

## SIMCET HOMEWORK LAB EXERCISES

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## PART B: EXAMPLES ON PRACTICE SIMULATIONS

Part B provides detailed step-by-step instructions on how to start using SIMCET for PID tuning practice. It also describes how to configure SIMCET for creating new custom simulations for your specific process.

After starting SIMCET on the SIMCET Menu, you see the Tuning Practice options. There more than are several tuning groups of processes for PID tuning practice and the first group is labelled CHEMICAL.

If you click on CHEMICAL, then the following PID tuning practice examples are available:

- Steam Flow Control on a Heat Exchanger
- Jacket Temperature Control on Reactor
- Level Control on Mixed Tank
- Surge Control on Gas Compressor
- Tray Temperature Control on Distillation Column
- Product Composition Control on Distillation Column

We recommend that you practice these six PID practice simulations under the CHEMICAL group and then you will have the knowledge to practice tuning on all other groups provided (AIR SEPARATION, COMPRESSOR, TURBINE, POLYETHYLENE REACTOR and others).

You will also learn how to create a new custom simulation, something specific to your plant or process. You can take drawings from your DCS or PLC HMI in JPG or BMP file format and easily incorporate into SIMCET. SIMCET allows you to quickly and conveniently develop a simulation of your real PID control loop on your own computer.

Note that the initial PID tuning parameters that you will find in all of the PID tuning examples in SIMCET are deliberately set to be poor (oscillatory or sluggish). Some PID tuning parameters are highly aggressive causing oscillations and others rather sluggish resulting in poor control quality. Your job is to take these initial PID tuning parameters and improve them. Tune all practice PID tuning examples as well as you can (to the best of your capability). This will help you develop good PID tuning skills.

## 1.0 EXERCISE #1: Tune Flow Control PID on a Heat Exchanger

This PID tuning practice exercise is a flow controller (FC) on a heat exchanger. See Figure 7. You are going to tune the steam flow FC (shown by a cyan circle) on the heat exchanger.

**Step #1:** Start SIMCET. On SIMCET Menu, click on CHEMICAL and then click on Flow Control on Heat Exchanger under the Tuning Practice menu screen. You will notice that the simulation starts to run. The red trend in the upper trend box is the flow PV. The blue line is the SP (setpoint). The green trend in the bottom trend box is the PID OP (output) which is also the steam flow control valve position. The SP, PV and OP values are displayed both inside the process graphic (near the cyan circle showing the FC) and on the blue, red and green bars located near the bottom right corner of the screen.

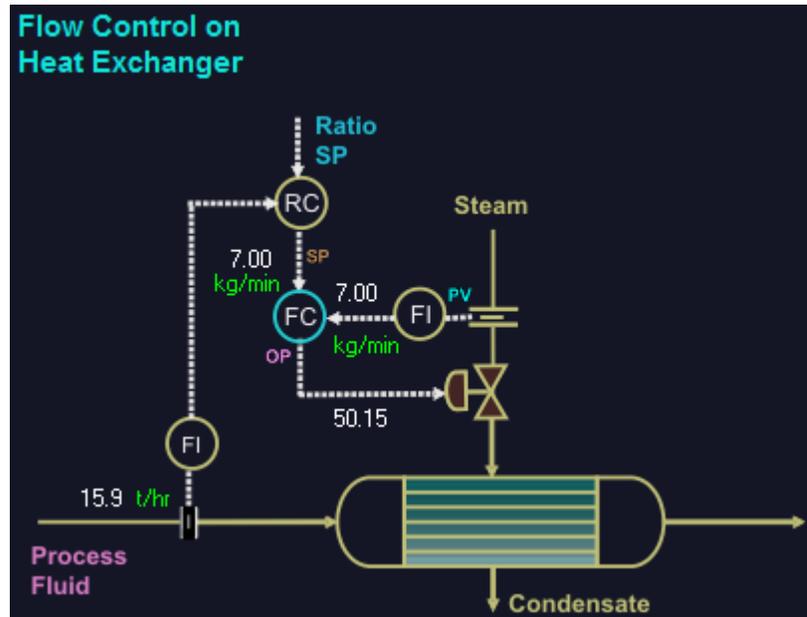
**Step #2:** Click on the Halt Simulation button on the right side of the screen to halt the simulation. Click on the Start Simulation button to restart the simulation. The Halt Simulation / Start Simulation button toggles the simulator state from start to halt.

**Step #3:** Click on Start Simulation to restart the simulation. Change the SP value from 7 to 11, press the Enter key. Notice that the PID controller (FC) reduces the OP, thereby putting less steam flow into the heat exchanger. The PV (steam flow) reduces and reaches the new SP. Click on the up/down arrows near the SP field to change the SP. Notice that the SP value changes with each click on the up or down arrows. The PID controller mode has to be Auto for you to be able to change the SP.

**Step #4:** Click on the blue button labeled Auto. This toggles the FC from auto mode to Manual mode. Notice that the green trend draws a flat line because the PID is in manual mode and its OP value is fixed. Click on OP and increase or decrease the OP value by about 5%. Now we have changed the steam valve position by 5% and you will see the blue trend (PV) changing steadily to reach new value. Make more changes in the OP value and watch the steam flow (PV). Click

on the up/down arrows near the OP field to change the OP. Notice that the OP value changes with each click on the up or down arrows. The controller mode has to be Manual for you to be able to change the OP.

**Figure 7. Tune Flow Control PID on a Heat Exchanger**



**Step #5:** Click on the red Manual button to toggle the PID to Auto mode again. Notice that the PV once again goes back to the SP. Click on Prop. Gain field and change the value from 0.1 to 3, press Enter. Notice that now the proportional action is too high and the controller starts to oscillate. The steam flow control valve goes from 0 to 100%. The FC is unstable. You will get a PV Low Alarm and PV High Alarm as the PV gets too low or too high. Change the Prop. Gain back to 0.1. The controller becomes a little more stable again.

**Step #6:** With the FC still in Auto mode, change the Integral value from 5 to 0.5, press Enter. Notice that now the integral action is too high and the controller starts to oscillate. The steam flow control valve goes from 0 to 100%. The FC is unstable. You will get a PV Low Alarm and PV High Alarm as

the PV gets too low or too high. Change the Integral back to 5. The controller becomes stable again.

**Step #7:** With the FC still in Auto mode, change the Derivative value from 0 to 10, press Enter. Notice that now the derivative action is too high and the controller output (control valve position) becomes very jagged. The steam flow control valve goes from 0 to 100%. The FC control action gets very erratic. Try different, higher values for the Derivative, (say) 25, 50 etc. Notice how jagged the control action becomes.

Note that this is a FC and normally derivative action is never used on FCs. We are adding derivative here to show the effect of derivative action for practice purposes.

