Open Building Control

Open-loop Validation - Review

Chiller Plant Sequences

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Agenda

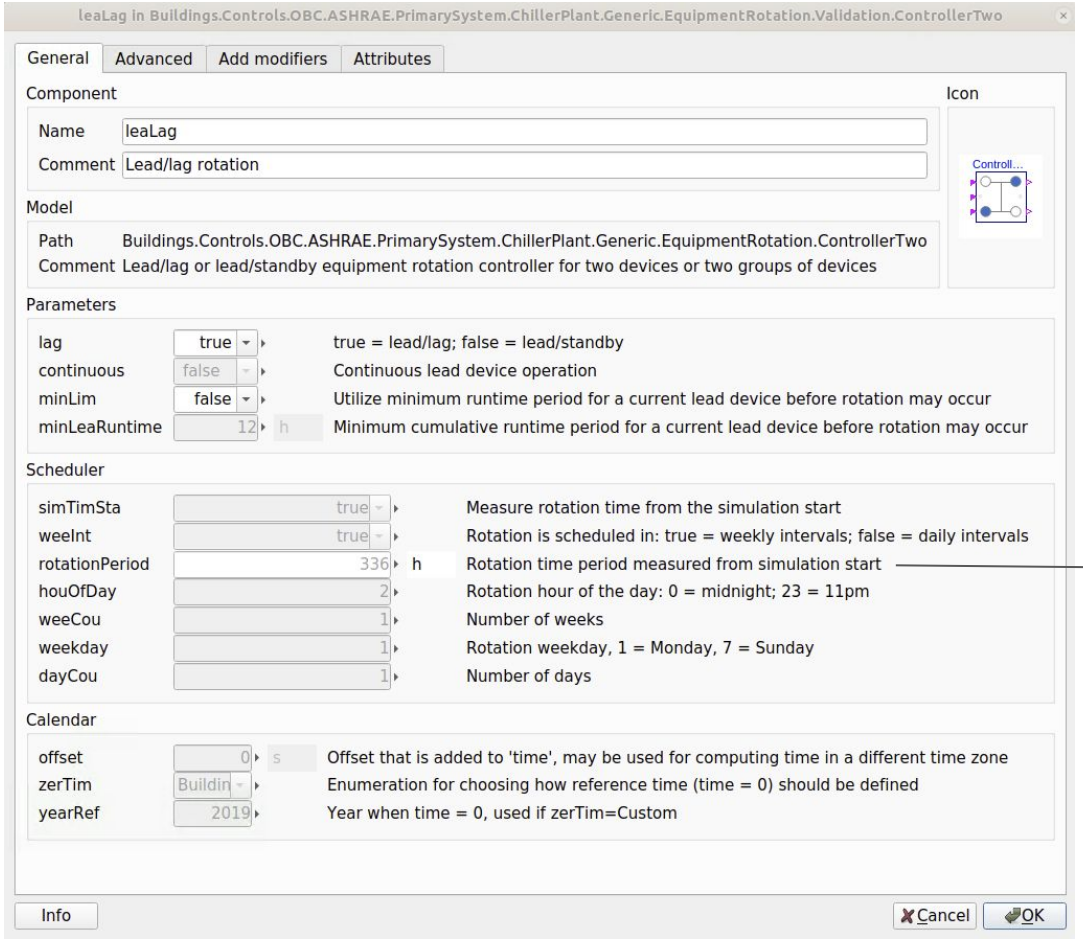
- Get familiarized with the chiller plant sequences in CDL
  - Package vs 1711 structure

- 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.

OpenBuildingControl

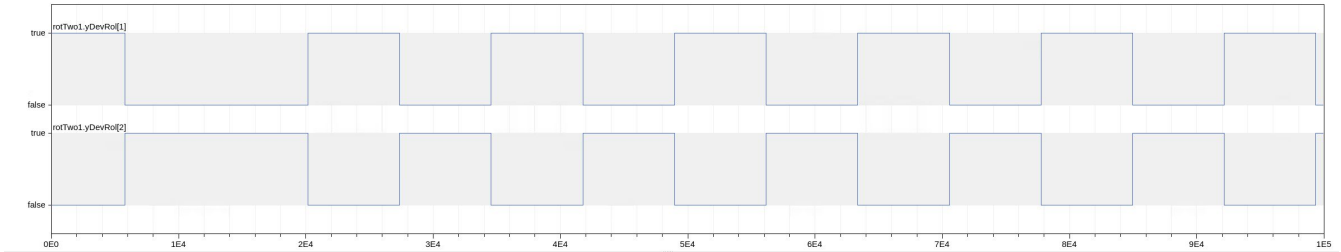
Updated for May 22: Equipment rotation, Sec. 5.1.2



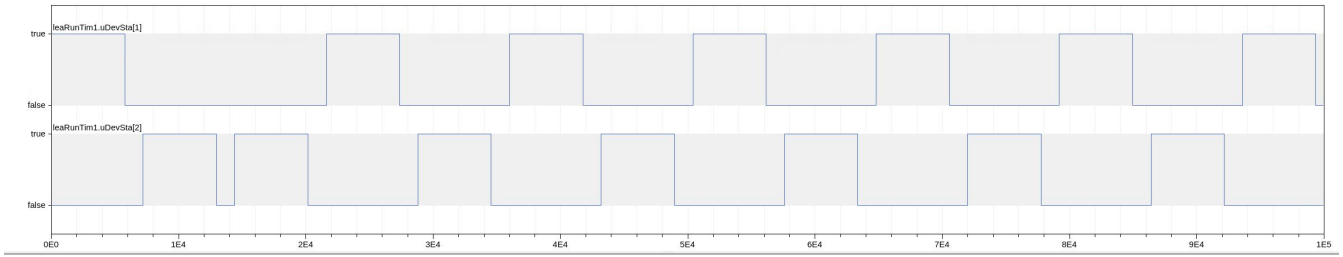
Currently implemented for two devices and groups of devices.

