ControlSoft

Top 6 Questions to Answer to Reduce Process Variability

eBook

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Introduction

There are times when a process variable (PV) shows an unacceptable level of variability around its setpoint (SP) while being regulated by a PID controller. In order to improve the quality of regulation of the process variable, there are six important questions to consider.

In this eBook we provide the six questions along with subsequent observations to help you in answering the questions.

Q1

What is causing the process variability?

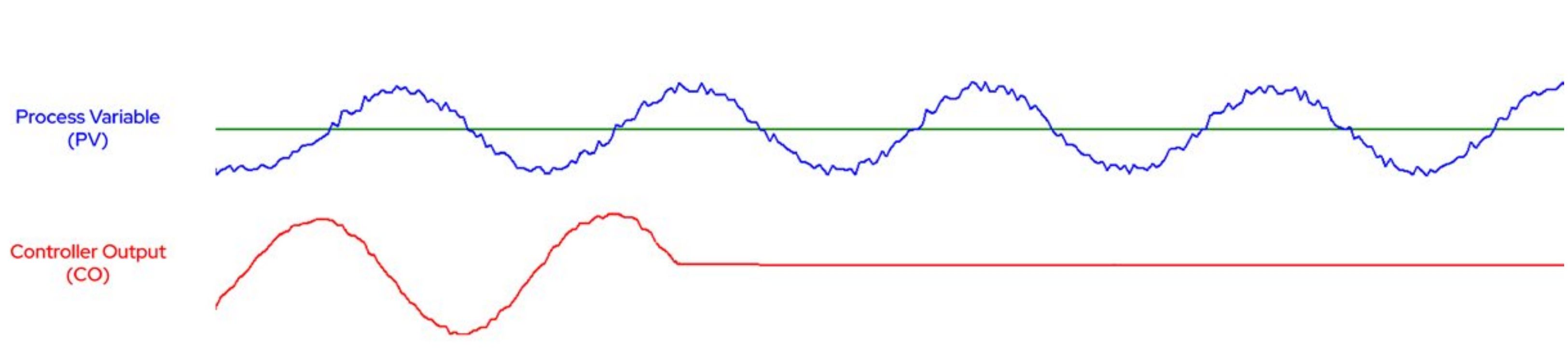
WHAT TO DETERMINE

Is the process variability caused by poor tuning and aggressive action by the underlying PID controller?

WHAT TO OBSERVE

To find out, put the PID controller into manual mode and observe the pattern of the process variable. If the concerning pattern of variability persists or intensifies then the loop controller is not the cause of variability. In this case, the variability is a disturbance input to the loop and the PID controller is responding to the loop disturbances in automatic mode.

Figure 1 - Process Variability Continues When PID Controller is in Manual Mode



On the other hand, if the concerning pattern of variability largely disappears from the process variable, then the automatic action of PID controller is likely causing the variability. This indicates the necessity of tuning the controller and/or improving the underlying control strategy. It is noteworthy that the pattern of variability due to poor and aggressive tuning of the loop controller is mostly sinusoidal.

