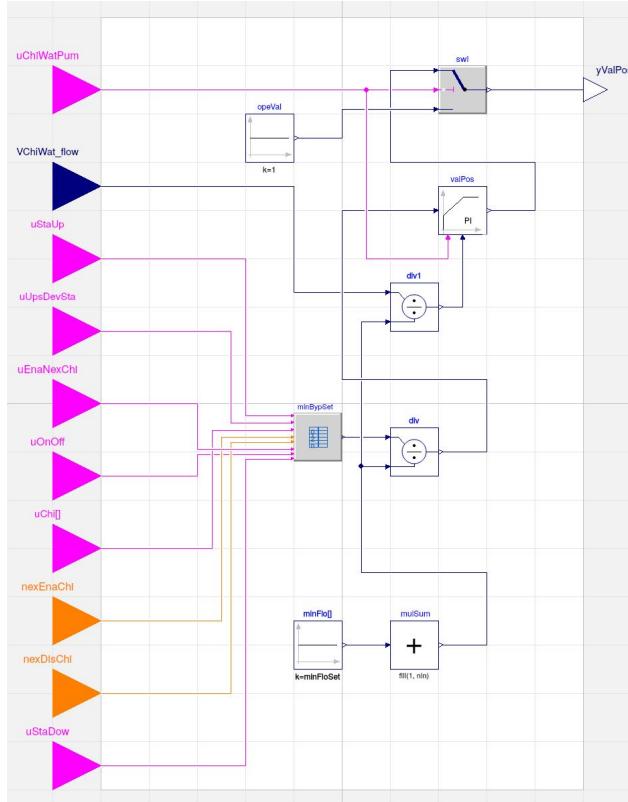
"if a head pressure control signal is not available from the chiller controller, a reverse acting PID loop shall maintain the temperature differential between the chiller's condenser water return temperature and chilled water supply temperature at LIFTminX"

--- Does it mean when the LIFT becoming smaller, the loop output should be larger?

Head pressure control (Sec. 5.2.10)



Minimum flow bypass control (Sec. 5.2.8)



Parameters

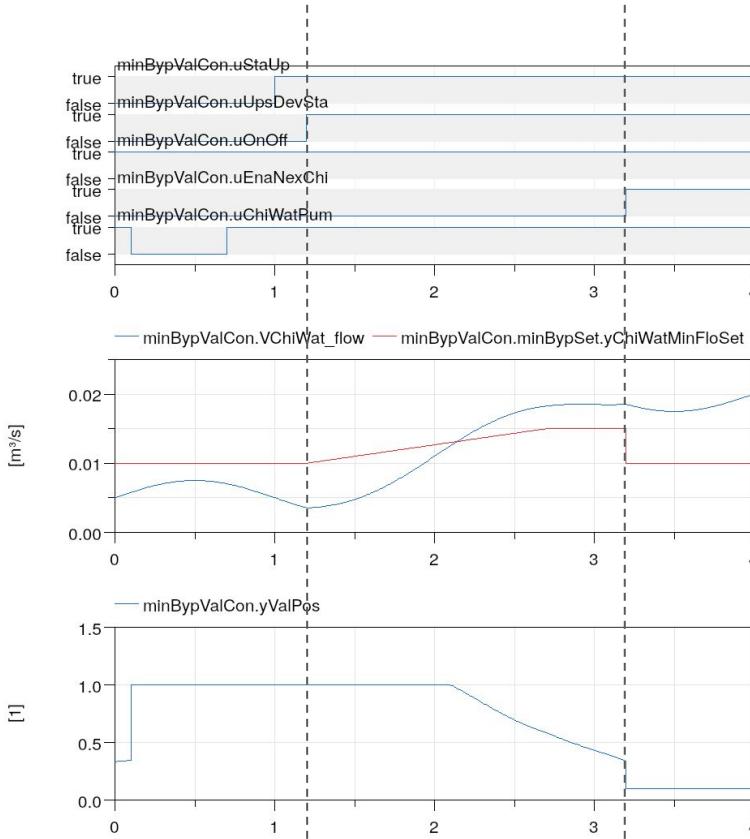
| Type | Name | Default | Description |
|------------------|-------------------|---------------------------------|---|
| Integer | nChi | | Total number of chillers |
| Boolean | isParallelChiller | | Flag: true means that the plant has parallel chillers |
| Time | byPasSetTim | | Time constant for resetting minimum bypass flow [s] |
| VolumeFlowRate | minFloSet[nChi] | | Minimum chilled water flow through each chiller [m ³ /s] |
| VolumeFlowRate | maxFloSet[nChi] | | Maximum chilled water flow through each chiller [m ³ /s] |
| Controller | | | |
| SimpleController | controllerType | Buildings.Controls.OBC.CDL.T... | Type of controller |
| Real | k | 1 | Gain of controller |
| Time | Ti | 0.5 | Time constant of integrator block [s] |
| Time | Td | 0 | Time constant of derivative block [s] |
| Real | yMax | 1 | Upper limit of output |
| Real | yMin | 0.1 | Lower limit of output |

Connectors

| Type | Name | Description |
|--------------------|--------------|--|
| input BooleanInput | uChiWatPum | Maximum status feedback of all the chilled water pumps: true means at least one pump is proven on |
| input RealInput | VChiWat_flow | Measured chilled water flow rate through chillers [m ³ /s] |
| input BooleanInput | uStaUp | Stage up logical signal |
| input BooleanInput | uUpsDevSta | During chiller stage changing process, resetting status of device before reset minimum flow setpoint |
| input BooleanInput | uEnaNexChi | Status to indicate that it starts to enable another chiller. This input is used when the stage change needs chiller on/off |
| input BooleanInput | uOnOff | Indicate if the stage change requires one chiller to be enabled while another is disabled |
| input BooleanInput | uChi[nChi] | Chiller status: true=ON |
| input IntegerInput | nexEnaChi | Index of next chiller to be enabled |
| input IntegerInput | nexDisChi | Index of next chiller to be disabled |
| input BooleanInput | uStaDow | Stage down logical signal |
| output RealOutput | yValPos | Chilled water minimum flow bypass valve position [1] |

