THREE MODE CONTROLLER (PID) TUNING

Three Mode Controller (PID) Tuning

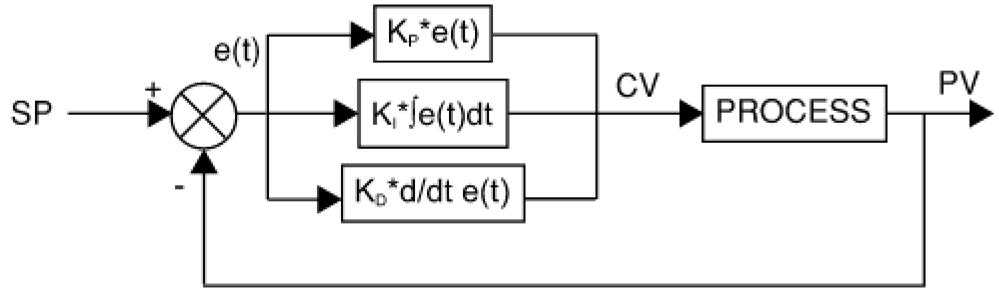
Agenda

- What is a PID controller?
- Motivation to optimize PID tuning
- Tuning by feel
- Ziegler Nichols tuning method
- First order plus dead time (FOPDT) tuning method

What is a PID controller?

Proportional Integral Derivative

- A method of control that uses three terms to control a process
- Developed in 1911 for ship steering and formalized in 1922
- A setpoint (SP) is entered on the lefthand side of the block diagram
- The measured process variable (PV) is compared to the setpoint to get the error e(t)
- This feedback is called closed-loop control
- Widely used due to its simplicity, familiarity, and relative ease of tuning

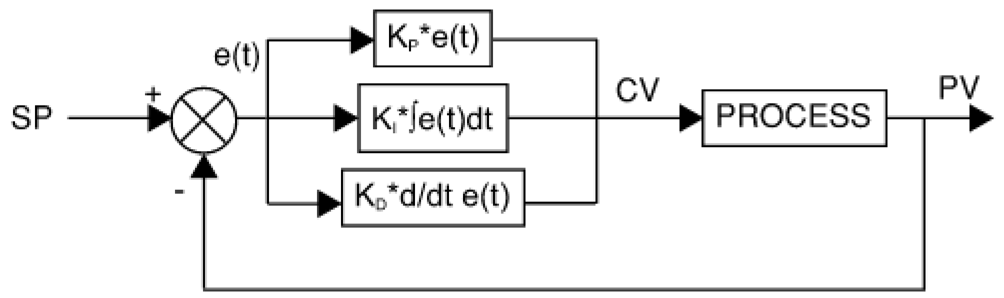


PID Block Diagram In The Time Domain

What is a PID controller?

Proportional Integral Derivative

- The error is multiplied by the proportional gain(Kp)
- The integral of the error with respect to time is multiplied by the integral gain (Ki)
- The derivative of the error with respect to time is multiplied by the derivative gain (Kd)
- The three terms are summed together to form the output of the PID controller, or control variable (CV)
- The CV is sent to the final control element which is the device that manipulates the process



PID Block Diagram In The Time Domain

Motivation for optimizing PID tuning

Why do we care?

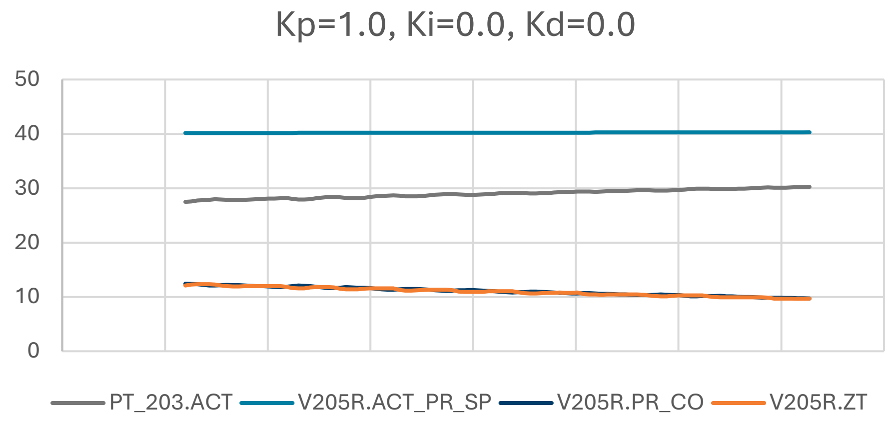
- A poorly tuned PID loop has more variability in the process variable
- In addition to the safety concern of the process becoming uncontrolled, variability in the PV can increase energy usage, material usage or increase wear on components
- A poorly tuned loop may also require more human intervention which can be a drain on staff that are already stretched thin