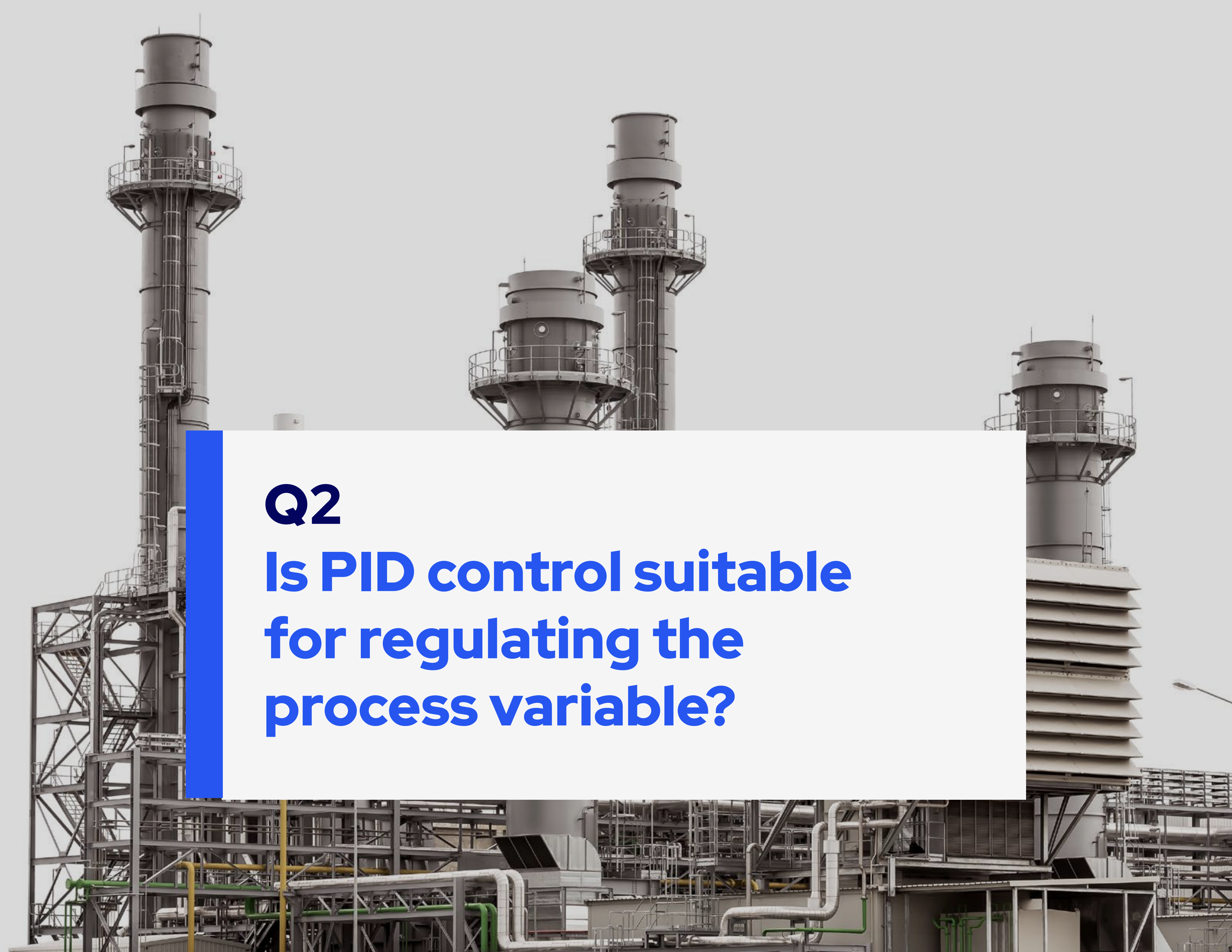
Figure 2 - Process Variability Reduces When PID Controller is in Manual Mode

We recommend recognizing the type of process, i.e. whether it is integrating or non-integrating, before putting the loop controller into manual mode.

If the process is integrating, then the process variable will drift away from its set-point non-stop after putting its controller into manual mode, and thus could violate process limits in manual mode.

On the other hand, if the process is non-integrating, then the process variable will deviate from its set-point in manual mode. However, after a while will settle down around a level while having variability due to various loop disturbances.

Thus one should take caution in putting controller of an integrating process into manual mode.



Q2

Is PID control suitable for regulating the process variable?