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

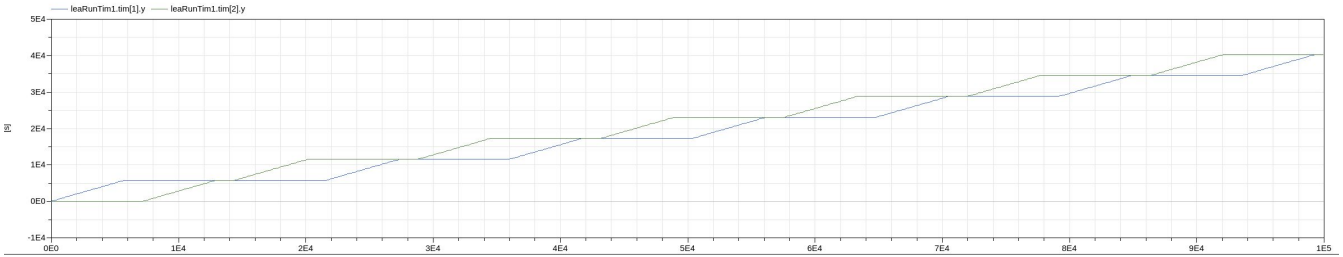
Updated for May 22: Equipment rotation - lead/standby case, default settings



yDevRol[i] - device *i* role, true is lead, false is lag



yDevSta[i] - device *i* status



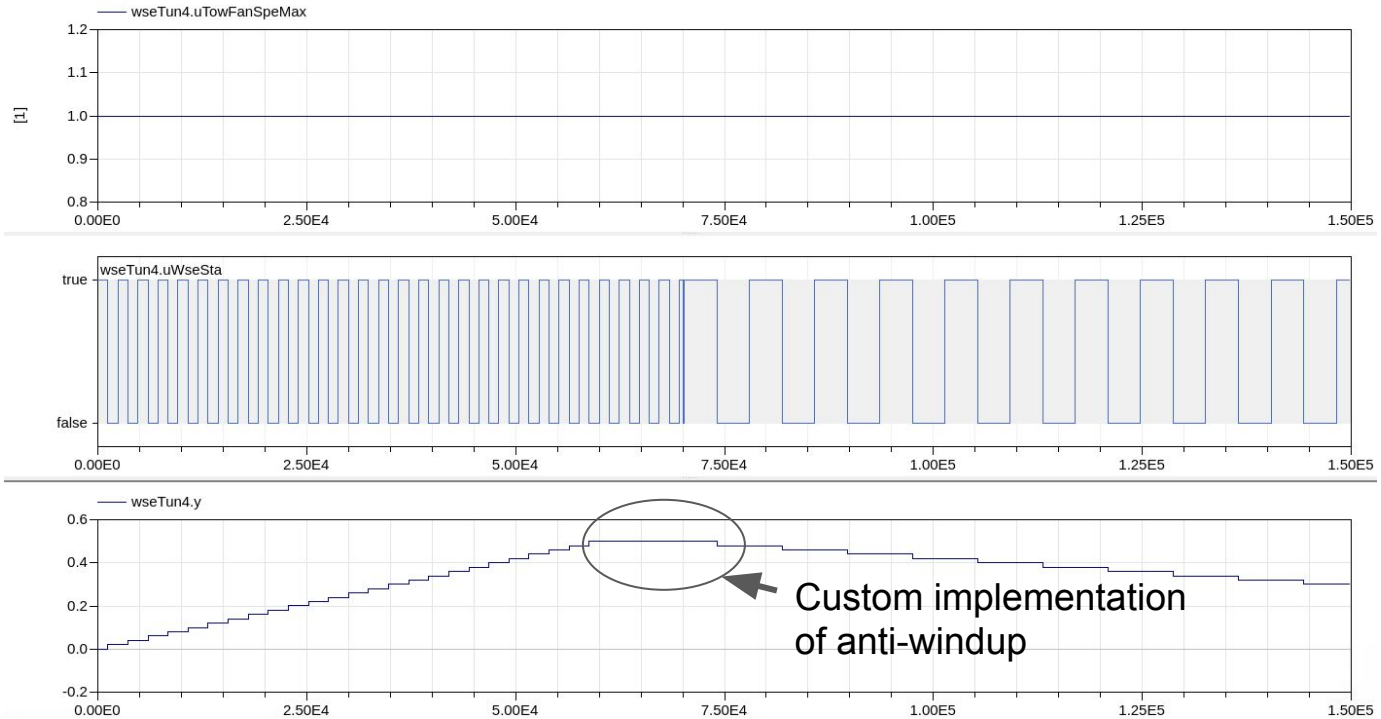
Runtime counters for each device/group of devices