The time unit in this example is seconds and so the derivative value you are specifying here is in seconds.

Note that in many DCSs, the time unit for derivative tuning is in minutes and the maximum derivative value rarely exceeds 0.5 to 2.0 minutes. Values in excess of 2 minutes are very high and probably undesirable. These are general rules for derivative tuning. Set the Derivative back to 0.

**Step #8:** With the FC still in Auto mode, change the Filter Time Constant value from 0 to 2, press Enter. Notice now that the PV signal that was so noisy before is more stable. Increase the filter time constant to 5, press Enter. Wait for at least half a minute or more and notice the stabilizing effect on the previously noisy PV. Increase the filter time constant to 100 and then you will notice that the filtering is so excessive that it manifests as extra dead time in the loop and harms control performance.

Typically for noisy flow signals, filter time constant is set to about 0.05 to 0.2 minutes. For very noisy signals, the filter can be set to 0.5 or 1 minute, but the need for such high filtering is rare. Note that in this example, the time unit is in seconds, so a value of 5 here is about 0.1 minute filter time constant.

After you have finished studying the filter time constant, set it back to 0.

**Step #9:** Keep PID in Auto mode. Click on the PID Configuration icon in the top-bar and change the PV Noise value from 1.75 to 0, press Enter. Notice now that the noise in the PV is gone. The PV Noise field allows you to quickly and easily add signal noise to the PV to make it look like a very

real plant simulation signal.

Change the SP value to (say) 10, 15, 20 etc. and notice that the PV signal reaches the new SP now without the previous noisiness. Try different values for PV Noise and press Enter each time after you make a change. You can thus adjust the level of PV signal noise. After you have finished studying the PV Noise, set it back to 1.75.

**Step #10:** The Simulation Speed control is located near the bottom right corner of the screen.

Click on Slower to slow down the simulation. Click on faster to speed up the simulation. Click on Normal for the maximum simulation speed.

When the simulation speed bar is fully blue, this means simulation speed is fastest. When the simulation speed bar is fully white, this means simulation speed is slowest.

**Step #11:** Click on Halt Simulation. Now the simulation is halted. Near the bottom of the screen, change the Simulation Time to 1000 and press Enter. Click on Start Simulation. Now notice that the simulation time span is longer. You can see more PV, SP and OP data on the trend plot windows compared to before.

Using the Simulation Time and Simulation Speed controls, you can create a simulation to just precisely match your real process dynamics. You will then feel as if you are tuning a PID controller on your DCS in your control room. Building such simulations quickly and easily is great for PID training.

**Step #12:** Click on the PID Configuration icon in the top-bar. You will see all the typical PID configuration parameters matching with the DCS and PLC systems. For detailed explanation of all the various fields and options, please see Part D, Section 2.4.

**Step #13:** Click on the Transfer Function icon in the top-bar. You will see the process transfer function parameters and the disturbance transfer function parameters. Note that the Delay, Tau1 and Tau2 (time constants) should be specified in the time unit (millisecond, second or minute) as specified next to Simulation Time near the bottom right corner on the main screen. If your units are not any of the above three choices, there is a "None" option too. For this example, the time unit is Second.

**Step #14:** At the top, you will see the top-bar menu icons:



For a description and explanation on these icons and their functionality, please see Section 2, Part D.

**Step #15:** Try to improve the control by adjusting the PID tuning parameters. You can see the control quality by making some SP changes and then make iterative adjustments.

**Step #16:** SIMCET allows you to generate CSV data files containing the PV and OP data. These CSV data files can be then read into PiControl's PITOPS software for transfer function identification and PID tuning optimization. To use this function, before making the SP step tests in Auto mode or OP step tests, click on Start Data Collection. When you are ready to save the file, click on Stop Data Collection and then click on Save Data. The CSV file is saved in the OUTPUT folder under the SIMCET root directory and now can be used in PITOPS.

After completing your study and practice of this PID loop, click on Exit Practice, and click on Yes to return to the SIMCET Menu.

## 2.0 EXERCISE #2: Tune Temperature Control PID on a Jacketed Reactor

This PID tuning practice exercise is a temperature controller (TC) on a steam heated jacketed reactor. See Figure 8. You are going to tune the TC (shown by a cyan circle) on the reactor process graphic.

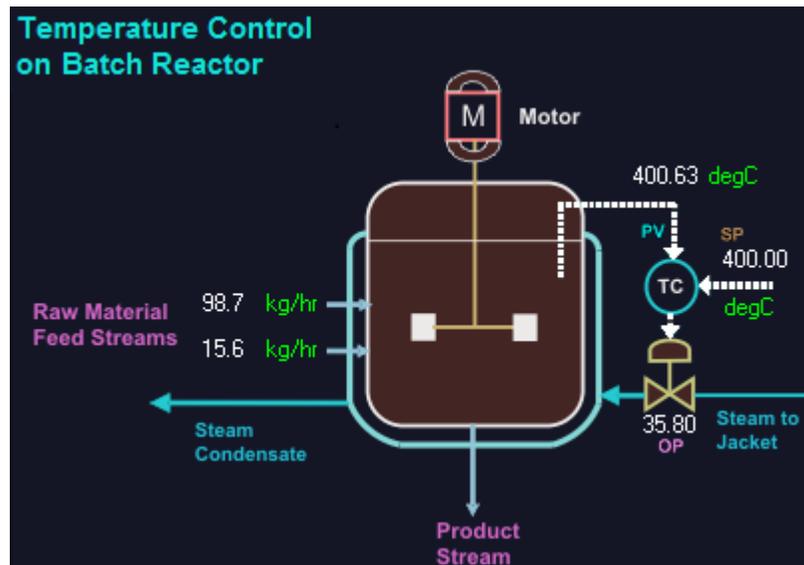
**Step #1:** Start SIMCET. On SIMCET Menu, click on CHEMICAL and then click on Temperature Control on Reactor under the Tuning Practice menu screen. You will notice that the simulation starts to run. The red trend in the upper trend box is the temperature PV. The blue line is the SP (setpoint). The green trend in the bottom trend box is the PID OP (output) which is also the steam control valve position. The SP, PV and OP values are displayed both inside the process graphic (near the cyan circle showing the TC) and on the blue, red and green bars located near the bottom right corner of the screen.

**Step #2:** Click on the Halt Simulation button on the right side of the screen to halt the simulation. Click on the Start Simulation button to restart the simulation. The Halt Simulation / Start Simulation button toggles the simulator state from start to halt.

**Step #3:** Click on Start Simulation to restart the simulation. Change the SP value from 400 to 425°C, press the Enter key. Notice that the PID controller (TC) increases the OP, thereby opening the steam control valve. The PV (temperature) increases and reaches the new SP.