WHAT TO DETERMINE

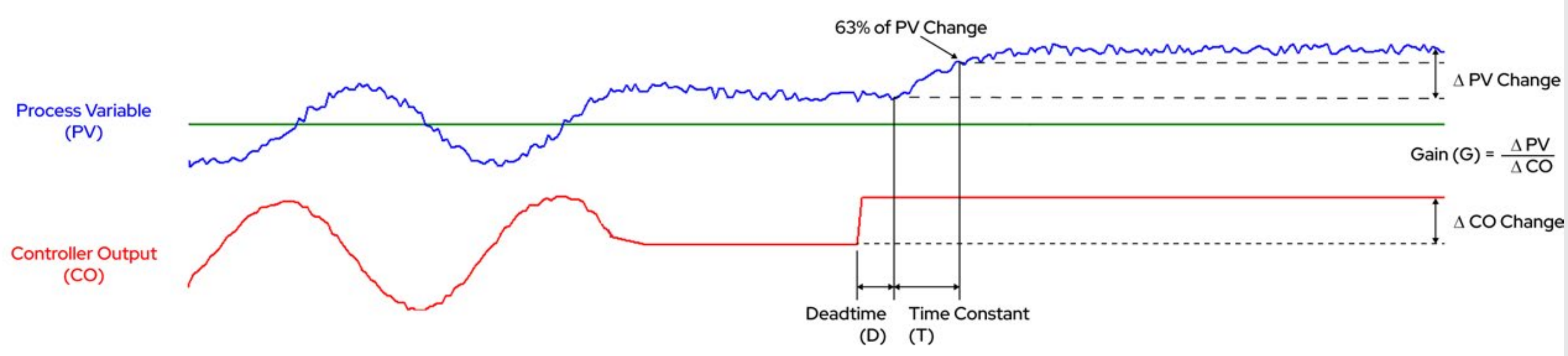
Using PID control has certain drawbacks and may not work well for extremely complicated or nonlinear systems. By performing a controller output step test, you can determine if PID control is appropriate for your application.

WHAT TO OBSERVE

To find out, perform a controller output step test of the process in manual mode (also called an open loop bump test), and then model the dynamics of the process.

If Process Is	The structure of model of interest is:
Non-integrating	A cascade of gain, first order lag and deadtime functions
Integrating	A cascade of gain, first order lag, deadtime and integrator functions

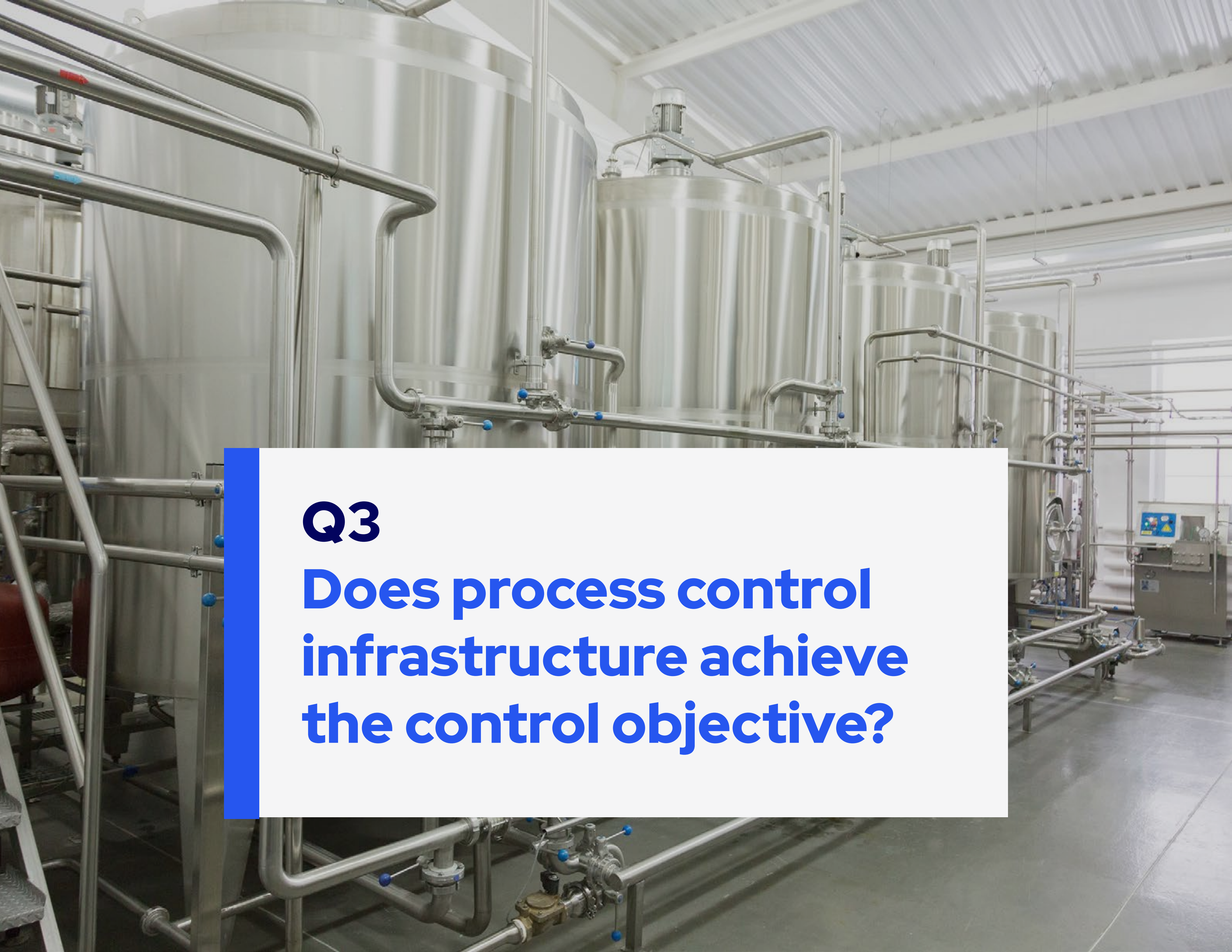
Figure 3 - Process Shows Suitability for PID Control