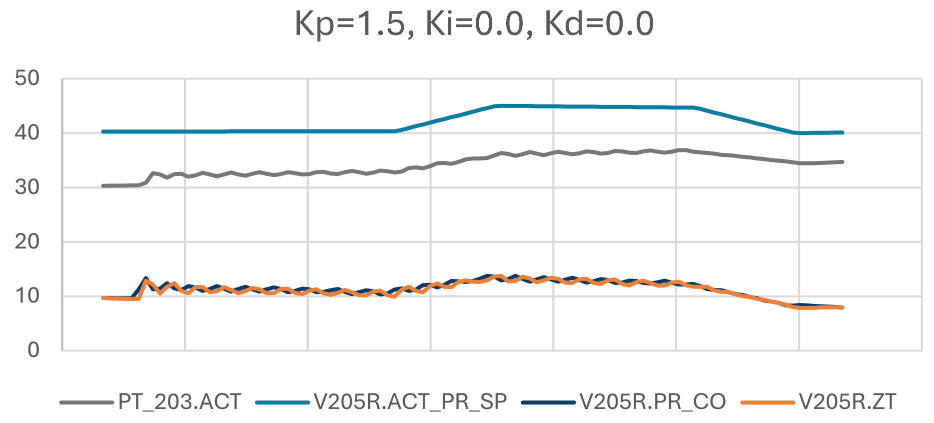
PID Tuning
Tune By Feel

PID Tuning – Tune By Feel

Step 1

- Zero out integral and derivative gain and set proportional gain to 1
- Increase proportional gain until oscillations in PV are observed but decay quickly (underdamped)