Click on the up/down arrows near the SP field to change the SP. Notice that the SP value changes with each click on the up or down arrows. The PID controller mode has to be Auto for you to be able to change the SP.

**Figure 8. Tune Temperature Control PID on a Jacketed Reactor**



**Step #4:** Click on the blue button labeled Auto. This toggles the TC from auto mode to Manual mode. Notice that the green trend draws a flat line because the PID is in manual mode and its OP value is fixed. Click on OP and increase or decrease the OP value by about 5%. Now we have changed

the steam valve position by 5% and you will see the blue trend (PV) changing steadily to reach new value. Make more changes in the OP value and watch the temperature (PV). Click on the up/down arrows near the OP field to change the OP. Notice that the OP value changes with each click on the up or down arrows. The controller mode has to be Manual for you to be able to change the OP.

**Step #5:** Click on the red Manual button to toggle the PID to Auto mode again. Notice that the PV once again goes back to the SP. Click on Prop. Gain field and change the value from 3 to 11, press Enter. Notice that now the proportional action is too high and the controller starts to oscillate. The steam control valve goes from 0 to 100%. The TC is unstable. You will get a PV Low Alarm and PV High Alarm as the PV gets too low or too high. Change the Prop. Gain back to 13. The controller becomes somewhat stable again.

**Step #6:** With the TC still in Auto mode, change the Integral value from 3 to 0.3, press Enter. Notice that now the integral action is too high and the controller starts to oscillate. The steam control valve goes from 0 to 100%. The TC is unstable. You will get a PV Low Alarm and PV High Alarm as the PV gets too low or too high. Change the Integral back to 3. The controller becomes somewhat stable again.

**Step #7:** With the TC still in Auto mode, change the Derivative value from 0.25 to 5, press Enter. Notice that now the derivative action is too high and the controller output (control valve position) becomes very jagged. The TC control action gets very erratic. Try different, higher values for the Derivative, (say) 25, 50 etc. Notice how jagged the control action becomes. Restore Derivative back to 0.25.

Note that this is a TC and derivative action can benefit in some cases if signal is not too noisy or if adequate filtering is used on the PV.

The time unit in this example is minute and so the derivative value you are specifying here is in minutes. Near the bottom right corner of the screen, to the right of Simulation Time, you will see that Minute has been selected and all time dependent parameters in this example must be specified in minutes for consistency and correctness. If you click on Minute, you can see the four options – None, Millisecond, Second and Minute.

Note that in many DCSs, the time unit for derivative tuning is in minutes and the maximum derivative value rarely exceeds 0.5 to 2.0 minutes. Values in excess of 2 minutes are very high and probably undesirable. These are some concise rules of thumb for derivative tuning.

**Step #8:** Keep the TC still in Auto mode. Click on the PID Configuration icon in the top-bar, click on PV Noise and change the value from 0.33 to 4, and click OK. The PV Noise field allows you to quickly and easily add signal noise to the PV to make it look like a very real plant simulation signal. The value 4 we just changed defines the noise band as a percent of the CV range of the instrument. The CV Range can also be seen under the PID Configuration menu. Click on the PID Configuration icon in the top-bar and see the CV Range is 0-500. The 4% PV Noise band we defined means that we have a noise signal in the PV that is 4% of the CV range which is 500. Now the PV will randomly move by 4% of 500 or 20.

**Step #9:** With the TC still in Auto mode, change the Proportional Gain to 1.0 and change the Filter Time Constant value from 0 to 1.5, press Enter. Notice now that the PV signal that was just a little noisy before is now more stable. Reduce the filter time constant to 0 and then you will notice the increase in noise in the PV.

Typically for noisy temperature signals, filter time constant is set to about 0.02 to 0.2 minutes. For very noisy signals, the filter can be set to 0.5 minute, but the need for such high filtering is rare. Note that in this example, the time unit is in minutes. After you have finished studying the filter time constant, set it back to 0.

**Step #10:** The Simulation Speed control is located near the bottom right corner of the screen. Click on Slower to slow down the simulation. Click on faster to speed up the simulation. Click on Normal for the maximum simulation speed.

When the simulation speed bar is fully blue, this means simulation speed is fastest. When the simulation speed bar is fully white, this means simulation speed is slowest.

**Step #11:** Click on Halt Simulation. Now the simulation is halted. Near the bottom of the screen, change the Simulation Time to 1000 and press Enter. Click on Start Simulation. Now

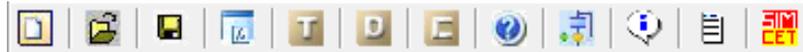
notice that the simulation time span is longer. You can see more PV, SP and OP data on the trend plot windows compared to before.

Using the Simulation Time and Simulation Speed controls, you can create a simulation to just precisely match your real process dynamics. You will then feel as if you are tuning a PID controller on your DCS in your control room. Building such simulations quickly and easily is great for PID training and practice.

**Step #12:** Click on the PID Configuration icon in the top-bar. You will see all the typical PID configuration parameters matching with the DCS and PLC systems. For detailed explanation of all the various fields and options, please see Part D, Section 2.4.

**Step #13:** Click on the Transfer Function icon in the top-bar. You will see the process transfer function and the disturbance transfer function parameters for the PID control loop.

**Step #14:** At the top, you will see the top-bar menu icons:



For a description and explanation on these icons and their functionality, please see Section 2, Part D.

**Step #15:** Make some SP changes and adjust the PID tuning to improve the control to the best of your capability. After completing your study and practice of this PID loop, click on Exit Practice, and click on Yes to return to the SIMCET Menu.

### 3.0 EXERCISE #3: Tune Level Control PID on a Mixed Tank Reactor

This PID tuning practice exercise is a level controller (LC) on a mixed tank reactor. See Figure 9. You are going to tune the LC (shown by a cyan circle) on the reactor process graphic.