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

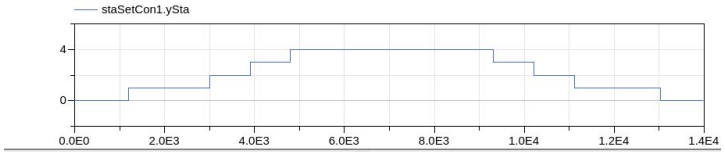
wseTun4 - instance name of the tuning parameter model



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

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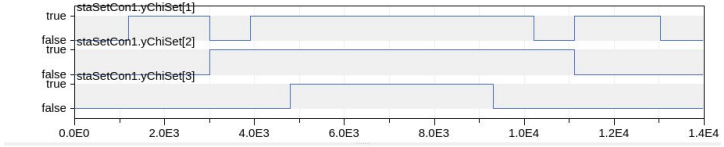
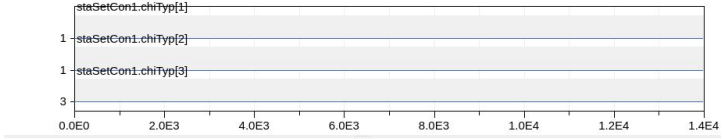
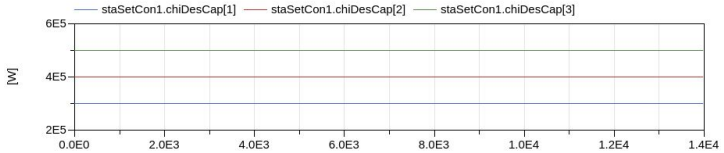
capReq.y - capacity requirement based on load



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

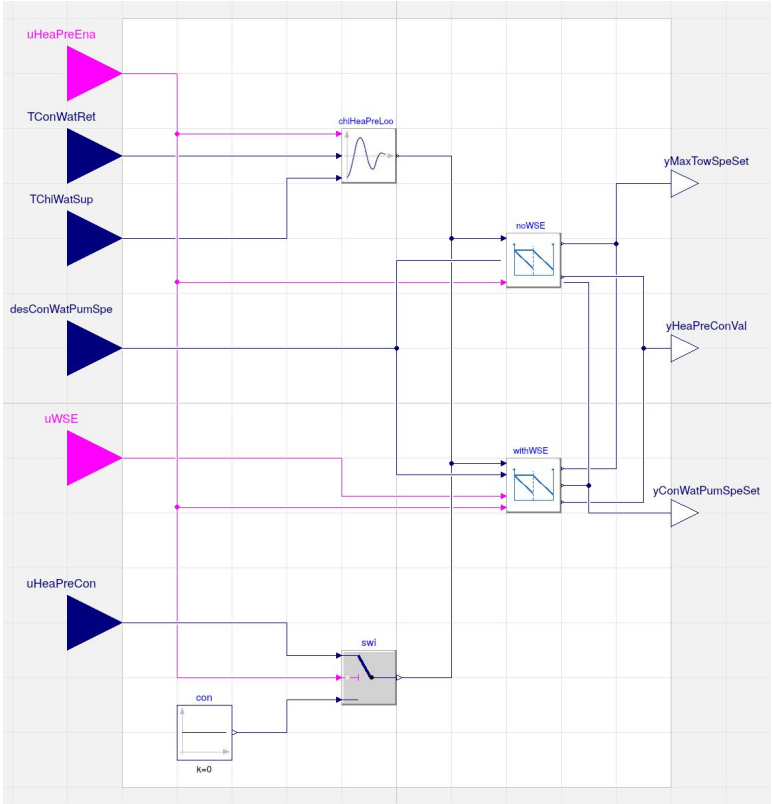


cap.chiTyp[i] - Chiller *i* type



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]

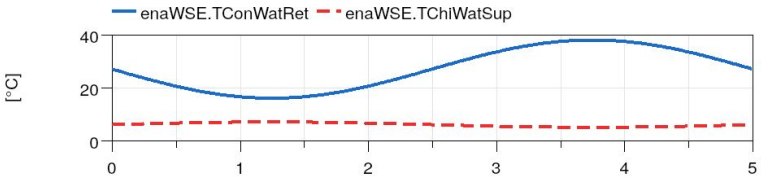
Connectors

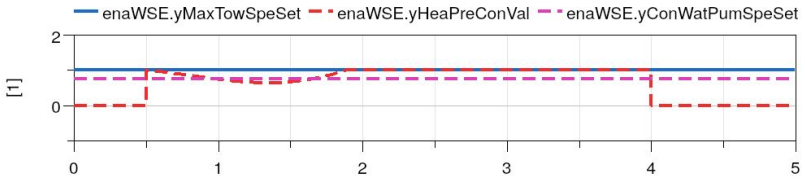
Type	Name	Description
input BooleanInput	uHeaPreEna	Status of head pressure control: true = ON, false = OFF
input RealInput	TConWatRet	Measured condenser water return temperature [K]
input RealInput	TChiWatSup	Measured chilled water supply temperature [K]
input RealInput	desConWatPumSpe	Design condenser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