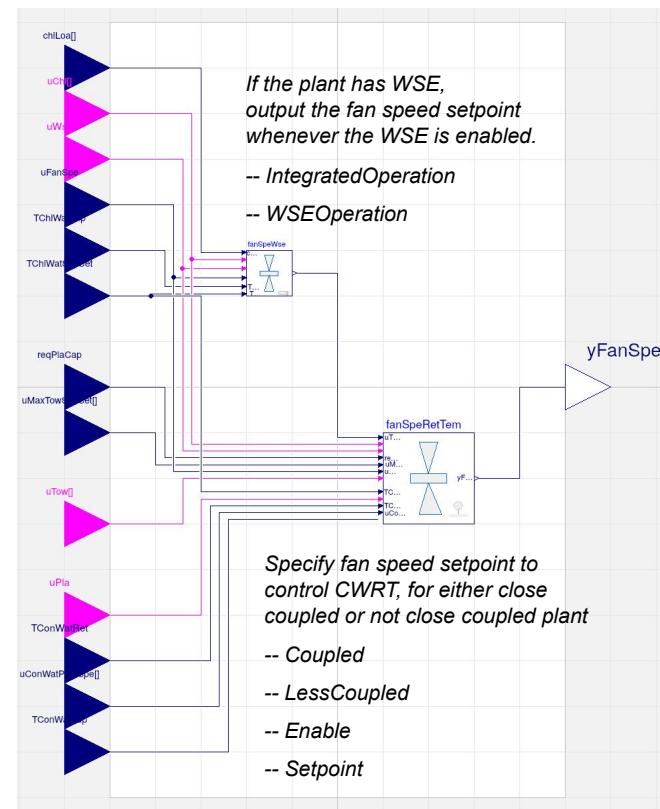
*Should the minimum flow setpoint be reset slowly?
If yes, how slowly should it be?*

Minimum flow bypass control (Sec. 5.2.8)



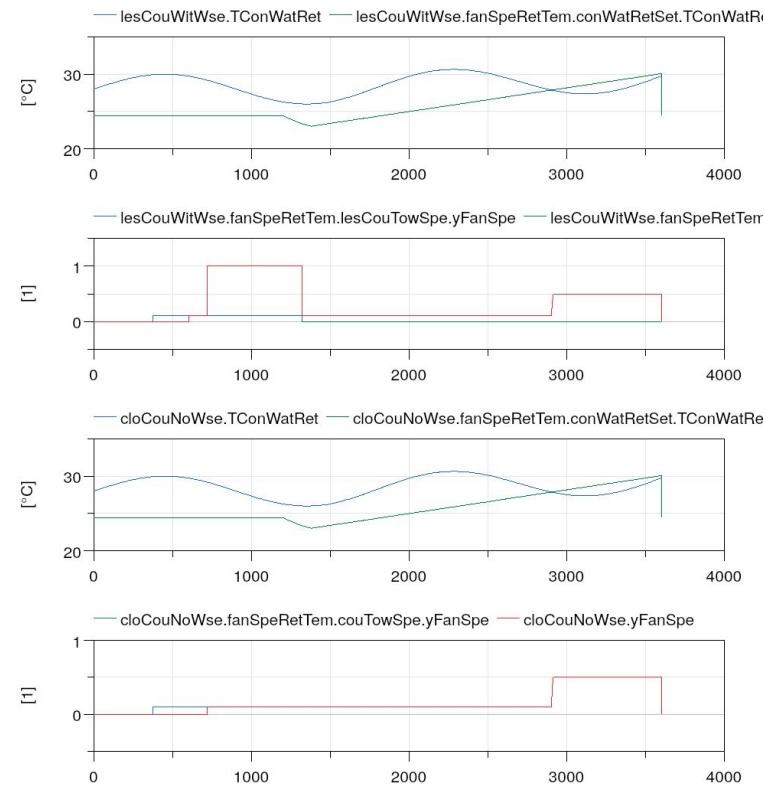
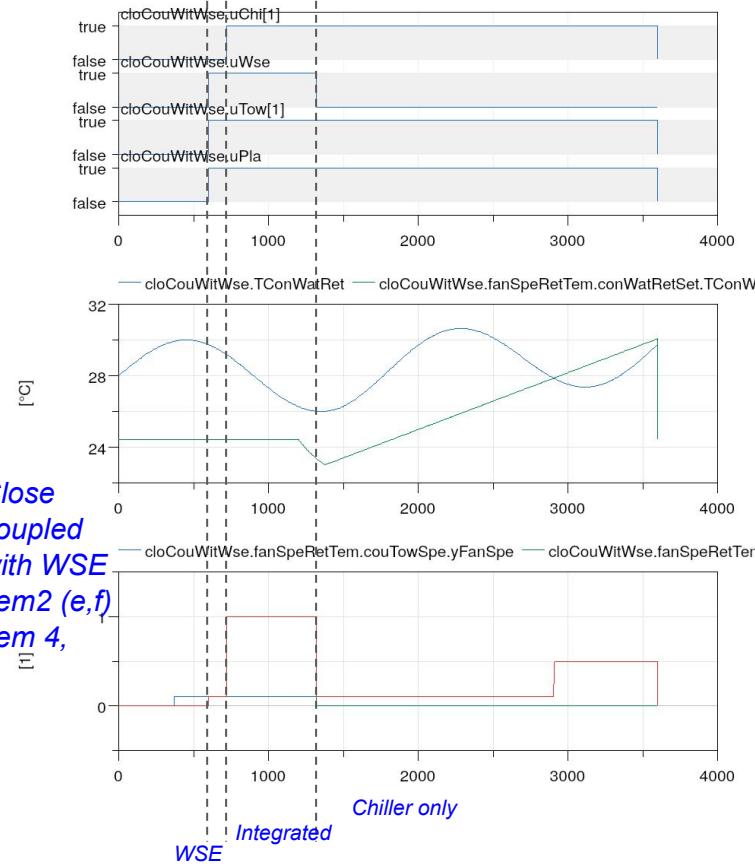
- total 3 chillers (have the same miniflow setpoints 0.005 m³/s), 2 chillers are running initially.
- stage up: enable a larger chiller, disable a small chiller ($uOnOff = \text{true}$)
- in the stage up process ($uStaUp = \text{true}$)
- after the upstream steps are finished ($uUpsDevSta = \text{true}$)
- slowly changing minimum flow setpoints from the one for 2 initial chillers (total 0.01 m³/s), to the one for 2 initial chillers + 1 to be enabled chiller (total 0.015 m³/s).
- when it is time to actually enabling the next chiller, change the setpoint to the one for 1 initial chiller and the enabled chiller (total 0.01 m³/s)