**Step #1:** Start SIMCET. On SIMCET Menu, click on CHEMICAL and then click on Level Control on Mixed Tank under the Tuning Practice menu screen. You will notice that the simulation starts to run. The red trend in the upper trend box is the reactor level PV. Note that various unmeasured disturbances are present in this simulation that causes the

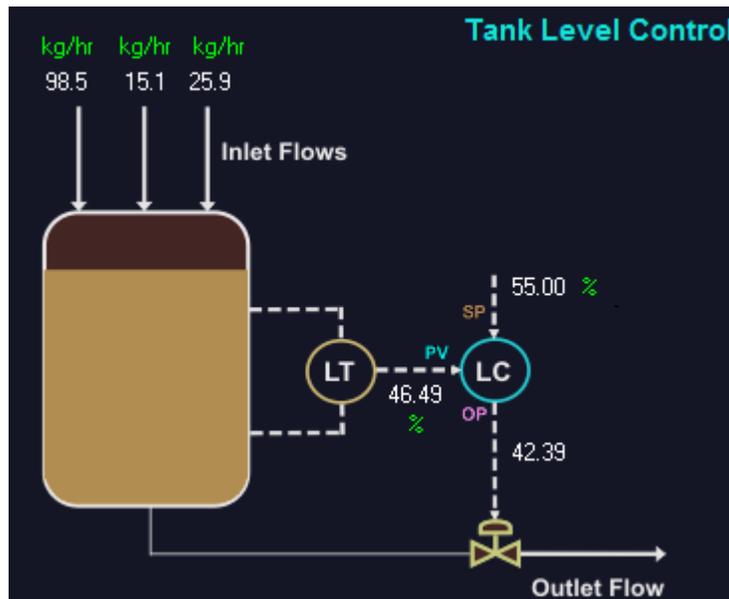
level PV to dip and spike at different times. Your job is to tune the LC well so that it provides the best control for rejecting the disturbances as well as providing good SP control.

The blue line is the SP (setpoint). The green trend in the bottom trend box is the LC OP (output) which is also the outflow control valve position.

The SP, PV and OP values are displayed both inside the process graphic (near the cyan circle showing the LC) and on the blue, red and green bars located near the bottom right corner of the screen.

**Step #2:** Click on the Halt Simulation button on the right side of the screen to halt the simulation. Click on the Start Simulation button to restart the simulation. The Halt Simulation / Start Simulation button toggles the simulator state from start to halt.

**Figure 9. Tune Level Control PID on a Mixed Tank Reactor**



**Step #3:** Click on Start Simulation to restart the simulation. Change the SP value from 55 to 40%, press the Enter key. Notice that when the SP was changed, the PID controller (LC) immediately increases the OP, thereby opening the valve.

Note that the PV (reactor level) is oscillatory due to bad PID tuning. Your job is to adjust the PID tuning parameters so that the oscillations are gone and SP changes produces fast and stable control.

Click on the up/down arrows near the SP field to change the SP. Notice that the SP value changes with each click on the up or down arrows. The PID controller mode has to be Auto for you to be able to change the SP.

**Step #4:** Click on the blue button labeled Auto. This toggles the LC from auto mode to Manual mode. Notice that the green trend draws a flat line because the LC is in manual mode and its OP value is fixed. Click on OP and increase or decrease the OP value by about 10%. Now we have changed the outflow valve position and you will see the blue trend (level PV) change steadily. Make more changes in the OP value and watch the level PV. Click on the up/down arrows near the OP field to change the OP. Notice that the OP value changes with each click on the up or down arrows. The controller mode has to be Manual for you to be able to change the OP.

**Step #5:** Click on the red Manual button to toggle the PID to Auto mode again. Notice that the PV once again goes back to the SP. Click on Prop. Gain field and change the value from to 10, press Enter. Notice that now the proportional action is too high and the controller starts to oscillate severely. The outflow control valve goes from 0 to 100%. The LC is unstable. You will get a PV Low Alarm and PV High Alarm as the PV gets too low or too high. Change the Prop. Gain back to the original value and try to make the control stable.

**Step #6:** With the LC still in Auto mode, change the Integral value from 5 to 0.5 and press Enter. Notice that now the integral action is too high and the controller starts to oscillate. The control valve goes from 0 to 100%. The LC is unstable. You will get a PV Low Alarm and PV High Alarm as the PV gets too low or too high. Change the Integral back to 40. The controller becomes stable again.

**Step #7:** With the LC still in Auto mode, change the Derivative value from 0.5 to 5, press Enter. Notice that now the derivative action is too high and the controller output (control valve position) becomes very jagged. The LC control action gets very erratic. Try different, higher values for the

Derivative, (say) 10, 15 etc. Notice how jagged the control action becomes.

Note that this is a LC and derivative action can benefit in some cases if signal is not too noisy or if adequate filtering is used on the PV.

Near the bottom right corner of the screen, notice next to Simulation Time, the time unit in this example is Minute. This means that all parameters that have time unit must be specified values that are in minutes. This includes the integral and derivative tuning parameters, which must be entered in minutes. Also please note that the transfer function for level type transfer function is zero-order transfer function (also called ramp or integrating type transfer function). The process gain for zero-order transfer function is the ramp rate which has the unit of CV/MV/Time, so in this case the unit is % level/%valve position/minute.

Note that in many DCSs, the time unit for derivative tuning is in minutes and the maximum derivative value rarely exceeds 0.5 to 2.0 minutes. Values in excess of 2 minutes are very high and probably undesirable. These are general rules for derivative tuning. Set the Derivative back to 0.5.

**Step #8:** With the LC still in Auto mode, change the Prop. Gain to 1.0, Integral to 20, Derivative to 0, Filter Time Constant to 0 and Simulation Time to 200. Click on the PID Configuration icon in the top-bar, click on PV Noise and change the value from 2 to 5, and click OK. Click on Start Simulation. Notice now that the noise level in the PV is very high. The PV Noise field allows you to quickly and easily add signal noise to the PV to make it look like a very real plant simulation signal.

Change the SP value by (say) 10 or 15% and study the effect of different noise levels on the PV signal and the LC control action.

**Step #9:** With the LC still in Auto mode, change the Filter Time Constant value to 5, press Enter. Notice now that the PV signal that was very noisy before is now smoother and more stable.

Change the filter time constant to 2, 10, etc. and press Enter after each change. Wait for at least half a minute or more and notice the effect of filtering.

Reduce the filter time constant to 0 and then you will notice the increase in noise in the PV.

Filtering is typically not needed on most LCs because the PV noise level is normally quite low. For noisy level signals, filter time constant can be set to about 0.02 to 0.05 minutes.

**Step #10:** The Simulation Speed control is located near the bottom right corner of the screen.

Click on Slower to slow down the simulation. Click on faster to speed up the simulation. Click on Normal for the maximum simulation speed.

When the simulation speed bar is fully blue, this means simulation speed is fastest. When the simulation speed bar is fully white, this means simulation speed is slowest.

**Step #11:** Click on Halt Simulation. Now the simulation is halted. Near the bottom of the screen, change the Simulation Time to 100 and press Enter. Click on Start Simulation.

Now notice that the simulation time span is shorter. You can see more PV, SP and OP data on the trend plot windows compared to before.

Using the Simulation Time and Simulation Speed controls, you can create a simulation to just precisely match your real process dynamics.

You will then feel as if you are tuning a PID controller on your DCS in your control room. Building such simulations quickly and easily is great for PID training and practice.