Simple PID feedback control is suitable for monotonic processes where a step change in controller output in manual mode produces unidirectional change in the process variable. Such processes are called minimum phase systems. On the other hand if a process is non-minimum phase, where process variable changes its direction of change in time after the step action in the controller output then it is likely that the impact of the control action on the process variable is through multiple, parallel paths having varying dynamics. PID control strategy should often be augmented by advanced control techniques to deal with process variability in non-minimum phase processes. Note that observing the process response to step change in controller output helps to determine whether the process is a minimum phase system.

The ratio of process deadtime to the summation of process deadtime and lag time is called normalized deadtime. Normalized deadtime could be considered as a measure of difficulty of controlling the process by a PID controller. Normalized deadtime for a pure deadtime process equals one, and for a pure lag process equals zero.

In a non-integrating process, the closer to one of a normalized deadtime we have, the more difficult of a PID control we will have. This difficulty is a consequence of overcompensating for the loop error during process deadtime by the integral action of the PID controller. Our recommendation is to consider augmenting PID control with advanced control techniques when normalized deadtime is bigger than 0.67, i.e. process deadtime is more than twice its lag time. Process deadtime produces limit cycles in PID-controlled integrating processes and as the higher gain of integrating process we have the smaller deadtime could cause difficulty in automatic control.