Tower control: fan speed (Sec. 5.2.12.2)

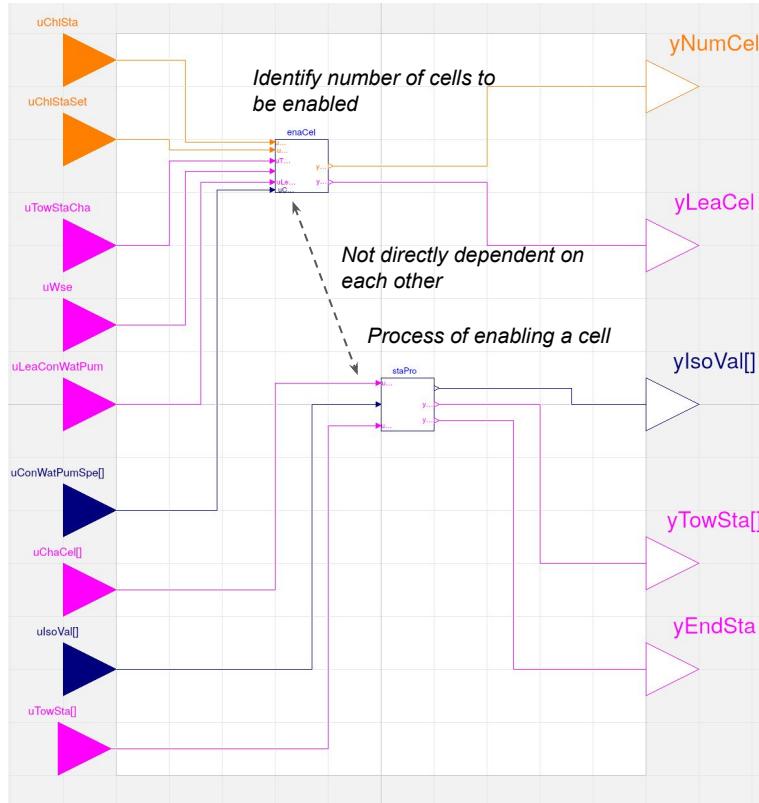


| Parameters | | | |
|---|--------------------------|---------------------------------|---|
| Type | Name | Default | Description |
| Integer | nChi | 2 | Total number of chillers |
| Integer | nTowCel | 4 | Total number of cooling tower cells |
| Integer | nConWatPum | 2 | Total number of condenser water pumps |
| Boolean | closeCoupledPlant | true | Flag to indicate if the plant is close coupled |
| Boolean | have_WSE | true | Flag to indicate if the plant has waterside economizer |
| Real | desCap | 1e6 | Plant design capacity [W] |
| Real | fanSpeMin | 0.1 | Minimum tower fan speed |
| Real | fanSpeMax | 1 | Maximum tower fan speed |
| WSE Enabled | | | |
| Integrated | | | |
| Real | chiMinCap[nChi] | [1e4,1e4] | Minimum cycling load below which chiller will begin cycling [W] |
| SimpleController | intOpeCon | Buildings.Controls.OBC.CDL.T... | Type of controller |
| Real | kIntOpe | 1 | Gain of controller |
| Real | TiIntOpe | 0.5 | Time constant of integrator block [s] |
| Real | TdIntOpe | 0.1 | Time constant of derivative block [s] |
| WSE-only | | | |
| SimpleController | chiWatCon | Buildings.Controls.OBC.CDL.T... | Type of controller |
| Real | kWSE | 1 | Gain of controller |
| Real | TIWSE | 0.5 | Time constant of integrator block [s] |
| Real | TDWSE | 0.1 | Time constant of derivative block [s] |
| Return temperature control | | | |
| Setpoint | | | |
| TemperatureDifference | LIFT_min[nChi] | [12.12] | Minimum LIFT of each chiller [K] |
| Real | TConWatSup_nominal[nChi] | [293.15,293.15] | Design condenser water supply temperature (condenser entering) of each chiller [K] |
| Real | TConWatRet_nominal[nChi] | [303.15,303.15] | Design condenser water return temperature (condenser leaving) of each chiller [K] |
| Real | TChiWatSupMin[nChi] | [278.15,278.15] | Lowest chilled water supply temperature of each chiller [K] |
| Coupled plant | | | |
| SimpleController | couPlaCon | Buildings.Controls.OBC.CDL.T... | Type of controller |
| Real | kCoupPla | 1 | Gain of controller |
| Real | TiCoupPla | 0.5 | Time constant of integrator block [s] |
| Real | TdCoupPla | 0.1 | Time constant of derivative block [s] |
| Real | yCoupPlaMax | 1 | Upper limit of output |
| Real | yCoupPlaMin | 0 | Lower limit of output |
| Less coupled plant | | | |
| Real | samplePeriod | 30 | Period of sampling condenser water supply and return temperature difference |
| SimpleController | supWatCon | Buildings.Controls.OBC.CDL.T... | Type of controller |
| Real | kSupCon | 1 | Gain of controller |
| Real | TiSupCon | 0.5 | Time constant of integrator block [s] |
| Real | TdSupCon | 0.1 | Time constant of derivative block [s] |
| Real | ySupConMax | 1 | Upper limit of output |
| Real | ySupConMin | 0 | Lower limit of output |
| Advanced | | | |
| Real | speChe | 0.005 | Lower threshold value to check fan or pump speed |
| Return temperature control: Enable tower | | | |
| Real | cheMinFanSpe | 300 | Threshold time for checking duration when tower fan equals to the minimum tower fan speed [s] |
| Real | cheMaxTowSpe | 300 | Threshold time for checking duration when any enabled chiller maximum cooling speed equals to the minimum tower fan speed [s] |
| Real | cheTowOff | 60 | Threshold time for checking duration when there is no enabled tower fan [s] |
| Return temperature control: Setpoint | | | |
| Real | iniPlaTim | 600 | Time to hold return temperature to initial setpoint after plant being enabled [s] |
| Real | ramTim | 180 | Time to ramp return water temperature from initial value to setpoint [s] |