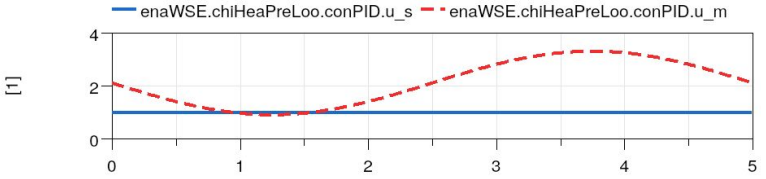
--- *Does it mean when the LIFT becoming smaller, the loop output should be larger?*

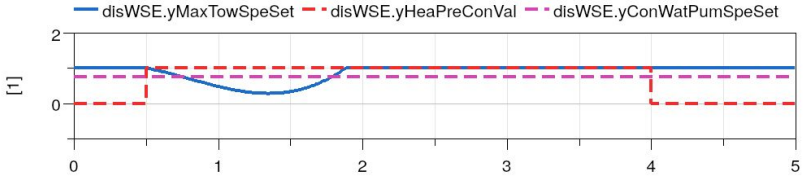
Head pressure control (Sec. 5.2.10)



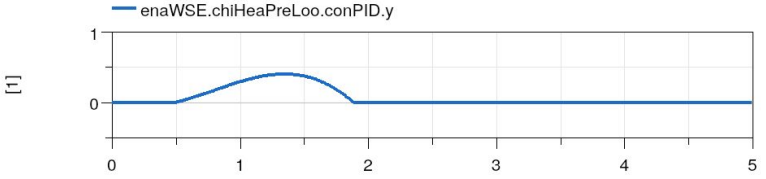


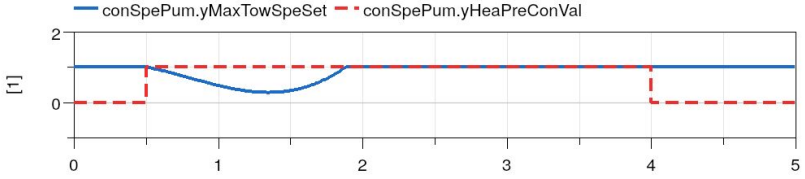
5.2.10.6
When WSE is enabled



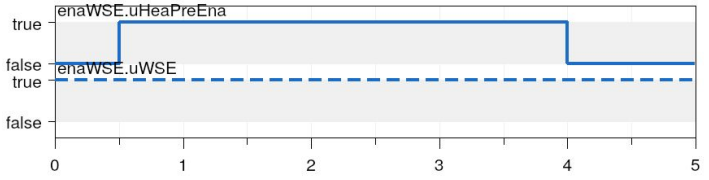


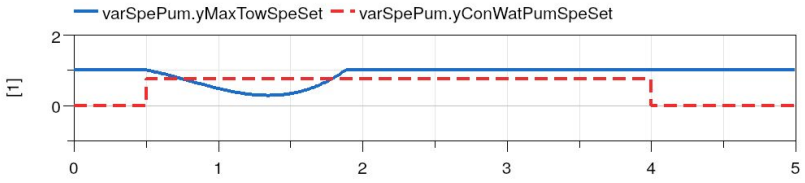
5.2.10.5
When WSE is disabled





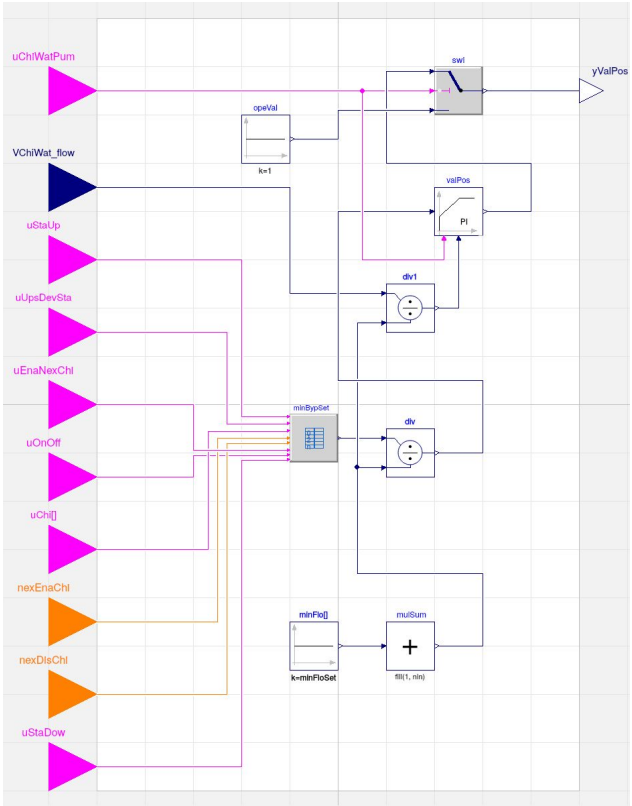
5.2.10.3
Fixed speed CW pump





5.2.10.4
variable speed CW pump

Minimum flow bypass control (Sec. 5.2.8)