Q3

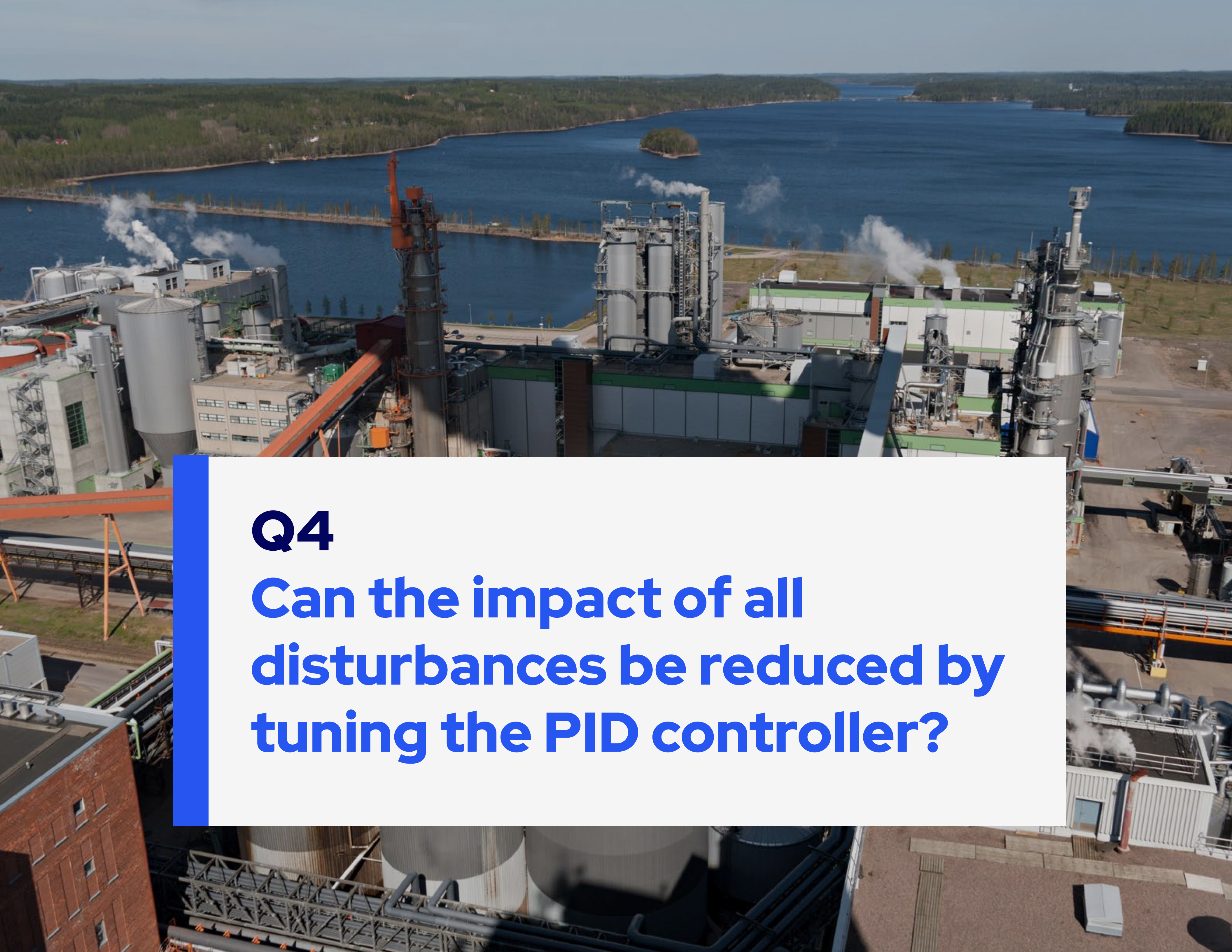
Does process control infrastructure achieve the control objective?

WHAT TO DETERMINE

Given acceptable size of loop error defined as the difference between process variable set-point and measurement, are the accuracy of sensor, the precision of actuator, and the data sampling rate sufficient for achieving the control objective?

WHAT TO OBSERVE

By performing a manual bump test and identifying process gain, lag time constant and deadtime, one could preliminarily evaluate sufficiency of functionality of loop instrumentation. Ideally the minimum achievable loop error is the bigger of two values: sensor precision level and the value calculated by multiplying actuator precision with process model gain in non-integrating processes, and in the case of integrating processes by further multiplying the result by the length of process deadtime. We recommend devising the control loop so to have this ideal error level be smaller than the control objective by at least one order of magnitude. We also recommend having a data sampling rate that provides 20 samples within one lag time constant of the process. Although data sampling adds to the deadtime of process by one sample time, this recommended rate of sampling does not increase normalized deadtime much and allows capture of dynamics, without aliasing distortion, of frequency components more than 60 times the cut off frequency of process itself. Given precision of actuator, process gain and time constant, one could also evaluate a maximum level for beneficiary sampling rate.



Q4

Can the impact of all disturbances be reduced by tuning the PID controller?