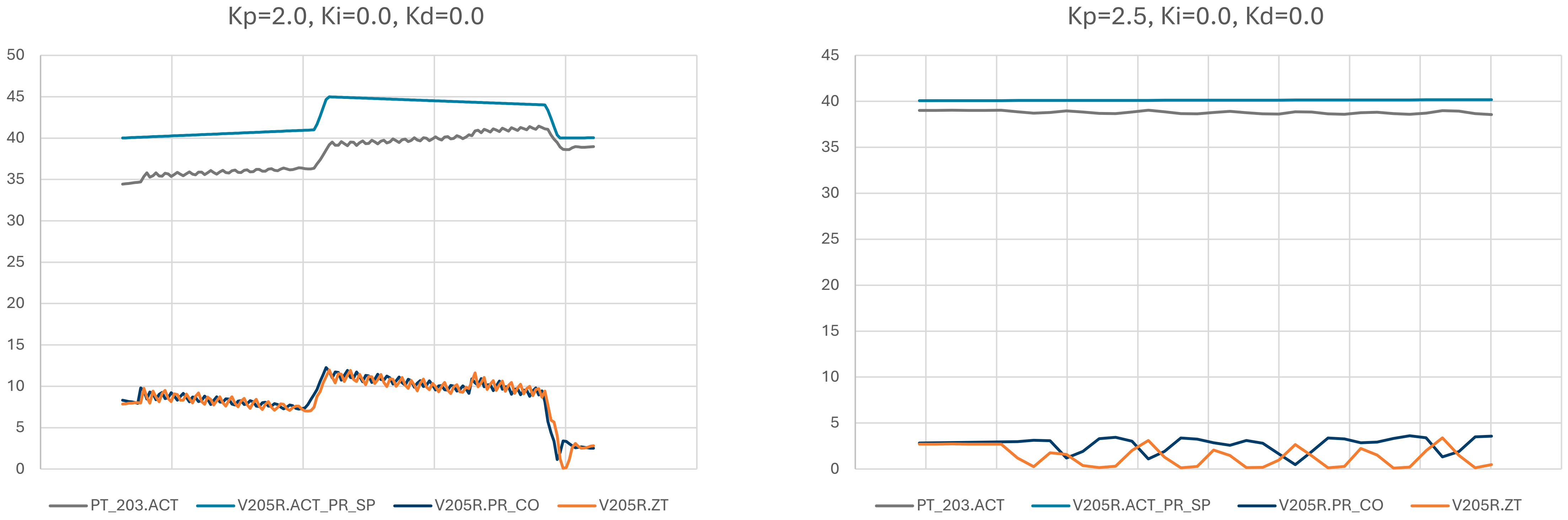




Increasing proportional gain

PID Tuning – Tune By Feel

Step 1 (continued)