Parameters

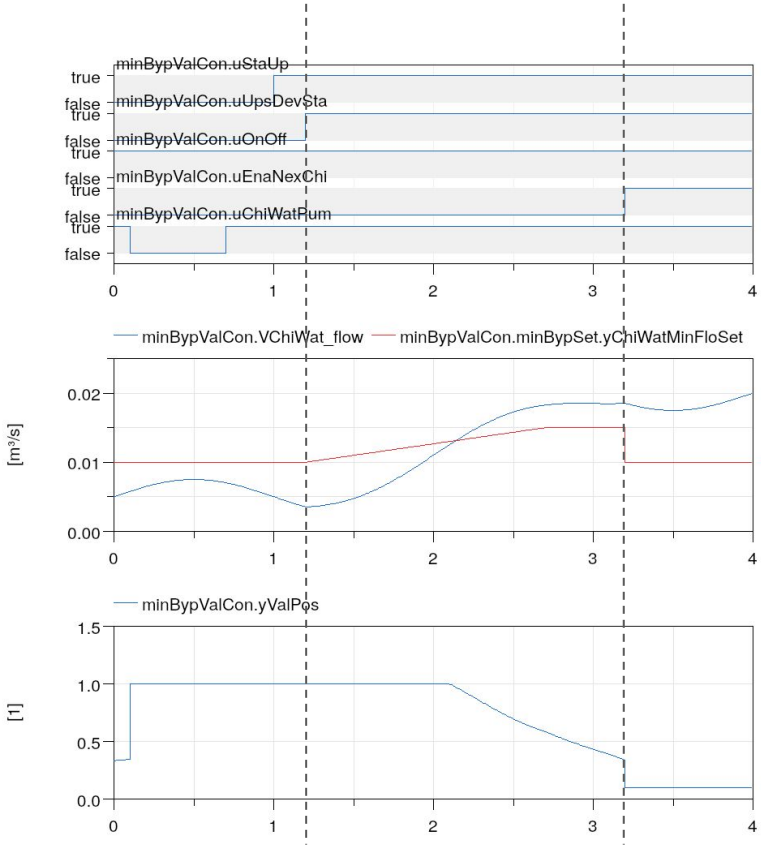
Type	Name	Default	Description
Integer	nChi		Total number of chillers
Boolean	isParallelChiller		Flag: true means that the plant has parallel chillers
Time	byPasSetTim		Time constant for resetting minimum bypass flow [s]
VolumeFlowRate	minFloSet[nChi]		Minimum chilled water flow through each chiller [m3/s]
VolumeFlowRate	maxFloSet[nChi]		Maximum chilled water flow through each chiller [m3/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 [m3/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]

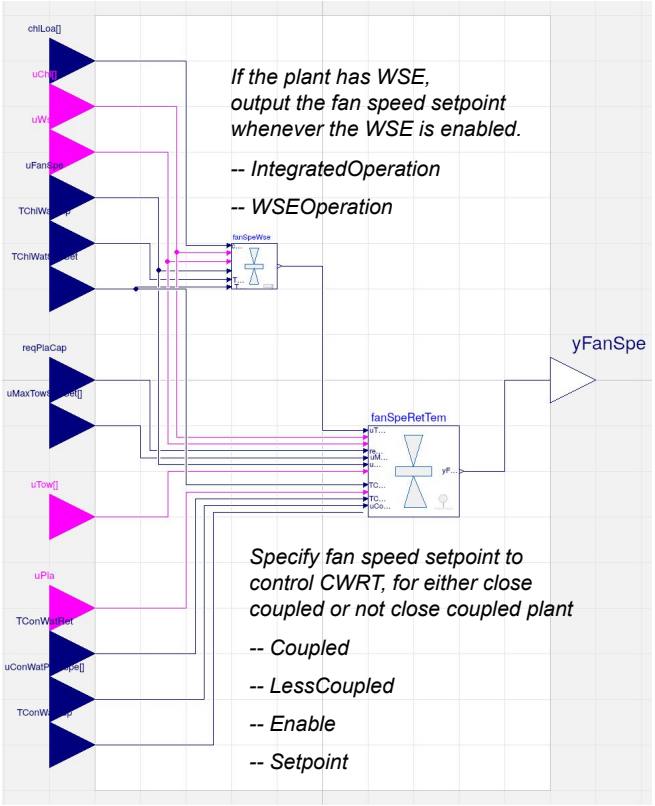
Should the minimum flow setpoint be reset slowly?
If yes, how slowly should it be?

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 = true`)
- in the stage up process (`uStaUp = true`)
- after the upstream steps are finished (`uUpsDevSta = 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)

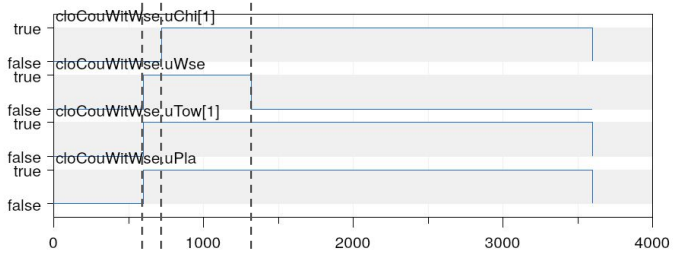
Tower control: fan speed (Sec. 5.2.12.2)