Tower control: fan speed (Sec. 5.2.12.2)



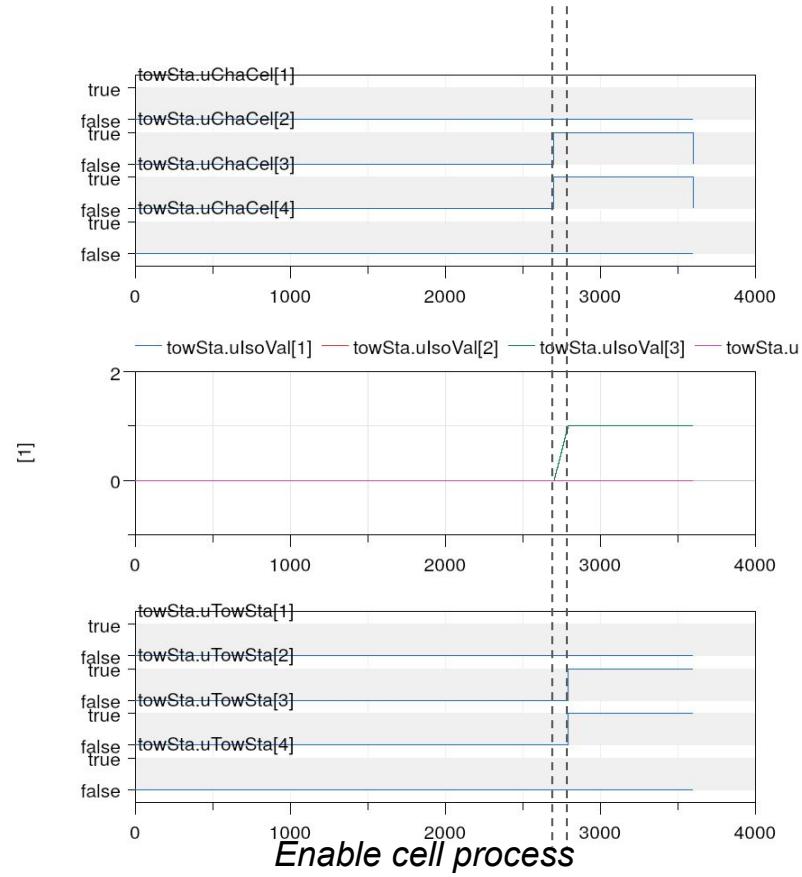
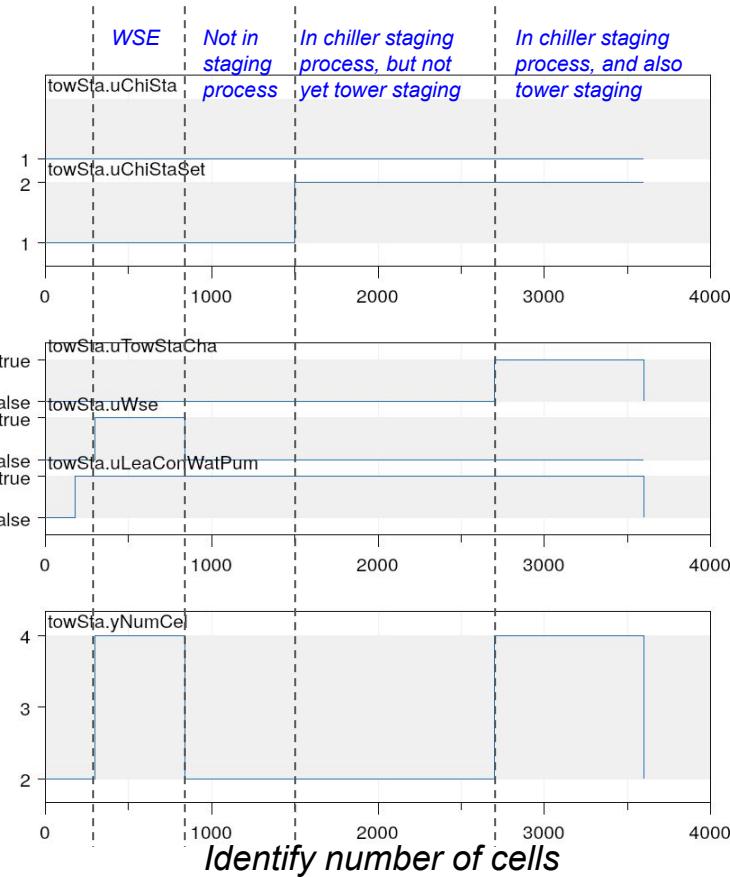
Tower control: staging (Sec. 5.2.12.1)