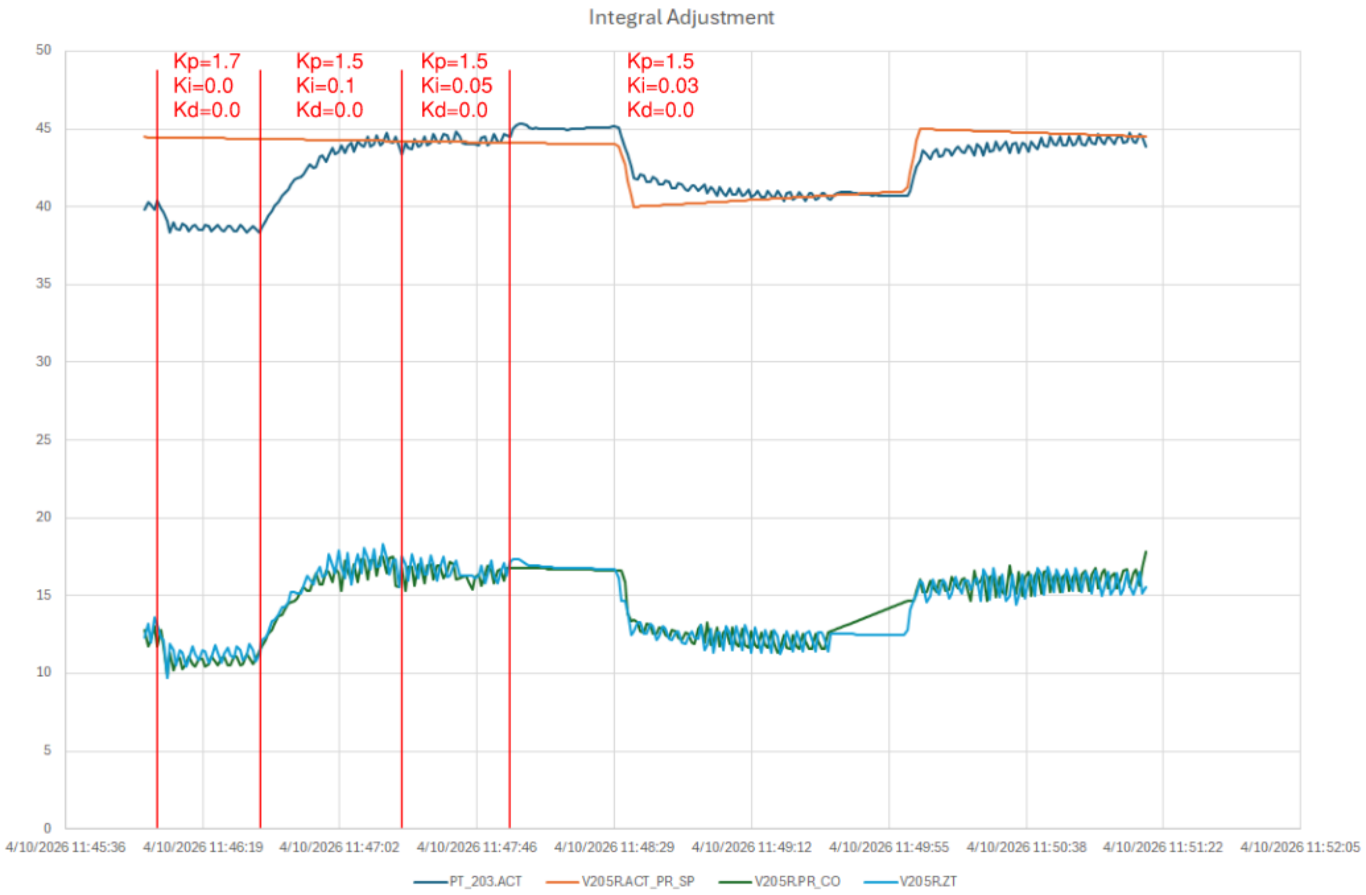


Increasing proportional gain

PID Tuning – Tune By Feel

Step 2

- Decrease proportional gain by at least 25%
- Increase integral gain to minimize or eliminate steady-state error
- Test the tuning parameters by making several setpoint changes



Adjusting integral gain

PID Tuning – Tune By Feel

Step 3

- Make small adjustments as necessary based on this chart

EFFECTS OF INDEPENDENT P, I, AND D TUNING

Closed-Loop Response	Rise Time	Overshoot	Settling Time	Steady-State Error	Stability
Increasing K_P	Decrease	Increase	Small Increase	Decrease	Degrade
Increasing K_I	Small Decrease	Increase	Increase	Large Decrease	Degrade
Increasing K_D	Small Decrease	Decrease	Decrease	Minor Change	Improve

PID Tuning – Tune By Feel

Summary

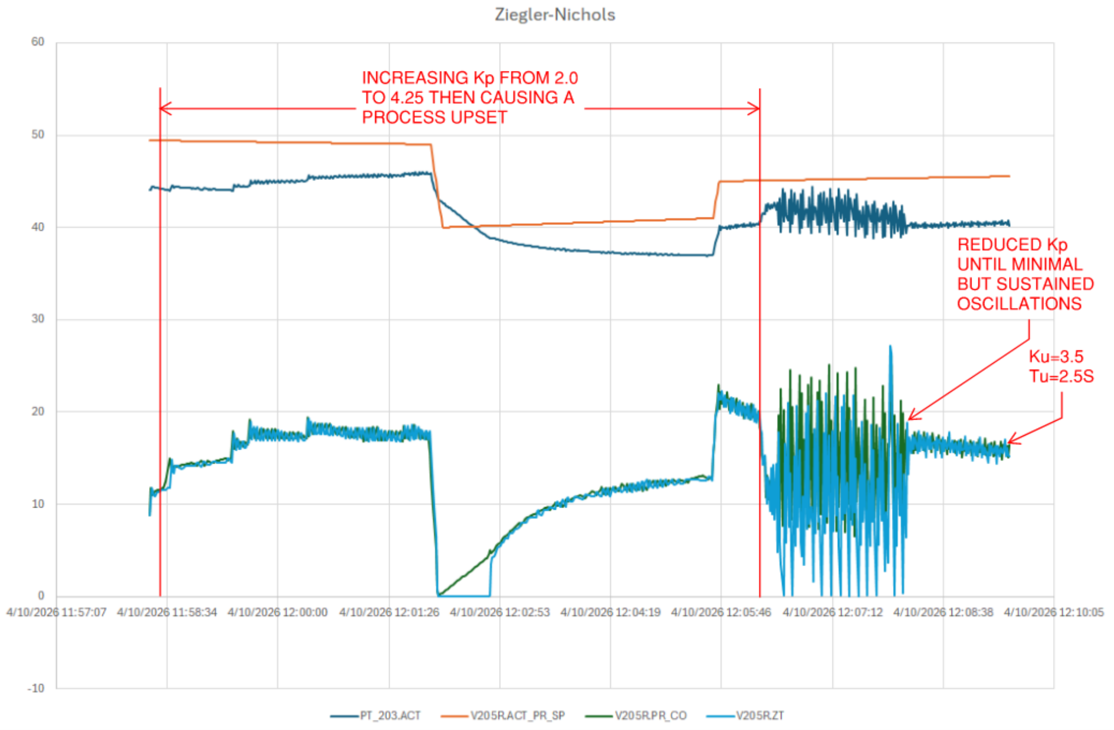
- Tuning by feel can be quick but leads to inconsistent results
- May not always be possible, especially if a loop is unstable, unusually fast or unusually slow