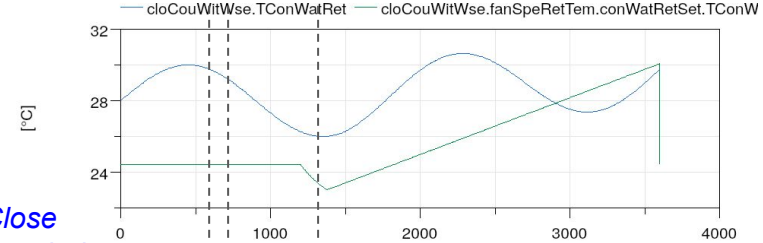


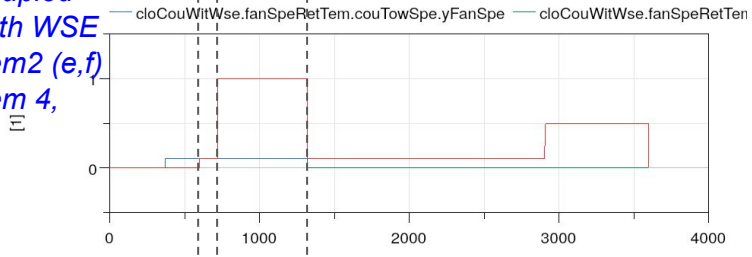
Parameters

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 cyclining 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	kCouPla	1	Gain of controller
Real	TiCouPla	0.5	Time constant of integrator block [s]
Real	TdCouPla	0.1	Time constant of derivative block [s]
Real	yCouPlaMax	1	Upper limit of output
Real	yCouPlaMin	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)





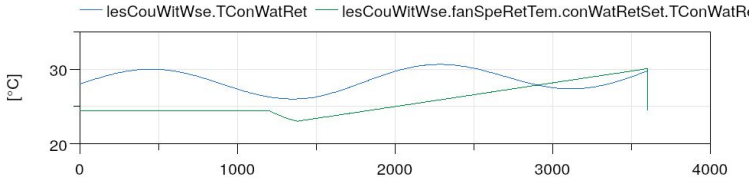


Close coupled with WSE item2 (e,f) item 4,

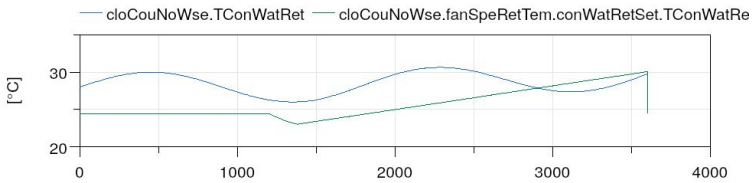
WSE

Integrated

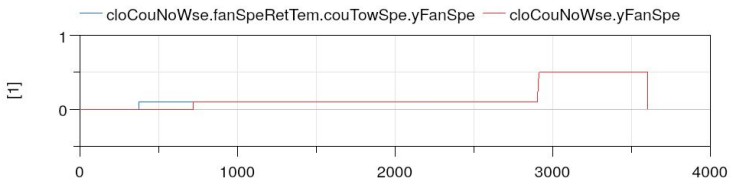
Chiller only



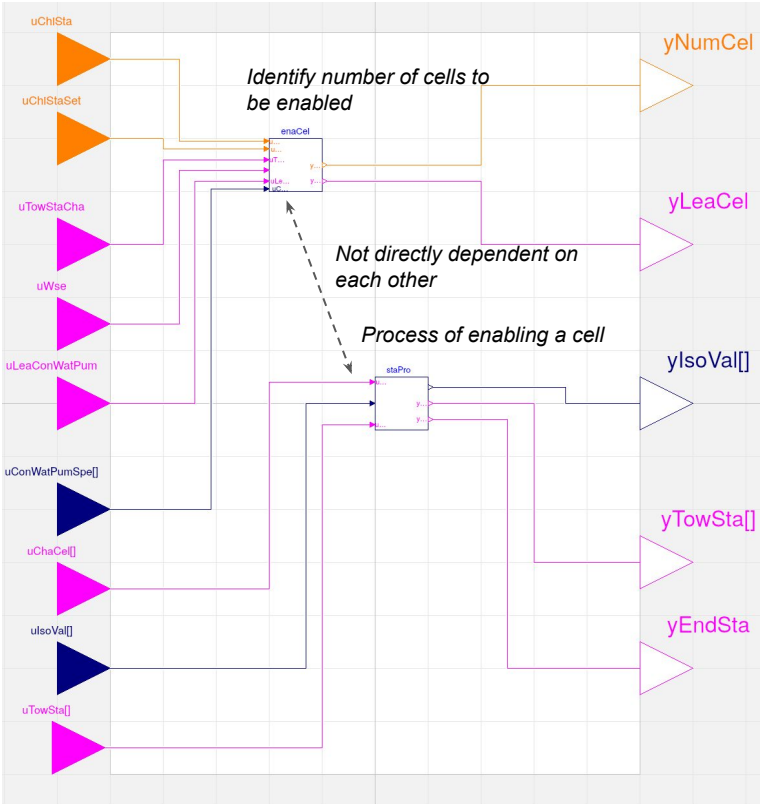
Less coupled with WSE (item 2 (g, h, i) 4)



Close coupled without WSE



Tower control: staging (Sec. 5.2.12.1)