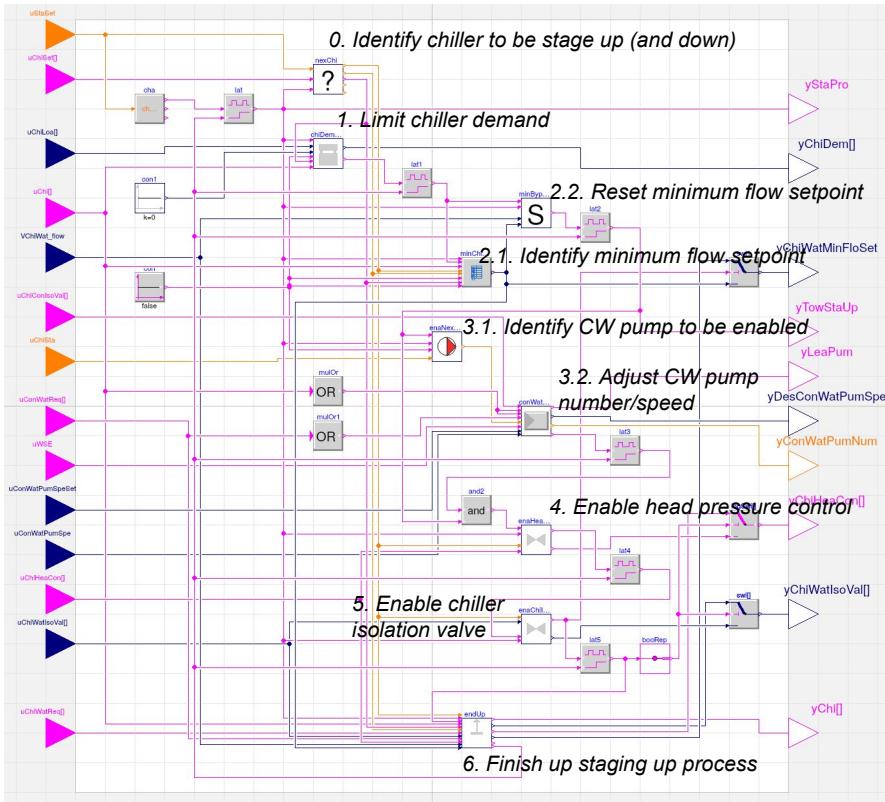
| Parameters | | | |
|-----------------|------------------------|---------------------|---|
| Type | Name | Default | Description |
| Boolean | have_WSE | true | Flag to indicate if the plant has waterside economizer |
| Integer | nTowCel | 4 | Total number of cooling tower cells |
| Integer | nConWatPum | 2 | Total number of condenser water pumps |
| Integer | totChiSta | 6 | Total number of plant stages, stage zero should be counted as one stage |
| Real | staVec[totChiSta] | {0,0.5,1,1.5,2,2.5} | Plant stage vector with size of total number of stages, element value like x.5 means chiller stage x plus WSE |
| Real | towCelOnSel[totChiSta] | {0,2,2,4,4,4} | Design number of tower fan cells that should be ON, according to current chiller stage and WSE status |
| Real | chaTowCellsOnTim | 90 | Nominal time needed for open isolation valve of the tower cells |
| Advanced | | | |
| Real | speChe | 0.01 | Lower threshold value to check if condenser water pump is proven on |

| Connectors | | | |
|----------------------|---------------------------|---|--|
| Type | Name | Description | |
| input IntegerInput | uChiSta | Current chiller stage | |
| input IntegerInput | uChiStaSet | Current chiller stage setpoint | |
| input BooleanInput | uTowStaCha | Cooling tower stage change command from plant staging process | |
| input BooleanInput | uWse | Water side economizer status: true = ON, false = OFF | |
| input BooleanInput | uLeaConWatPum | Enabling status of lead condenser water pump | |
| input RealInput | uConWatPumSpe[nConWatPum] | Current condenser water pump speed [1] | |
| input BooleanInput | uChaCel[nTowCel] | Vector of boolean flags to show if a cell should change its status: true = the cell should change status (be enabled or disabled) | |
| input RealInput | ulsoVal[nTowCel] | Vector of tower cells isolation valve position | |
| input BooleanInput | uTowSta[nTowCel] | Vector of tower cells proven on status: true=proven on | |
| output IntegerOutput | yNumCel | Total number of enabled cells | |
| output BooleanOutput | yLeaCel | Lead tower cell status | |
| output RealOutput | ylsoVal[nTowCel] | Vector of tower cells isolation valve position [1] | |
| output BooleanOutput | yTowSta[nTowCel] | Vector of tower cells status setpoint | |
| output BooleanOutput | yEndSta | Rising edge to indicate the staging process is done | |

Tower control: staging (Sec. 5.2.12.1)



Chiller staging up (Sec. 5.2.4.16)