**Step #12:** Click on the PID Configuration icon in the top-bar. You will see all the typical PID configuration parameters matching with the DCS and PLC systems. For detailed explanation of all the various fields and options, please see Part D, Section 2.4.

**Step #13:** Click on the Transfer Function icon  in the top-bar. You will see the disturbance transfer function parameters for the loop. Process transfer function parameters are not displayed.

**Step #14:** At the top, you will see the top-bar menu icons:



For a description and explanation on these icons and their functionality, please see Section 2, Part D.

**Step #15:** After completing your study and practice of this PID loop, click on Exit Practice, and click on Yes to return to the SIMCET Menu.

#### 4.0 EXERCISE #4: Tune Surge Control PID on a Compressor

SIMCET can be configured to simulate fast gas compressor surge control in the second to millisecond timeframe.

Compressor surge is controlled by manipulating the anti-surge valve, also called the kick-back valve or the spill-back valve. Many compressor control systems are equipped with custom process control hardware with an independent data trending system. Or, in some cases, fast scanning PC-based trending packages directly connected to the compressor signals allow you to see the compressor variables on a fast scan time base.

Different compressor vendors use different methods for calculating the surge variable. Surge is a function of the compressor power, or flow through the compressor and the suction/discharge pressure. The method of tuning explained here does not require the user to know the surge calculation method used by the vendor. All that is required is the transfer function between the spill-back valve and the surge variable.

This PID tuning practice exercise is a surge controller (UC) on a gas compressor. See Figure 10. A Surge Controller is often abbreviated as "UC". You are going to tune the UC (shown by a cyan circle) on the compressor process graphic.

**Step #1:** Start SIMCET. On SIMCET Menu, click on CHEMICAL, and then click on Surge Control on Gas Compressor. You will notice that the simulation starts to run.

The red trend in the upper trend box is the compressor surge PV. The blue line is the SP (setpoint). The green trend in the bottom trend box is the UC OP (output) which is also the recirculation (spill-back) valve position. The SP, PV and OP values are displayed both inside the process graphic (near the cyan circle showing the UC) and on the blue, red and green bars located near the bottom right corner of the screen.

**Step #2:** Click on the Halt Simulation button on the right side of the screen to halt the simulation. Click on the Start Simulation button to restart the simulation. The Halt

Simulation / Start Simulation button toggles the simulator state from start to halt.

**Step #3:** Click on Start Simulation to restart the simulation. Change the SP value from 17 to 21%, press the Enter key. Notice that the PID controller (UC) decreases the OP, thereby closing the spill-back control valve. The PV (compressor surge) decreases and reaches the new SP. Click on the up/down arrows near the SP field to change the SP. Notice that the SP value changes with each click on the up or down arrows. The PID controller mode has to be Auto for you to be able to change the SP.

**Step #4:** Click on the blue button labeled Auto. This toggles the UC from auto mode to Manual mode. Notice that the green trend draws a flat line because the UC is in manual mode and its OP value is fixed. Click on OP and increase or decrease the OP value by (say) 2%. Now we have changed the spill-back valve position and you will see the blue trend (surge) change steadily. Make more changes in the OP value and watch the level PV. Click on the up/down arrows near the OP field to change the OP. Notice that the OP value changes with each click on the up or down arrows. The controller mode has to be Manual for you to be able to change the OP.

**Step #5:** Click on the red Manual button to toggle the PID to Auto mode again. Notice that the OP starts to change again due to the PID control action. Click on Prop. Gain field and change the value from 2, press Enter. Notice that now the proportional action is too high and the controller starts to oscillate. The spill-back valve goes from 0 to 100%. The UC is unstable. You will get a PV Low Alarm and PV High Alarm as the PV gets too low or too high. Change the Prop. Gain to 0.15 and Integral to 30. The controller becomes stable again. Wait for at least a minute for the UC to stabilize.

**Step #6:** With the UC still in Auto mode, change the Integral value to 2, press Enter. Wait for 1-2 minutes to see the trends. Notice that now the integral action is too high and the controller starts to oscillate. The steam control valve goes from 0 to 100%. The UC is unstable. You will get a PV Low Alarm and PV High Alarm as the PV gets too low or too high. Change the Integral to 30. The controller becomes stable again.

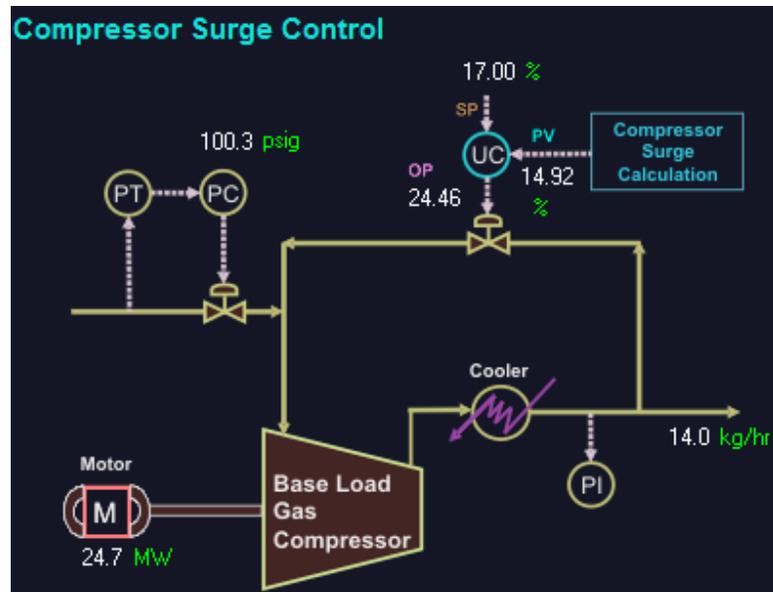
**Step #7:** With the UC still in Auto mode, change the Derivative value from 0 to 5, press Enter. Notice that now the derivative action is rather high and the controller output (spill-back valve position) becomes jagged. The UC control action gets erratic. Try other different, higher and lower values for the Derivative, (say) 0.2, 1, 2, 10 etc. and compare the control action.

Note that this is a compressor surge controller (UC) on which derivative action is rarely used.

The time unit in this example is Millisecond and so the derivative value you are specifying here is in milliseconds. Set the Derivative back to 0.

The time unit specification can be seen near the bottom right corner of the screen where you will see Millisecond. If you click on the Millisecond button, you see the various options. For creating a new simulation (the procedure for this is described later), you can change the time unit by clicking here (None, Millisecond, Second or Minute).

**Figure 10. Tune Surge Control PID on a Compressor**



**Step #8:** Click on the PID Configuration icon in the top-bar, click on PV Noise and change the value from 0.9 to 5, and click OK. Click on Start Simulation. Keep the UC still in Auto mode. Notice now that the noise level in the PV is very high. The PV Noise field allows you to quickly and easily add signal noise to the PV to make it look like a very real plant simulation signal.