PID Tuning
Ziegler Nichols

PID Tuning – Ziegler Nichols

Step 1

- Zero out integral and derivative gain and set proportional gain to 1
- Increase proportional gain until oscillations in PV are observed and sustained (undamped)
- This gain is termed ultimate gain (Ku) and the period of the oscillation is Tu



Increasing proportional gain

PID Tuning – Ziegler Nichols

Step 2

- Calculate your PID parameters based on this chart

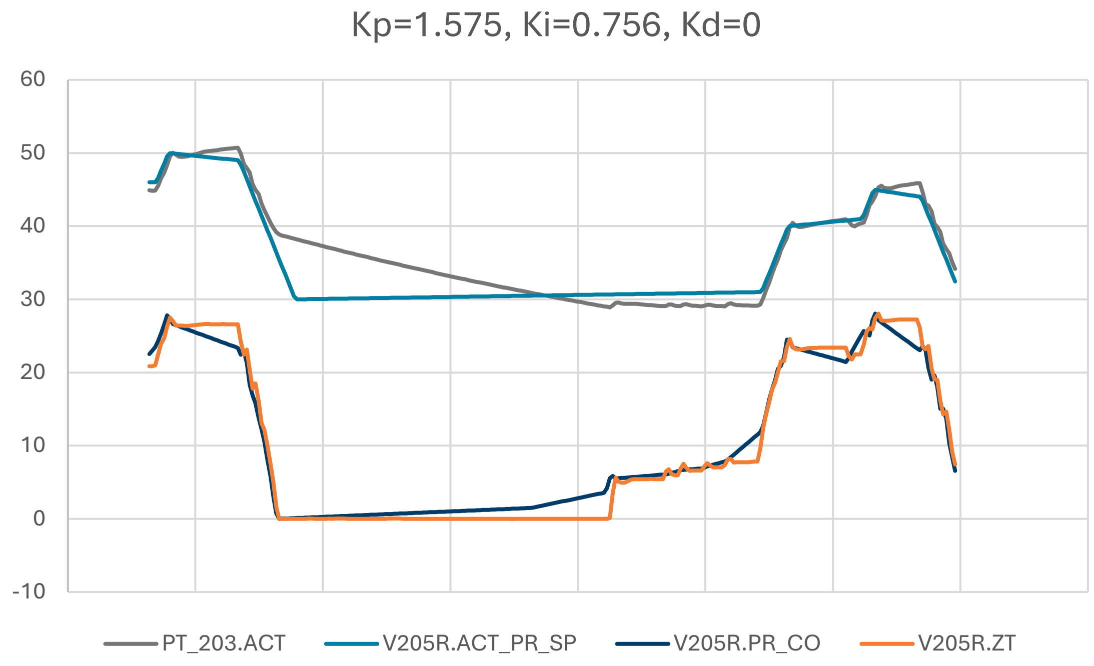
Control Type	K_p	K_i	K_d
P	$0.5K_u$	–	–
PI	$0.45K_u$	$0.54K_u/T_u$	–
PD	$0.80K_u$	–	$0.10K_uT_u$
PID	$0.60K_u$	$1.20K_u/T_u$	$0.075K_uT_u$