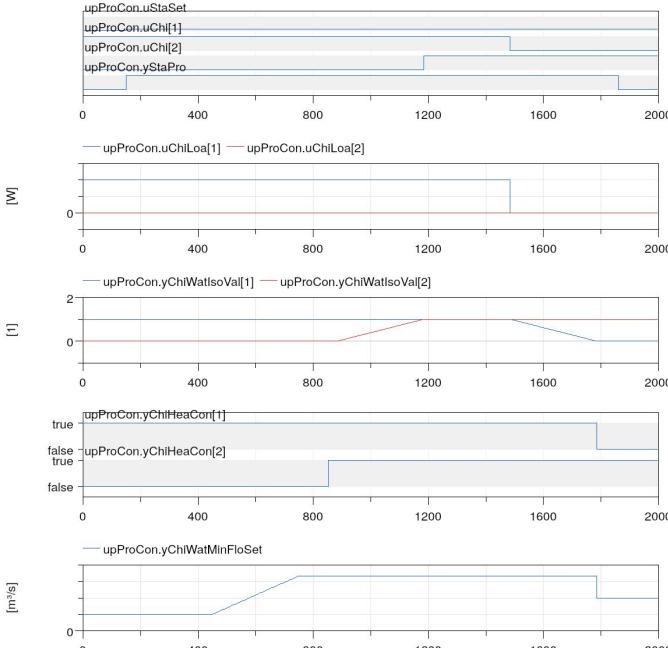
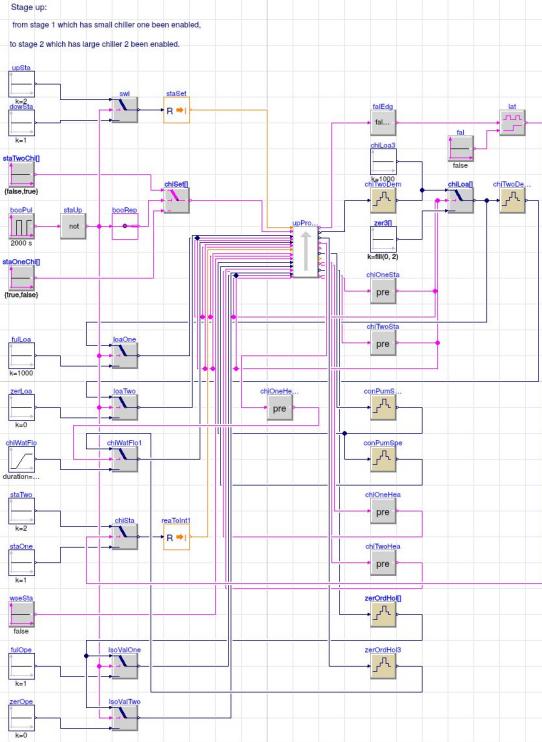


Parameters

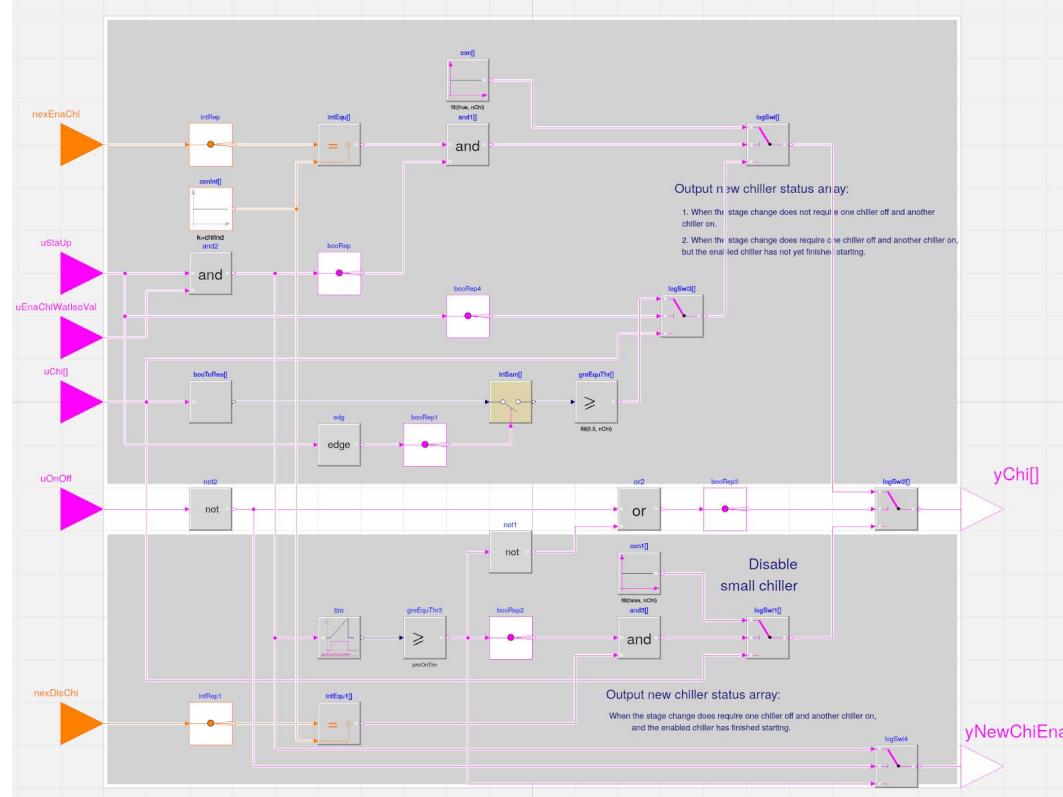
| Type | Name | Default | Description |
|---------------------------------|-------------------------|--------------------------------|--|
| Integer | nChi | 2 | Total number of chillers in the plant |
| Integer | totSta | 6 | Total number of stages, including the stages with a WSE, if applicable |
| Boolean | haveWSE | true | Flag: true = have waterside economizer |
| Boolean | havePonyChiller | false | Flag: true = have pony chiller |
| Boolean | isParallelChiller | true | Flag: true = the plant has parallel chillers |
| Boolean | isHeadered | true | Flag: true = headered condenser water pumps |
| Limit chiller demand | | | |
| Real | chiDemRedFac | 0.75 | Demand reducing factor of current operating chillers |
| Time | holChiDemTim | 300 | Maximum time to wait for the actual demand less than percentage of current load [s] |
| Reset CHW minimum flow setpoint | | | |
| Time | byPasSetTim | 300 | Time to reset minimum by-pass flow [s] |
| VolumeFlowRate | minFloSet[nChi] | [0.0089, 0.0089] | Minimum chilled water flow through each chiller [m ³ /s] |
| VolumeFlowRate | maxFloSet[nChi] | [0.025, 0.025] | Maximum chilled water flow through each chiller [m ³ /s] |
| Reset bypass | | | |
| Time | aftByPasSetTim | 60 | Time to allow loop to stabilize after resetting minimum chilled water flow setpoint [s] |
| Enable condenser water pump | | | |
| Real | staVec[totSta] | [0, 0.5, 1, 1.5, 2, 2.5] | Chiller stage vector, element value like x.5 means chiller stage x plus WSE |
| Real | desConWatPumSpe[totSta] | [0, 0.5, 0.75, 0.6, 0.75, 0.9] | Design condenser water pump speed setpoints, the size should be double of total stage numbers |
| Real | desConWatPumNum[totSta] | [0, 1, 1.2, 2, 2] | Design number of condenser water pumps that should be ON, the size should be double of total stage numbers |
| Enable head pressure control | | | |
| Time | thrTimEnb | 10 | Threshold time to enable head pressure control after condenser water pump being reset [s] |
| Time | waTim | 30 | Waiting time after enabling next head pressure control [s] |
| Enable CHW isolation valve | | | |
| Time | chaChiWatIsoTim | 300 | Time to slowly change isolation valve, should be determined in the field [s] |
| Enable next chiller | | | |
| Time | proOnTim | 300 | Threshold time to check if newly enabled chiller being operated by more than 5 minutes [s] |
| Advanced | | | |
| Enable condenser water pump | | | |
| Real | relSpeDif | 0.05 | Relative error to the setpoint for checking if it has achieved speed setpoint |
| Reset bypass | | | |
| Real | relFloDif | 0.05 | Relative error to the setpoint for checking if it has achieved flow rate setpoint |