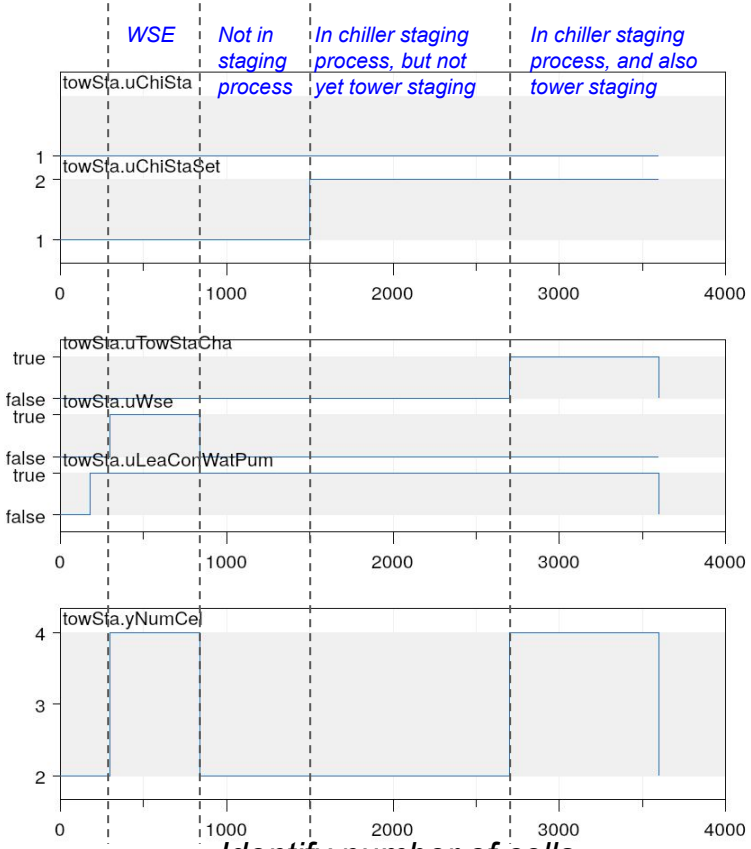
Parameters

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	towCelOnSet[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	chaTowCelIsoTim	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

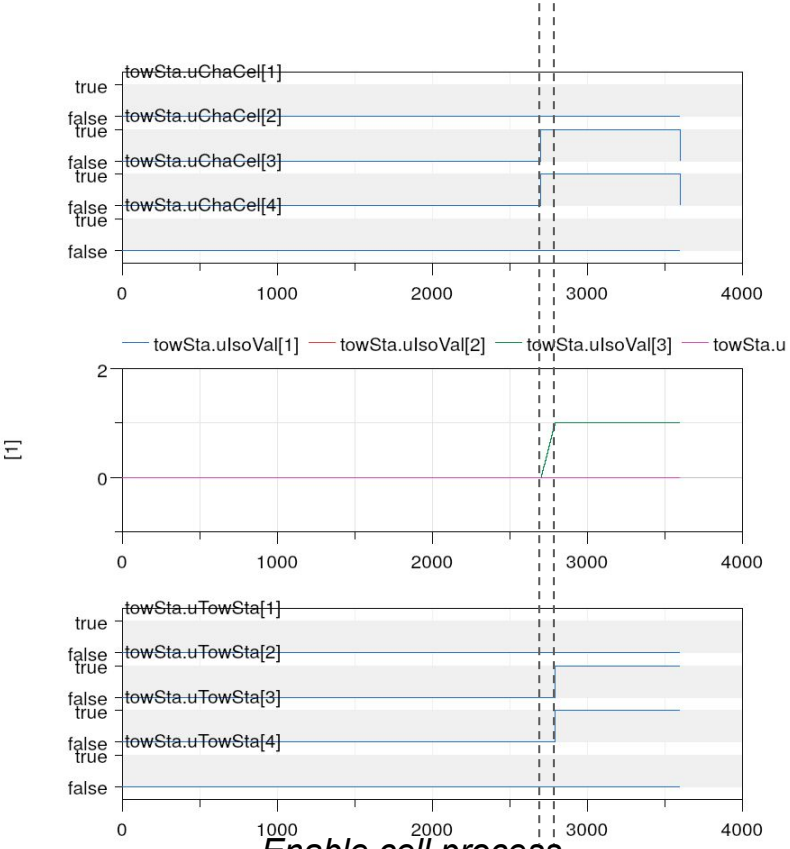
Connectors

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	uIsoVal[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	yIsoVal[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)