Ziegler Nichols PID parameters

PID Tuning – Ziegler Nichols

Step 3

- Test the tuning parameters by making several setpoint changes



Reaction to setpoint changes

PID Tuning – Ziegler Nichols

Summary

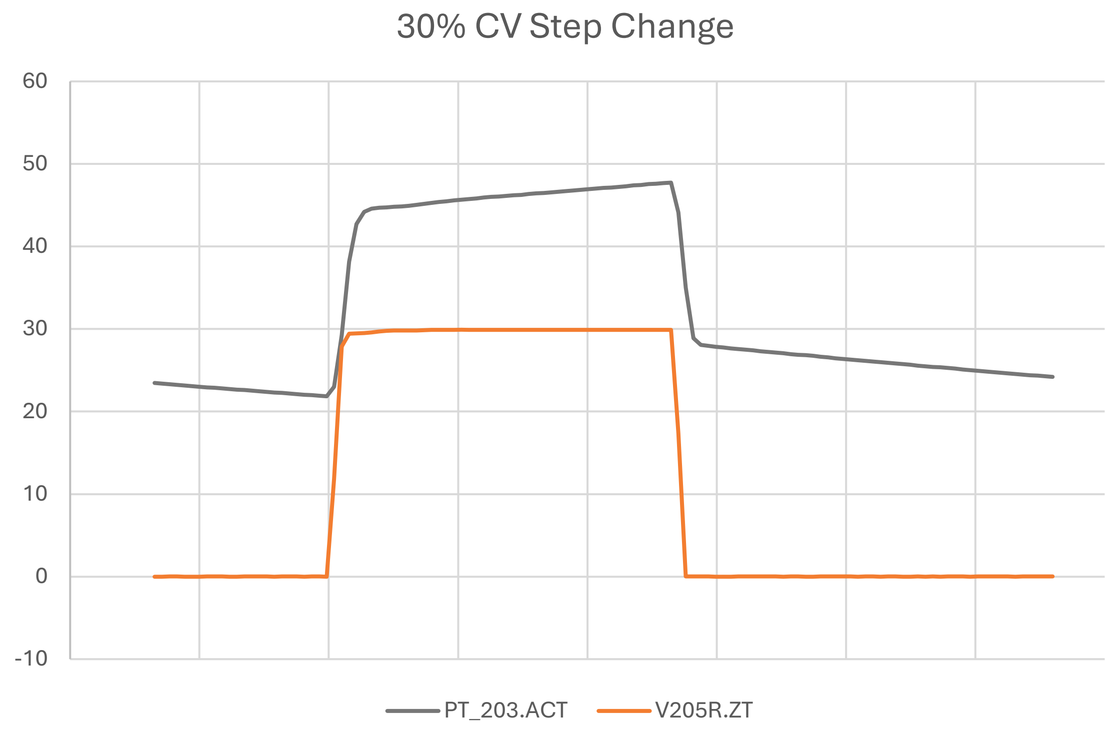
- Consistent results
- Often results in aggressive tuning that may be beneficial in some situations but may be a detriment in others

PID Tuning
First Order Plus Dead Time (FOPDT) Modeling

PID Tuning – First Order Plus Dead Time (FOPDT) Model

Step 1

- Place the PID in manual (open loop control) and make a step change in the control variable (CV)
- The change in CV should be sharp and significant
- To be significant it must be at lease 3%