Change the SP value by (say) 5 or 10% and study the effect of different noise levels on the PV signal and the UC control action.

**Step #9:** With the UC still in Auto mode, change the Filter Time Constant value from 0 to 5, press Enter. Notice now that the PV signal that was just a little noisy before is now smoother and more stable. Change the filter time constant to 2, 3, etc. and press Enter after each change. Wait for at least half a minute or more and notice the effect of filtering. Reduce the filter time constant to 0 and then you will notice the increase in noise in the PV.

Filtering can benefit UCs if the calculated surge signal is noisy. For noisy signals, filter time constant can be set to about 0.02 to 0.05 minutes. After you have finished studying the filter time constant, set it back to 0.

**Step #10:** The Simulation Speed control is located near the bottom right corner of the screen.

Click on Slower to slow down the simulation. Click on faster to speed up the simulation. Click on Normal for the maximum simulation speed.

When the simulation speed bar is fully blue, this means simulation speed is fastest. When the simulation speed bar is fully white, this means simulation speed is slowest.

**Step #11:** Click on Halt Simulation. Now the simulation is halted. Near the bottom of the screen, change the Simulation Time to 100 or 500 and press Enter. Click on Start Simulation. Now notice that the simulation time span is shorter. You can see more PV, SP and OP data on the trend plot windows compared to before.

Using the Simulation Time and Simulation Speed controls, you can create a simulation to just precisely match your real process dynamics. You will then feel as if you are tuning a PID controller on your DCS in your control room. Building

such simulations quickly and easily is great for PID training and practice.

**Step #12:** Click on the PID Configuration icon in the top-bar. You will see all the typical PID configuration parameters matching with the DCS and PLC systems. For detailed explanation of all the various fields and options, please see Part D, Section 2.4.

**Step #13:** Click on the Transfer Function icon  in the top-bar. You will see the process transfer function and the disturbance transfer function parameters for the PID control loop. The process transfer function parameters can also be estimated by doing a step test on the OP with the UC in Manual mode. By visual inspection, you can estimate the process transfer function parameters to be as follows:

- Delay time = 40 milliseconds
- Process Gain = 2.33 %surge / (%valve position)
- First order time constant = 25 milliseconds

These parameters define the process dynamics between the spill-back control valve and the surge calculation. This means that if the spill-back valve is changed by 1.0 %, the total final change in surge variable is 2.33 (units of % surge).

**Step #14:** At the top, you will see the top-bar menu icons:



For a description and explanation on these icons and their functionality, please see Section 2, Part D.

**Step #15:** After completing your study and practice of this PID loop, click on Exit Practice, and click on Yes to return to the SIMCET Menu.

## 5.0 EXERCISE #5: Tune Temperature Control PID on a Distillation Column

This PID tuning practice exercise is a temperature controller (TC) on a distillation column. You are going to tune the cascade TC only on the distillation column process graphic. The slave steam flow FC is well tuned already and does well to achieve the steam flow that the cascade TC asks for.

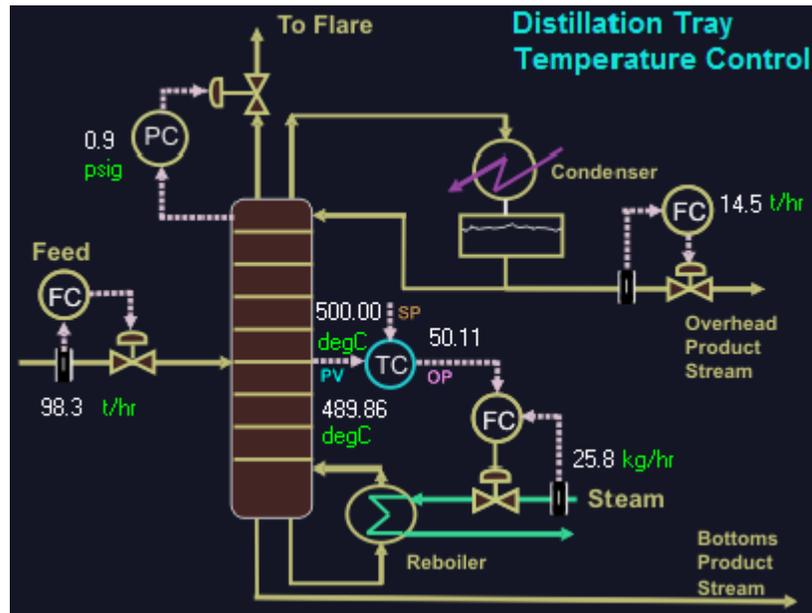
**Step #1:** Start SIMCET. On SIMCET Menu, click on CHEMICAL and then click on Temperature Control on Distillation Column. You will notice that the simulation starts to run. The red trend in the upper trend box is the temperature PV. The blue line is the TC's SP (setpoint). The green trend in the bottom trend box is the PID OP (output) which manipulates the slave steam flow FC. The SP, PV and OP values are displayed both inside the process graphic (near the cyan circle showing the TC) and on the blue, red and green bars located near the bottom right corner of the screen.

**Step #2:** Click on the Halt Simulation button on the right side of the screen to halt the simulation. Click on the Start Simulation button to restart the simulation. The Halt Simulation / Start Simulation button toggles the simulator state from start to halt.

**Step #3:** Click on Start Simulation to restart the simulation. Change the SP value from 500 to 600°C, press the Enter key. Notice that the PID controller (TC) increases the OP, thereby asking for more steam flow. The PV (temperature) increases and reaches the new TC SP. Click on the up/down arrows near the SP field to change the SP. Notice that the SP value changes with each click on the up or down arrows. The PID controller mode has to be Auto for you to be able to change the SP.

**Step #4:** Click on the blue button labeled Auto. This toggles the TC from auto mode to Manual mode. Notice that the green trend draws a flat line because the TC is in manual mode and its OP value is fixed. Click on OP and increase or decrease the OP value by about 5%. Now we have changed the TC's OP by 5%. This increases the steam FC's SP and causes the temperature PV to reach the new TC SP. Make more changes in the OP value and watch the temperature (PV). Click on the up/down arrows near the OP field to change the OP. Notice that the OP value changes with each click on the up or down arrows. The controller mode has to be Manual for you to be able to change the OP.

Figure 11. Tune Temperature Control PID on a Distillation Column



**Step #5:** Click on the red Manual button to toggle the TC to Auto mode again. Notice that the PV once again goes back to the SP. Click on Prop. Gain field and change the value to 3, press Enter. Notice that now the proportional action is too high and the controller starts to oscillate. The TC's OP goes up and down from 0 to 100%. The TC is unstable. You will get a PV Low Alarm and PV High Alarm as the PV gets too low or too high. Change the Prop. Gain back to 0.3 and Integral to 30. The controller becomes stable again. Wait for a minute or two to allow time for the controller to stabilize.