WHAT TO DETERMINE

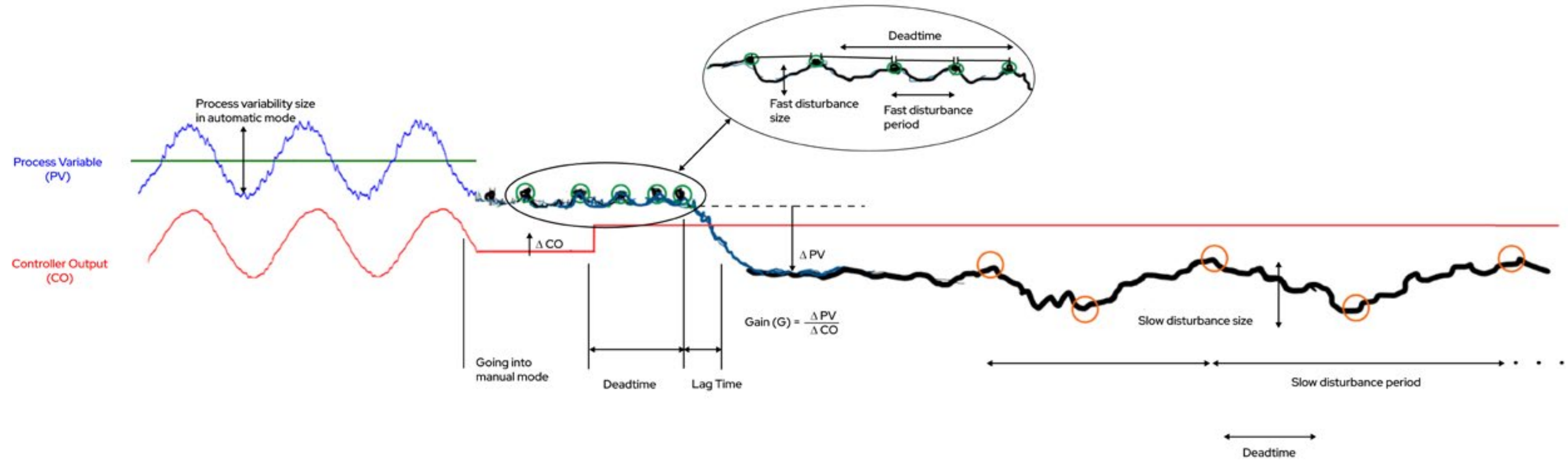
Can the impact of all disturbances be reduced by tuning the PID controller?

WHAT TO OBSERVE

PID, and for this matter any other type of simple feedback controller, are not able to reduce process variability caused by a disturbance that has dynamics faster than process deadtime. However, in the case of slow dynamic disturbances, a well-tuned PID controller could reduce the impact of disturbance subject to limitation imposed by control infrastructure.

By performing a manual bump test and identifying process deadtime and lag time and running (non-integrating) process in manual mode for an extended period, and reviewing natural process variability under manual control mode, one could roughly evaluate the size (e.g. average peak to peak size of the stochastic disturbance) and dynamics (e.g. average period of the stochastic disturbance) and compare these values to the desired closed loop error and process deadtime and preliminarily evaluate whether tuning the loop PID controller could have positive impact in reducing disturbance and achieving control goal stated in terms of closed loop error.