- Is it possible that “enable a larger chiller and disable a smaller chiller” happens other than staging-up from 1 to 2?

Chiller staging up (Sec. 5.2.4.16)



Chiller staging up: enable chiller



Parameters

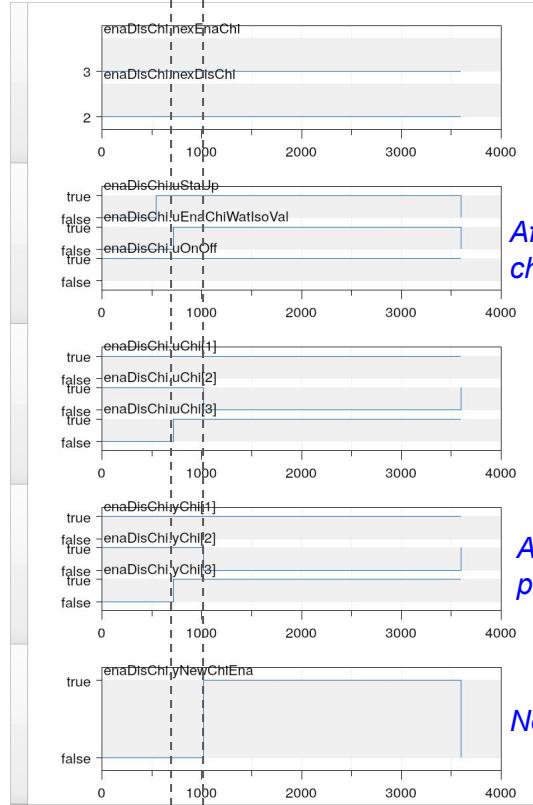
| Type | Name | Default | Description |
|---------|----------|--------------------------|---|
| Integer | nChi | Total number of chillers | |
| Time | proOnTim | 300 | Enabled chiller operation time to indicate if it is proven on [s] |

Connectors

| Type | Name | Description |
|----------------------|-------------------|--|
| input IntegerInput | nexEnaChi | Index of next enabling chiller |
| input BooleanInput | uStaUp | Indicate if there is stage-up command |
| input BooleanInput | uEnaChiWattIsoVal | Status of chilled water isolation valve control: true=enabled valve is fully open |
| input BooleanInput | uChi[nChi] | Chiller status: true=ON |
| input BooleanInput | uOnOff | Indicate if the stage require one chiller to be enabled while another is disabled |
| input IntegerInput | nexDisChi | Next disabling chiller when there is any stage up that need one chiller on and another off |
| output BooleanOutput | yChi[nChi] | Chiller enabling status |
| output BooleanOutput | yNewChiEna | Newly enabled chiller has been proven on by more than 5 minutes |

Chiller staging up: enable chiller

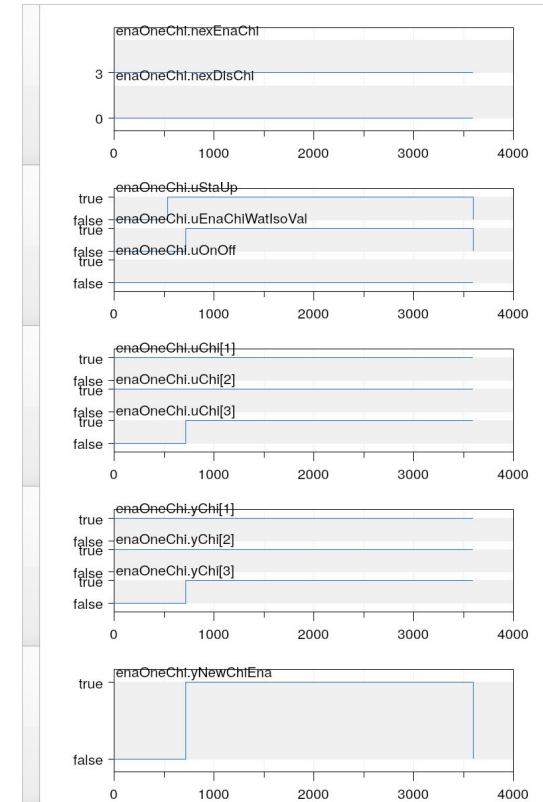
Enable large chiller (3), disable small chiller (2)