**Step #6:** With the TC still in Auto mode, change the Integral value to 2, press Enter. Notice that now the integral action is too high and the controller starts to oscillate. The TC's OP goes up and down from 0 to 100%. The TC is unstable. You will get a PV Low Alarm and PV High Alarm as the PV gets too low or too high. Change the Integral back to 30. The controller becomes stable again.

**Step #7:** With the TC still in Auto mode, change the Derivative value to 5, press Enter. Notice that now the derivative action is too high and the TC becomes unstable. Try different values for the Derivative, (say) 2, 10, 15 etc. Notice how undesirable the control action becomes.

Note that this is a TC and derivative action can benefit in some cases if signal is not too noisy or if adequate filtering is used on the PV.

The time unit in this example is minutes and so the derivative value you are specifying here is in minutes.

The time unit for this example is Minute. Notice the label Minute near the bottom right corner of the screen to the right of Simulation Time.

Note that in many DCSs, the time unit for derivative tuning is in minutes and the maximum derivative value rarely exceeds 0.5 to 2.0 minutes. Values in excess of 2 minutes are very high and probably undesirable. These are general rules of thumb for derivative tuning. Set the Derivative back to 1.

**Step #8:** With the TC still in Auto mode, change the Filter Time Constant value to 2, press Enter. Notice now that the PV signal that was just a little noisy before is now more stable.

Increase the filter time constant to 5, press Enter. Notice that if the filtering is very high (say) 50 or 100 then with excessive filtering the TC can become unstable. Reduce the filter time constant back to 0.

Typically for noisy temperature signals, filter time constant is set to about 0.02 to 0.2 minutes. For very noisy signals, the filter can be set to 0.5 minute, but the need for such high filtering is rare. Note that in this example, the time unit is in minutes.

**Step #9:** Keep the TC still in Auto mode. Click on the PID Configuration icon in the top-bar, click on PV Noise and change the value to 10, and click OK. Click on Start Simulation. Notice now that the PV signal becomes very noisy. The PV Noise field allows you to quickly and easily add signal noise to the PV to make it look like a very real plant simulation signal.

Try different values for PV Noise and press Enter each time after you make a change. You can thus adjust the level of PV signal noise. Afterwards, set it to 1.25.

**Step #10:** The Simulation Speed control is located near the bottom right corner of the screen.

Click on Slower to slow down the simulation. Click on faster to speed up the simulation. Click on Normal for the maximum simulation speed.

When the simulation speed bar is fully blue, this means simulation speed is fastest. When the simulation speed bar is fully white, this means simulation speed is slowest.

**Step #11:** Click on Halt Simulation. Now the simulation is halted. Near the bottom of the screen, change the Simulation Time to 1000 and press Enter. Click on Start Simulation. Now notice that the simulation time span is longer. You can see more PV, SP and OP data on the trend plot windows compared to before.

Using the Simulation Time and Simulation Speed controls, you can create a simulation to just precisely match your real process dynamics. You will then feel as if you are tuning a PID controller on your DCS in your control room. Building such simulations quickly and easily is great for PID training and practice.

**Step #12:** Click on the PID Configuration icon in the top-bar. You will see all the typical PID configuration parameters matching with the DCS and PLC systems. For detailed explanation of all the various fields and options, please see Part D, Section 2.4.

**Step #13:** Click on the Transfer Function icon in the top-bar. You will see the process transfer function and the disturbance transfer function parameters for the loop.

**Step #14:** At the top, you will see the top-bar menu icons:



For a description and explanation on these icons and their functionality, please see Section 2, Part D.

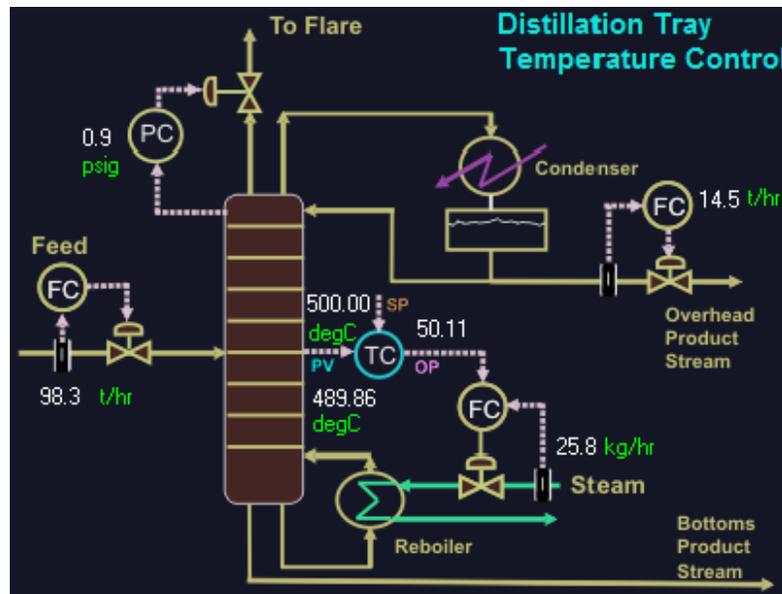
**Step #15:** After completing your study and practice of this PID loop, click on Exit Practice, and click on Yes to return to the SIMCET Menu.

## 6.0 EXERCISE #6: Create New Custom Simulation

This exercise shows you how to create a new custom simulation to fit your specific process at your plant. We will illustrate using a distillation column control scheme as shown in Figure 12.

The master TC (see cyan circle) controls temperature near the feed tray location by manipulating reboiler steam flow controlled by a slave FC. The master TC's temperature range (PV range) is 0 – 300 °C. Temperature typically runs at 170 °C. The slave FC is well tuned and has a flowmeter range of 0 - 50 t/h.

Figure 12. TC-FC Cascade Loop



See Figure 12 to see the steam flow versus temperature cascade dynamic relationship. The objective of this exercise is to find good tuning parameters for the master TC (the slave FC is already well tuned).

Now we will configure and tune the TC as explained below:

**Step #1:** Start SIMCET. On SIMCET Menu, click on the New Case File icon in the top-bar. This initializes data with startup default values to configure a new PID simulation. Click on Halt Simulation to stop the simulation.

**Step #2:** Near the bottom right corner of the screen, you will see a button labelled None. None means that we have not yet specified the time unit for this simulation example. Click on None and select Minute. In this simulation, our process is slow and time unit minute is the most suitable. For faster processes, use Second or Millisecond. Once you select the time unit as millisecond, second or minute then you must stay consistent and specify the values for all time-dependent parameters in the same selected time unit. In this example, since we have chosen minutes as the time unit, then all-time dependent variables - delay time, time constants, time axis (X-axis) are in minutes.