Figure 4 - Fast and Slow Disturbances Relative to Process Deadtime

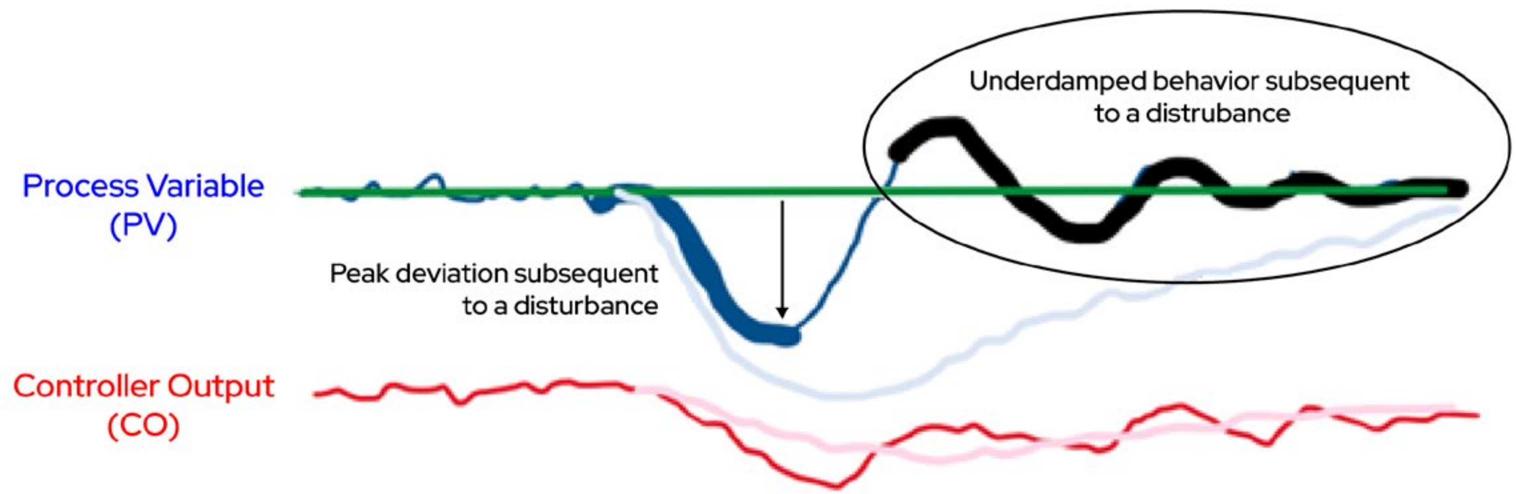


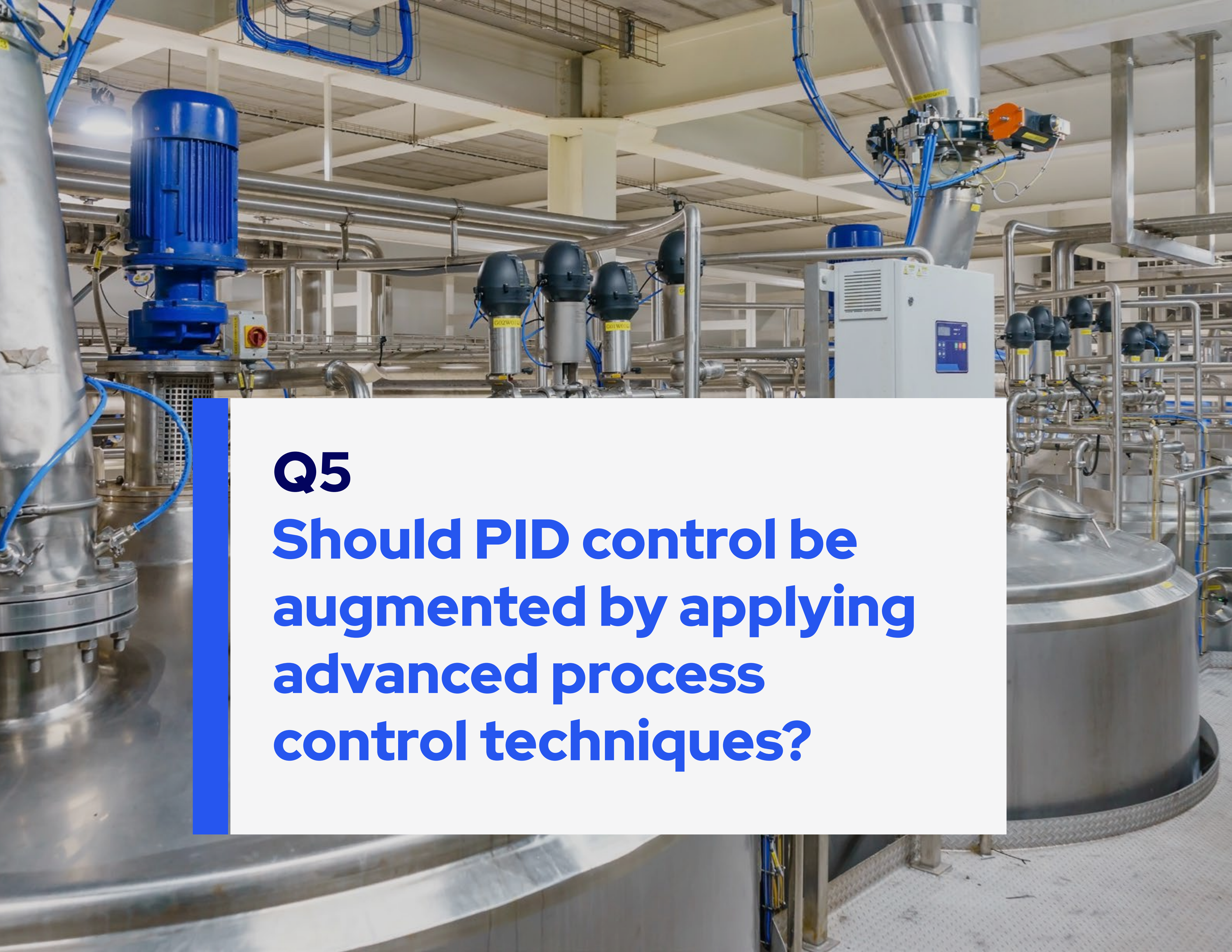
Consider the process depicted in the graph above. We could distinguish two categories of natural disturbances when the loop is run in manual mode, one tagged by green color and the other by orange. Average peak to peak size and average period of both kinds of disturbances are depicted in the trend. It is noteworthy that the average period of green color tagged disturbance is shorter than process deadtime, while the average of orange color tagged disturbance is longer than process deadtime. Considering this observation then we could expect that a well-tuned PID-controlled closed loop to have variability less than that of orange color tagged disturbance but continue to have variability at least as big of a size as that of green color tagged disturbance.

