Process Characterization

This whitepaper highlights how to identify simple process dynamics in process industry.

Introduction

What is the definition of a process?

It is an arbitrary configuration of equipments that act in input variables producing output variables. Hereafter are presented the process variables used in a control system.

Manipulated variable - Process input that can be adjusted to keep a control variable at a specific value;
Disturbance - Measured process input that can't be adjusted, it changes the process response;
Control variable - Process response that must be kept at a constant value;
Restriction - Process output that must be kept within limits, restricting the manipulated variables adjustments.

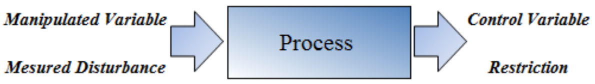

Figure 1 – Industrial Process

Process Characterization

In order to identify a process type, you have to run some tests and check the process response. Hereafter are presented three types of process, which are very common in process industry.

The first one is the process with dead time. The first-order process is stable, because, when a step change is applied, the PV stabilizes in steady value. The temperature response inside a furnace is an example of a process with dead time.

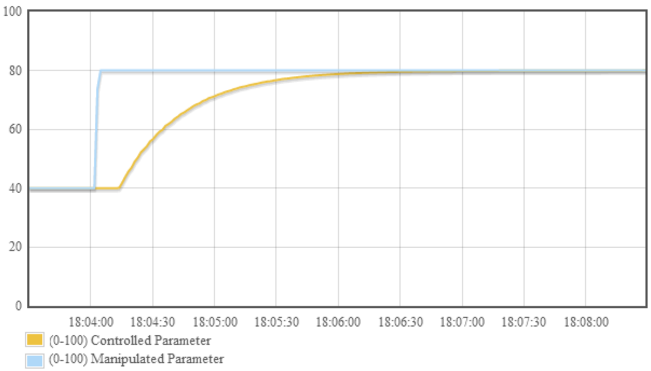

Figure 2 –Process with Dead Time

The second type is the integrating process. This process is unstable, because, when a step change is applied, the PV starts to change at an integral rate that can be calculated. The level in a tank is an example of an integrating process.

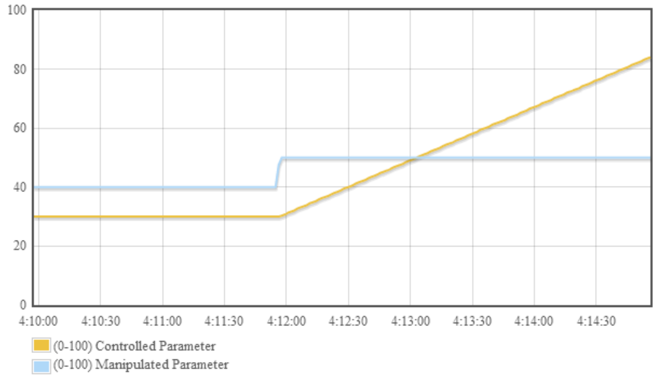

Figure 3 – Integrating Process

And lastly, the third type is the inverse process. When making a step change, the initial response direction is opposite to the final one. The bottom heating of a distillation column is an example of an inverse process. Figure 4 presents the characteristic curve of this type of response.

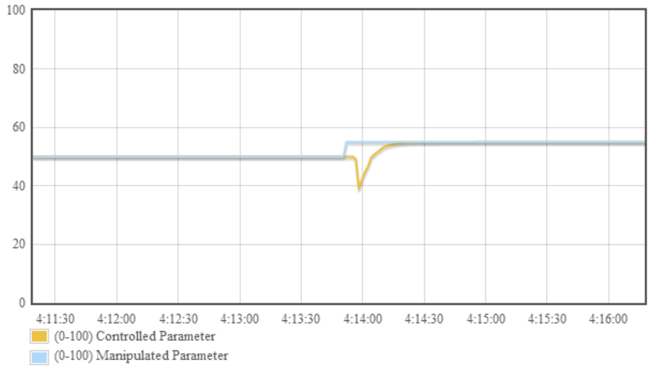

Figure 4 – Inverse Process

A process can be characterized by making a step change in the process input and then examining the process response due to changes in process input. There are some rules to find the Dead Time constant, process Gain and time constant of a first-order process.

There are some techniques to find second-order or higher-order process time constants, but, in most cases, they can be simplified to a first-order process, because second or higher orders may have no considerable effects in process response.

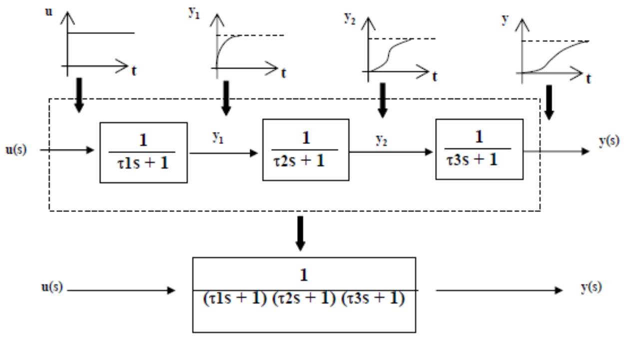

Figure 5 – Higher-Order Process

The order of the process is rated by the number of time constants. For example, if there are two process Time Constants, it is classified as a second-order process; if there are three or more time constants, then the process is classified as a higher-order process.