**Step #3:** Click on PID Configuration icon in the top-bar and then click on Instrument Range.

Keep the CV Range Low at 0°C and change the CV Range High to 300 °C. This is the temperature range (master TC's range).

Keep the MV Range Low to 0 lb/h and change MV Range High to 50 t/h. This is the slave FC's range (also the TC's output range). The TC's OP manipulates the slave's SP.

Click on PID Equation. The default option is equation B0. Keep this B0 or select any other option to match your DCS or PLC.

Click on PID Execution Period. The default option is 1. You can select any other option, as desired.

Click on PV Noise and set it to 2.0 and then click OK. This adds some random noise to the simulation.

You can now go to the next step below, since the remaining fields are of an advanced nature and may be left at their default values. However, if you want to familiarize with all the fields - PID Equation, PID Execution Period, PV Sample Delay, Gap Action, Initial PID Output, and Transform, please see Part D, Section 2.4.

Click on Start Simulation.

**Step #4:** Click on the Transfer Function icon . You will see the Process and Disturbance transfer function parameters.

You can change these transfer function parameters based on your process knowledge. The default parameters are: Process Transfer Function: Delay = 5 minute, Gain = 2, Tau1 = 20 minute and Tau2 = 0 minute and for Disturbance Transfer Function: Delay = 0 min, Gain = 1, Time Constant = 5 minute (same as Tau1 for disturbance).

**Step #5:** On the simulation screen, set SP = 170°C, and then press Enter. Click on Halt Simulation / Start Simulation button. This initializes the SP to 170°C.

**Step #6:** Change SP from 170 to 190°C and press the Enter key. Notice that the OP (steam flow) increases and the PV (temperature) starts changing to its new SP of 190°C.

The initial default tuning parameters are: Prop. Gain = 0.2, Integral = 15, Derivative = 0 and Filter Time Constant = 0. Try different tuning parameters and filtering. Click Start Simulation. Sample trial values: Proportional Gain = 0.5, 1, 3, 5, 10, Integral = 5, 10, 15, 30, 100, Derivative = 0.5, 1, 3, 5, 10, Filter = 0.5, 1, 2, 3.

**Step #7:** Now we will configure and activate disturbance signals. See Figure 13 below for the location and details of the disturbance signal. (Click on the Control Schematic icon in the top-bar at any time for a quick reference also).

**Step #8:** Click on the Disturbances icon to see the Disturbances menu.

Click on Pulse. Click On to activate the pulse. Set Width to 70 (minutes) and Change to 10 °C. Keep the default Regular option selected. See Section 2.6, Part D for detailed explanation on these parameters. Click OK. On the main screen click on the blue Auto button to toggle the controller to Manual mode. Now you can see the effect of the pulse disturbance on the simulation. Click on Start Simulation if simulation is not running.

**Step #9:** Click on the Disturbances icon to see the Disturbances menu. Turn the Pulse to Off.

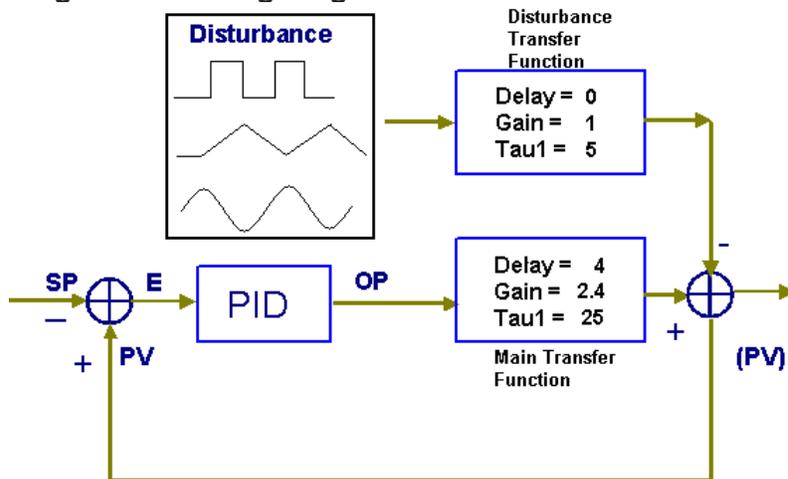
Click on Ramp. Click On to activate the ramp. Set Rate to 0.3 and Change to 15. See Section 2.6, Part D for detailed explanation on these parameters. Click OK. With the controller in Manual mode you can see the effect of the ramp disturbance on the simulation. Click on Start Simulation if simulation is not already running.

**Step #10:** Click on the Disturbances icon to see the Disturbances menu. Turn the Pulse and Ramp to Off. Click on Sine. Click On to activate the sinusoidal wave disturbance. Set Frequency to 0.1 and Amplitude to 5. See Section 2.6, Part D for detailed explanation on these parameters. Click OK. With the controller in Manual mode you can see the effect of the sine wave disturbance on the simulation. Click on Start Simulation if simulation is not already running.

**Step #11:** Click on the Disturbances icon to see the Disturbances menu. Turn all three disturbances (Pulse, Ramp and Sine) to On. Click OK.

Set PV Noise = 0, press Enter. Click on Start Simulation if simulation is not already running. Now you can see the effect of the three combined disturbance signals on the simulation. Click on the red Manual button to put the PID in auto mode. Now you will see the PID control action in the presence of disturbances.

**Figure 13. Configuring External Disturbances in SIMCET**



**Step #12:** Try various PID tuning parameters and filtering. The control action seems to be crisp, strong but stable with Prop. Gain = 3, with Integral = 20, Derivative = 2, Filter = 1. Try more aggressive tuning to generate oscillations. Also, try sluggish tuning to cause an **offset**.

**Step #13:** Click on the Save icon in the top-bar to save this simulation for future PID tuning practice by you and others. Change the directory for saving as desired and then specify a filename with “.pid” for filename extension.

SIMCET allows you to associate a process graphic with each new simulation. If you click No, then your simulation will be saved along with the default PID control simulation schematic that you see on the screen. If you click Yes, then you can select from the various different available process schematic options. Select from any of the available options and then click OK. Now click on the X in the top right corner to exit and to go back to SIMCET Main Menu. If you like to add a few new process schematics not provided currently, please contact PiControl Solutions LLC for assistance by sending an email to [info@picontrolsolutions.com](mailto:info@picontrolsolutions.com).

**Step #14:** Exit completely and then re-start SIMCET. Click on the Open Case File icon in the top-bar. Double-click on the filename specified above. Now you will see that the previously configured and saved simulation is restored.