PID Controller Exercise

Objectives

Use the Zeigler-Nichols method to tune a PID controller

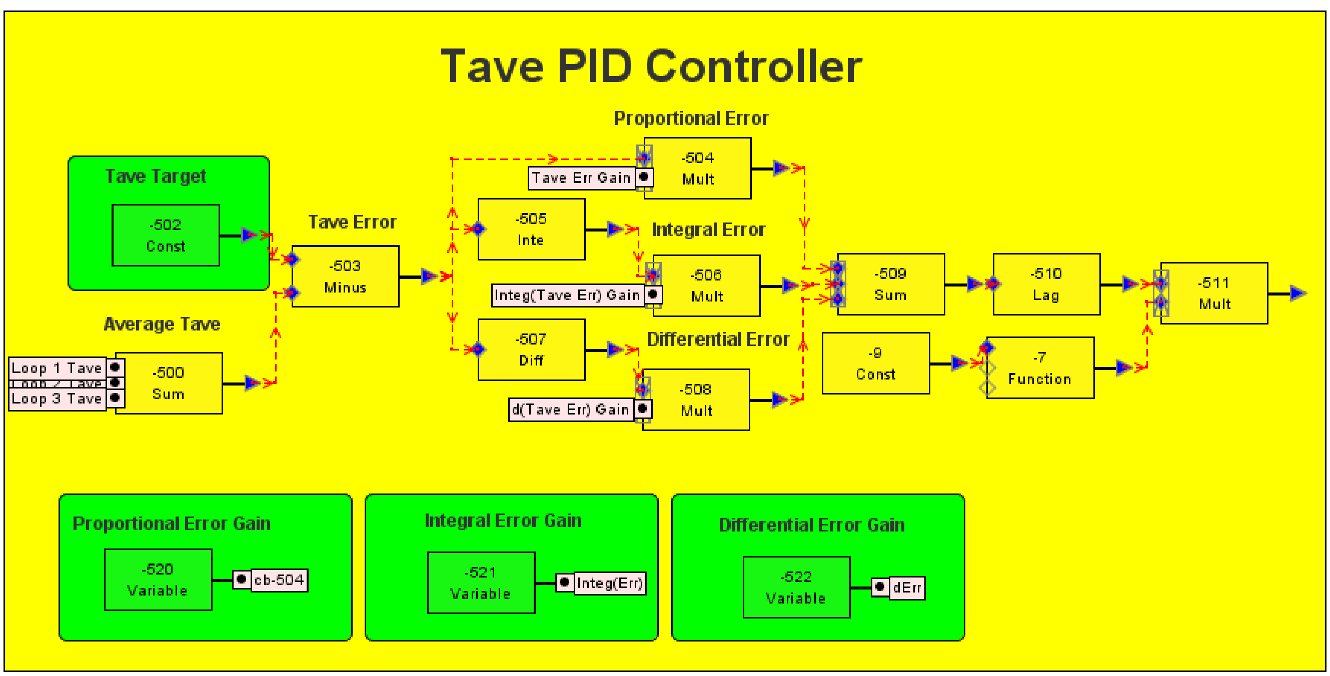
Preliminary Setup (Open Model)

Close all previous SNAP Model Editor files.

Open the 'Day3\Afternoon\PWR\2_Achieving_Steady-State\' folder and double click on 'PWR2-SS3.med' if your model is not current.

Tave Controller

The loop average temperature (T_{ave}) controller depicted below has been included in the PWR model. This adjusts the turbine control valve area in order to set the secondary side pressure. The secondary side pressure determines the secondary side boiling point which strongly influences T_{ave} .



Determine the Proportional Gain Stability Limit

To apply the Zeigler-Nichols method, the integral and differential gains should be set to zero, and the proportional gain is set to the stability limit where the T_{ave} response is oscillatory with approximately constant amplitude. To find the stability limit:

1. In the PWR model, go to the `Control System` tab and set integral gain and differential gain control variables to zero (cb -521 and cb -522).

> The proportional, integral, and differential gain control blocks (-520, -521, and -522 respectively) are Interactive Variable control blocks. Interactive Variables can be modified from a SNAP animation. We will use this to adjust the gains as the simulation runs to determine the stability limit, and later to tune the controller.