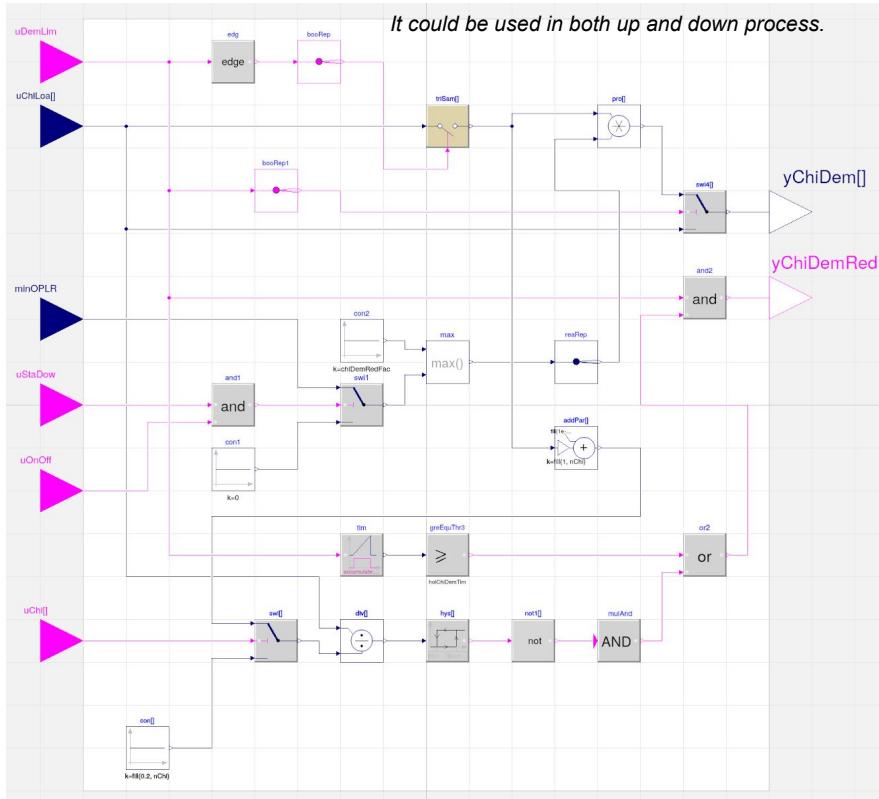
After enabling chiller (3) has been proven on, disable chiller 2

Newly enabled chiller is proven on

Enable a chiller



Chiller staging: reduce demand



Parameters

| Type | Name | Default | Description |
|---------|--------------|---------|---|
| Integer | nChi | | Total number of chillers in the plant |
| Real | chiDemRedFac | 0.75 | Demand reducing factor of current operating chillers |
| Time | hotChiDemTim | 300 | Maximum time to wait for the actual demand less than percentage of current load [s] |

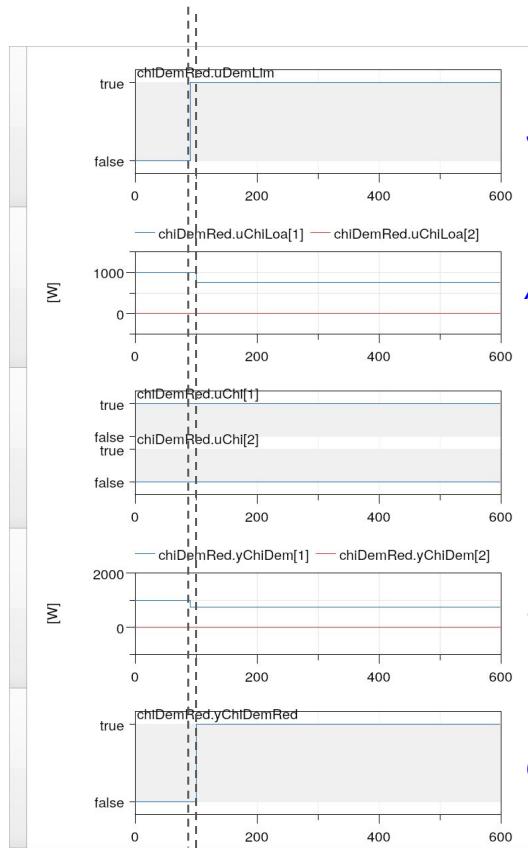
Connectors

| Type | Name | Description |
|----------------------|---------------|---|
| input BooleanInput | uDemLim | Demand limit: true=limit chiller demand |
| input RealInput | uChiLoa[nChi] | Current chiller load [W] |
| input RealInput | minOPLR | Current stage minimum cycling operative partial load ratio [1] |
| input BooleanInput | uStaDow | Stage down status: true=stage-down |
| input BooleanInput | uOnOff | Indicate if the stage require one chiller to be enabled while another is disabled |
| input BooleanInput | uChi[nChi] | Chiller status: true=ON |
| output RealOutput | yChiDem[nChi] | Chiller demand setpoint [W] |
| output BooleanOutput | yChiDemRed | Indicate if the chiller demand reduction process has finished |

- What does the “chiller load” mean? Is it a reading data from chiller itself?
- How is the “chiller demand” signal being sent to the chiller?
- Does the minimum OPLR input (*minOPLR*) refer to each chiller individually or to a stage, or something else?

Chiller staging: reduce demand

Enable one more chiller



Should limit the demand

Actual chiller load

“Demand setpoint”

Chiller demand has been limited.

Down: enable 1 and disable another