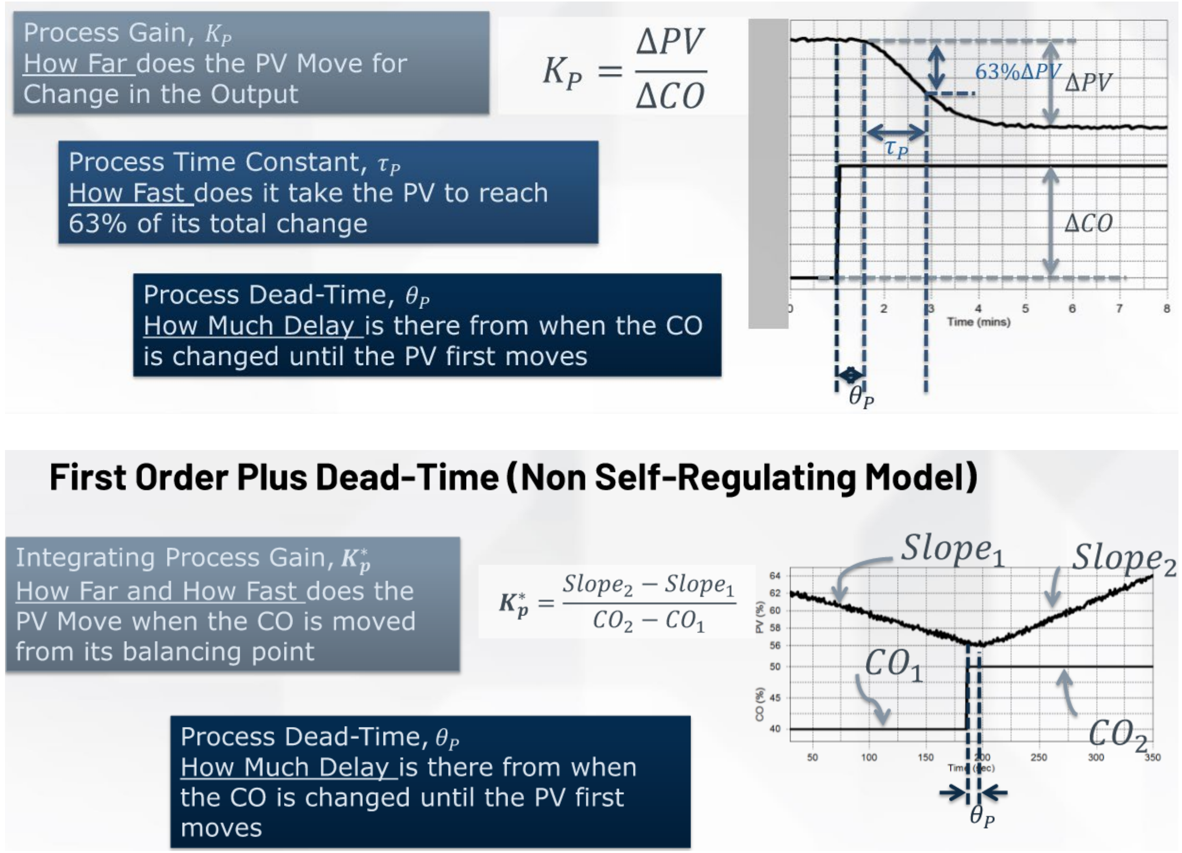


Open loop step response

PID Tuning – First Order Plus Dead Time (FOPDT) Model

Step 2

- Identify if the process is self-regulating or non-self-regulating
- If it is self-regulating find the process gain, process time constant and process dead time
- If it is non-self-regulating find the process gain and process dead time



Self-regulating vs non-self-regulating step response

PID Tuning – First Order Plus Dead Time (FOPDT) Model

Step 3

- Calculate the PID parameters based on the appropriate chart

- First compute, τ_C, the closed loop time constant
  - aggressive: τ_C is the larger of $0.1\,\tau_p$ or $0.8\,\theta_p$
  - moderate: τ_C is the larger of $1\,\tau_p$ or $8\,\theta_p$
  - conservative: τ_C is the larger of $10\,\tau_p$ or $80\,\theta_p$

	P	I	D
PI	$\frac{1}{K_P}\frac{\tau_p}{(\theta_p+\tau_C)}$	τ_p	
PID	$\frac{1}{K_P}\frac{(\tau_p+0.5\theta_p)}{(\tau_C+0.5\theta_p)}$	$\tau_p+0.5\theta_p$	$\frac{(\tau_p\theta_p)}{(2\tau_p+\theta_p)}$

- The Closed Loop Time Constant, τ_C, should be as large as possible but still fast enough to arrest or recover from a major disturbance.