2. Set proportional gain G_p (control block -520) to the estimated stability limit from the last exercise.
3. In order to provide time to dynamically adjust the proportional gain during the simulation, go to `Model Options` in the Navigator Window and in the `Timestep Data` table set the simulation `End Time` to 2000 seconds.
4. Close the animation file that is currently open and open the animation file PWR2-SS2-Anim.med. Note that this has fields for setting the gain values.
5. Go to the PWR model and from the `Job Status` tab `Execute` the simulation.
6. Go to the animation model and connect the animation to the simulation. The proportional gain GP should show 8.4e-3 and the integral (GI) and differential (GD) gains should show 0.0.
7. Allow the control system to run until the T_{ave} steadies out. Once the response is steady, try to approximately double the proportional gain (GP).
8. Repeat step 7 until the response stabilizes into a steady oscillation.
9. To refine the stability limit, decrease GP by increments until the response starts to

decay away. Record the stability limit (i.e., the value of G_p where steady oscillations start to occur):

$G_{PMax} =$

10. If the simulation has not ended, stop the simulation. You can use the stop button in the animation view to do this.

Determine the Oscillation Period

To set the integral gain in the Zeigler-Nichols method, the period of the oscillation is needed. To get the period of the oscillation:

1. In the PWR model, go to the `Control System` tab and set the proportional gain (control block -520) to the value of G_{PMax} from step 9 in the previous section.
2. From the `Job Stream` tab, execute the simulation.
3. Connect to the animation, and observe the T_{ave} response until the oscillations have stabilized, then stop the simulation.
4. Go to the `Job Status` window and open the AptPlot file via the AptPlot icon in the view that shows the simulation output.
5. In Aptplot, plot the T_{ave} response (cb108 is the response for loop 1). Zoom in on the plot to determine the oscillation period. The oscillation period is the peak to peak time for one oscillation. View the table of plot values if needed to estimate the period for one oscillation (TP).

Peak 1 Time (T_1)	**Peak 2 Time (T_2)**	$TP=T_2-T_1$
(s)	**(s)**	**(s)**

6. Calculate the P, PI, and PID controller gains for the Zeigler-Nichols method based on the oscillation period TP and G_{PMax} values calculated above in the table below:

Controller Type	**GP**	**GI**	**GD**
P Controller	GP = ½*GPMax =	GI=0	GD=0
PI Controller	GP = 0.45*GPMax =	GI = 1.2*GPMax/TP =	GD=0
PID Controller	GP = 0.6*GPMax =	GI = 2*GPMax/TP =	GD = TP*GPMax/8 =

The next few steps will examine the response of the T_{ave} controller by changing the gains calculated for the PI and PID controllers.

1. Go to the PWR model, go to the Job Status tab and execute the model.
2. Open the animation model and connect to the simulation.
3. After the calculation has run for about 100 seconds, interactively change the gains calculated for the **PI** controller (see GP, GI and GD calculated in the table above) in the animation. Make these changes in the boxes provided on the Animation Screen (pressing the enter key on the keyboard after each change).
   a) In the box next to **P Gain (GP):** input the calculated value for **GP in the PI row**. Press the enter key.
   b) In the box next to **I Gain (GI):** input the calculated value for **GI in the PI row**.
   c) In the box next to **D Gain (GD):** input the calculated value for **GD in the PI row**.
   d) Note the change in the T_{ave} response. How has the T_{ave} been affected by the change in the PI controller gains? Is the average temperature getting closer to the target value?

4. After the calculation has run for an additional 100 seconds, interactively change the gains calculated for the **PID** controller (GP, GI and GD calculated in the table above) in the animation (refer to Steps 4a through 4c). Note the T_{ave} response with the PID controller gains. How has the T_{ave} been affected by the change in the PID controller gains? Is the average temperature getting closer to the target value?

5. Adjust the gain values from the 'Tave Control' tab in the animation. See if you can improve the setting time using the guidelines from the presentation.

Assuming the sign of the gains is correct, and that a lag control of Gain 1 and Lag constant CL is added to the PID output, the typical effect of increasing $|GP|$, $|GI|$, $|GD|$, and CL is summarized in the Table below:

	Rise Time	Overshoot	Settling Time	S-S Error	Noise
$\|GP\|$	Reduce	Increase*	-	Increase	-
$\|GI\|$	Reduce	Increase*	Reduce or Increase*	Remove	-
$\|GD\|$	-	Reduce*	Reduce	-	Increase
CL	Increase	Reduce*	Increase or Reduce*	-	Reduce

* When over-correction occurs signaled by oscillations

1. When you are finished, stop the calculation by clicking on the  button in the "Job Status" window.