Measurement noise is also a stochastic disturbance to process and has dynamic that is faster than process dynamic. While in manual mode, one could evaluate the amplitude of noise to be 3 times the standard deviation of samples of process variable in a segment of time that process has stationary behavior and its statistical behavior does not change in time, e.g. the average of samples of process variable in time subsegments of the sample set remain constant. A PID controller cannot eliminate this noise, and hence target variability of process variable articulated in the control objective should take this noise level into consideration. It is noteworthy here that PID controllers having derivative action and or high proportional gain amplify process noise.

Two aspects of closed loop response to a disturbance are of particular importance: (1) peak deviation from setpoint that the close loop sustains after entry of a disturbance, and (2) persisting pattern of process variable in hunting its setpoint after entry of the disturbance. Tuning of PID controller impacts both aspects. By increasing the speed of response of PID controller one could reduce the size of peak deviation after entry of the disturbance; however, one would then increase the chances of creating underdamped pattern of hunting the set-point. The length of process deadtime and the intensity of disturbance sets the minimum level for peak deviation from the set-point that we could obtain by aggressively tuning the PID controller. If the control objective is tighter than this minimum achievable deviation, then we should investigate adopting advanced control techniques to realize the control objective.

Figure 5 - Peak Deviation Versus Underdamped Disturbance Rejection When Controller is in Automatic





Q5

Should PID control be augmented by applying advanced process control techniques?

WHAT TO DETERMINE

Would process variability be reduced by applying a combination of PID control and an advanced control scheme (e.g., cascade control, dynamic feedforward control, or Smith predictor deadtime compensation).

WHAT TO OBSERVE

If the process has considerable deadtime, i.e. its normalized deadtime is bigger than 0.67, then we should examine utilizing a combination of PID control and smith predictor, or even better utilize model-based control techniques.

If our investigation about process disturbances – as discussed in question 4 – revealed that we have process disturbances that have faster dynamics than the process and the goal of control demands tighter regulation to the set-point than the size of fast dynamic disturbances, then we must explore using cascade control and/or a combination of feedback and feedforward control to realize the objective.

If our process is not monotonic then PID feedback control should be enhanced by feedforward control action and or the utility of advanced model based coordinated control techniques should be examined.

Q6
Should PID control be replaced with advanced process control techniques?

WHAT TO DETERMINE

Would another form of advanced process control (e.g., model-based control (MBC), model-predictive control (MPC), or coordinated control (CC)) provide better overall results?

WHAT TO OBSERVE

PID control is a single input, single output control paradigm where one process variable (PV) is regulated to its set-point (SP) by modulating one actuator. PID control also faces an intrinsic limitation in the context of controlling deadtime-dominant processes.

In many process control applications, we are interested in regulating several process variables concurrently. And typically, each process variable of interest is influenced by several controllable inputs, e.g. having multiple actuating mechanisms, as well as being influenced by several uncontrollable however measurable inputs, otherwise called measurable disturbances. In the process industry having control loops subject to long process deadtime is also common.

PID control techniques follows a divide and conquer paradigm where each process variable is paired with one control action to close the loop and realize the control objective. However, PID control techniques fails to realize control objectives in the context of high-quality of control demanding applications, while ignoring the interaction among subprocesses and the impacts of measurable disturbances and long process deadtimes. In such applications control practitioners ought to examine the utility of advanced control techniques like coordinated and modular multivariable model-based control techniques which could be structured to take into consideration process interactions, coordinate multiple control actions and intrinsically could better deal with long process deadtime applications.

Resources

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