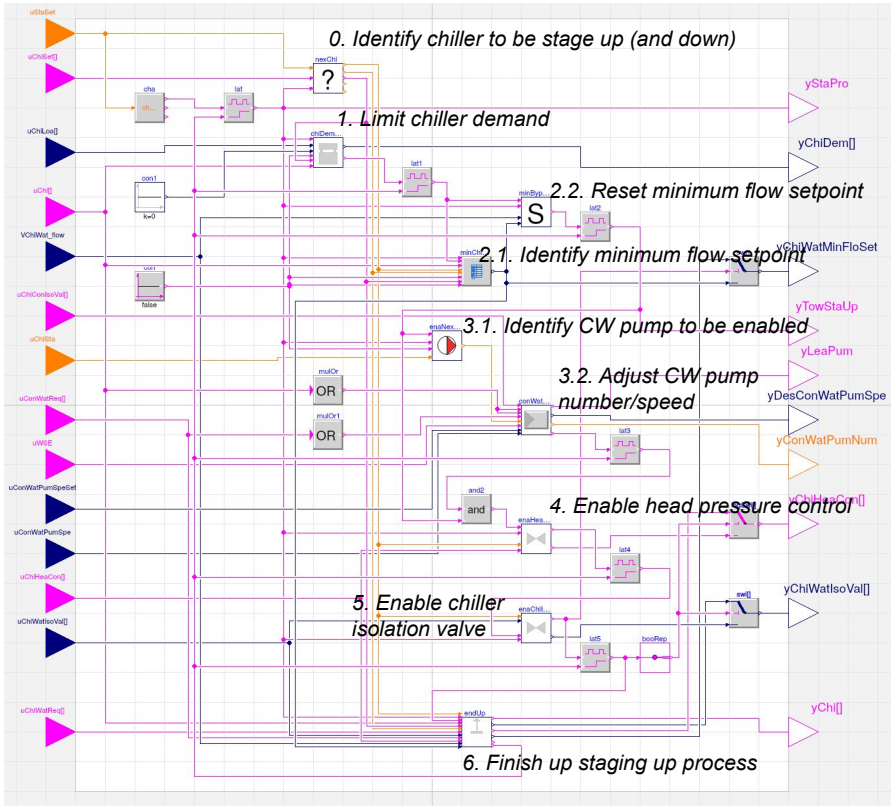


Identify number of cells



Enable cell process

Chiller staging up (Sec. 5.2.4.16)



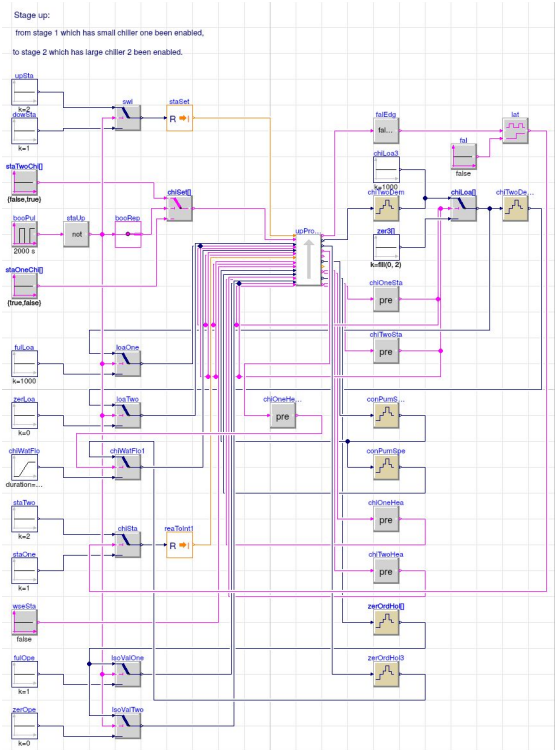
Parameters

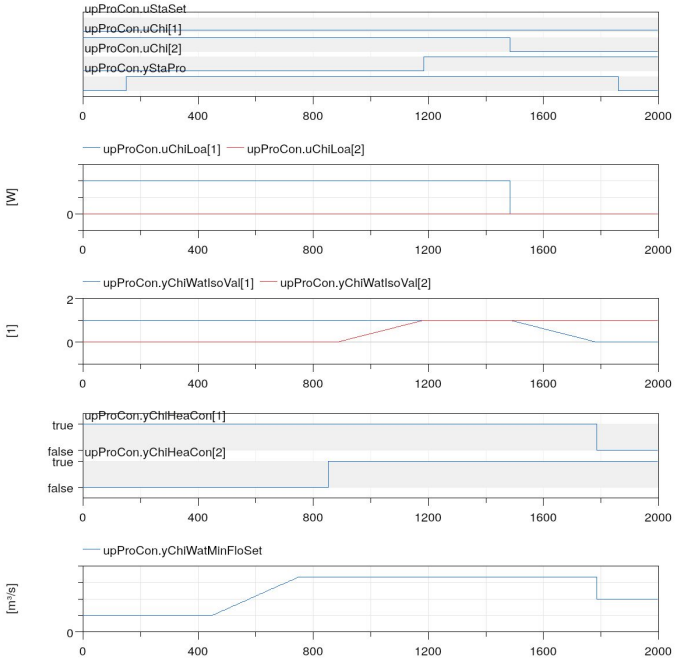
Type	Name	Default	Description
Integer	nChi	2	Total number of chillers in the plant
Integer	totSta	6	Total number of stages, including the stages with a WSE, if applicable
Boolean	haveWSE	true	Flag: true=have waterside economizer
Boolean	havePonyChiller	false	Flag: true =have pony chiller
Boolean	isParallelChiller	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 currnet 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 [m3/s]
VolumeFlowRate	maxFloSet[nChi]	{0.025,0.025}	Maximum chilled water flow through each chiller [m3/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 doule 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 doule 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	waiTim	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

- What does the “chiller load” mean? Is it a reading data from chiller itself?

- 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)





Stage setpoint
Chiller status setpoint
Stage process: On/Off

Initial chillers load

Chillers isolation valve

Chillers head pressure control

Chilled water minimum flow setpoint