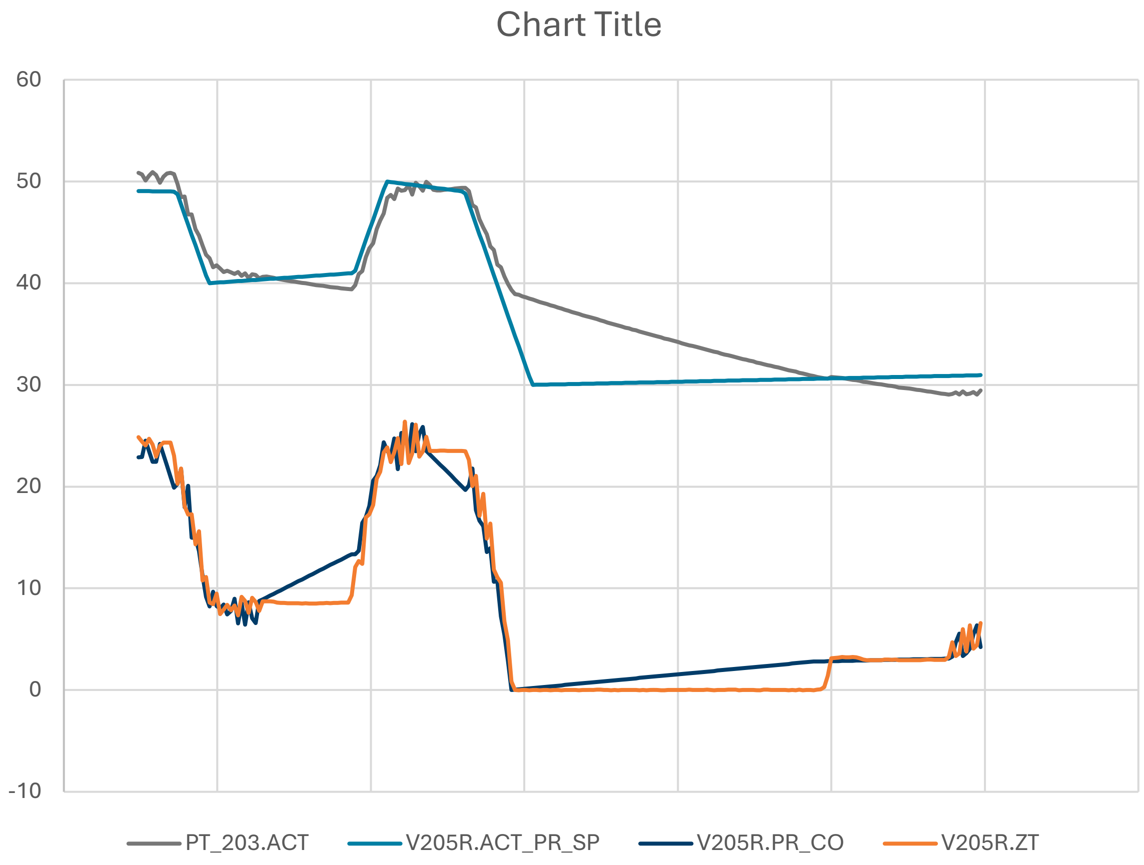
	P	I
PI	$\frac{1}{K_p^*}\left(\frac{2\tau_C+\theta_p}{(\tau_C+\theta_p)^2}\right)$	$2\tau_C+\theta_p$

Calculate PID parameters

PID Tuning – First Order Plus Dead Time (FOPDT) Model

Step 4

- Implement the calculated PID parameters
- Test the tuning by making several setpoint changes and observing the PV response



Observe the response to setpoint changes

PID Tuning – First Order Plus Dead Time (FOPDT) Model

Summary

- Offers a good balance of consistency and usability
- Can take more time but is generally recommended especially for more difficult to tune PID loops

PID Tuning

Conclusion

- Be safe! When performing PID tuning ensure that you can disrupt the process without causing damage
- In all cases you should document your results – tuning is a process and you or others may have to come back and adjust tuning, this documentation can help
- Tuning by feel can work in many situations but requires experience and may not be possible in all circumstances
- Ziegler Nichols delivers consistent results but my result in aggressive tuning
- FOPDT modeling is generally recommended for consistency and ease of use

Questions and Answers

Thank you!

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