Finding Process Constants

Finding the process constants is very useful when creating a simple model of your process dynamics, which is very important when you want to know the best control strategies for your process.

A first-order process can be characterized by making a step change in the process input and then examining the process response due to changes in process input, as presented in Figure 6.

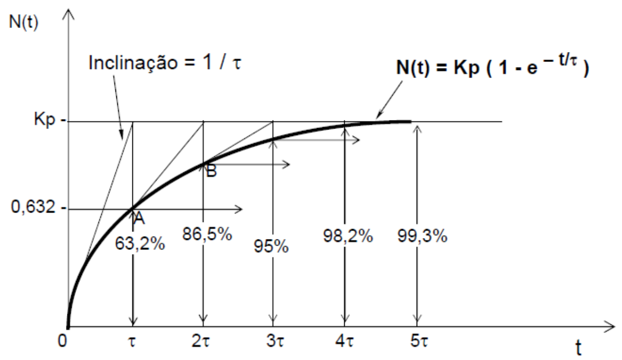

Figure 6 – Finding Time Constant and Process Gain

Process Gain and process Time Constant are represented by the variable Kp and the Greek letter τ, respectively. Notice that the process Time Constant can be found in point A and corresponds to the time the process output reaches 63.2% of the step change.

Figure 7 presents de measured Dead Time value for the process response. The Dead Time is the measured time between the step change and the initial process response. In this case, the step change was given at 18:04:00 and the process started to respond at 18:04:11.64, the time interval is 11.64 seconds, which means this value is the Dead Time for this process. Analyzing Figure 7, it's possible to identify that the process Gain value is 1, Δ(AI1/OUT) / Δ(AO1/SP), because the step change modified the output of the process by its own exact value.

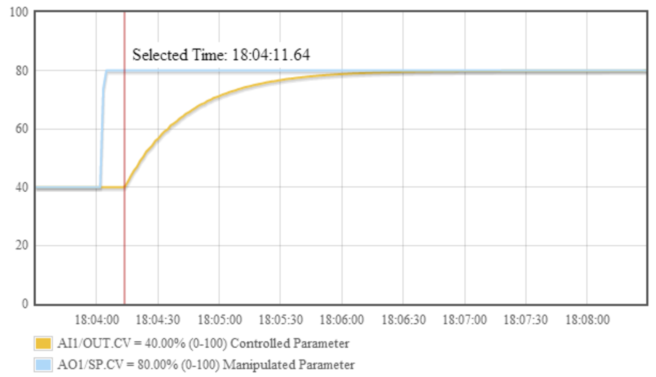

Figure 7 – Finding Process Dead Time

The calculated value for process Time Constant is the time frame between the initial process response and the time the controlled parameter reaches 63.2% of the step change, as can be easily identified in Figure 6. The initial time response is 18:04:11.64 and the time the controlled parameter reaches 63.2% of the step change is 18:04:44.5, as presented in Figure 8, which means that the process Time Constant for this example is approximately 33 seconds.

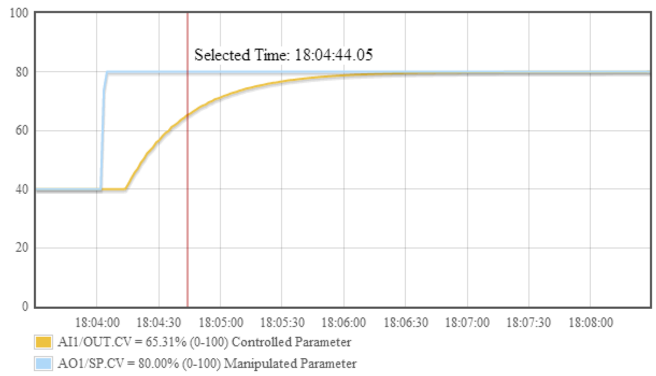

Figure 8 – Process Time Constant

Considerations and Conclusions

As defined in the beginning of this paper, a process is an arbitrary configuration of equipments that act in input variables producing output variables. The process presented here has no external interferences. Figure 9 presents a self-regulating process controlled by a PID controller in Automatic mode, in the indication line the controller is set in Manual Mode. Notice that the process has a Disturbance variable that changes its behavior, this variable can be included in the process models, as can the restrictions of the process. By considering this kind of external factors, a better model for the process can be achieved, which can be used for designing of complex strategies for PID controllers, as for Non-Linear Multivariable Controllers with restrictions, constraints and optimization variables.

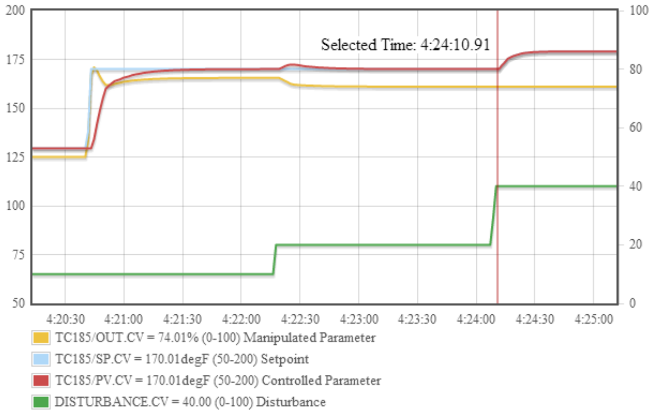

Figure 9 – Process Disturbance

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