Is Throttle Pressure Control a Self-Regulating or an Integrating Process?

By Jacques F. Smuts, Ph.D., P.E.

Self-regulating and integrating processes respond differently and require the use of different tuning methods. It is therefore important when tuning a controller to know if the process is an integrating or a self-regulating process.

Before we answer the question about throttle pressure, let's begin by reviewing self-regulating and integrating process types. To analyze the dynamics of a process in a control loop, we typically place the controller in manual, make a step change in the controller output, and see how the process responds.

Self-Regulating Processes

After a step change in controller output, the process variable of a self-regulating process moves toward a new level where it gradually settles out. A self-regulating process has an internal method of regulating its process variable to balance the change in controller output. The process naturally seeks its point of equilibrium. Most processes are self-regulating. A common example of a self-regulating process is a feedwater valve controlling the flow of feedwater into the boiler. If the valve is opened by a few percent, the feedwater flow rate will increase and then stabilize at a new level.

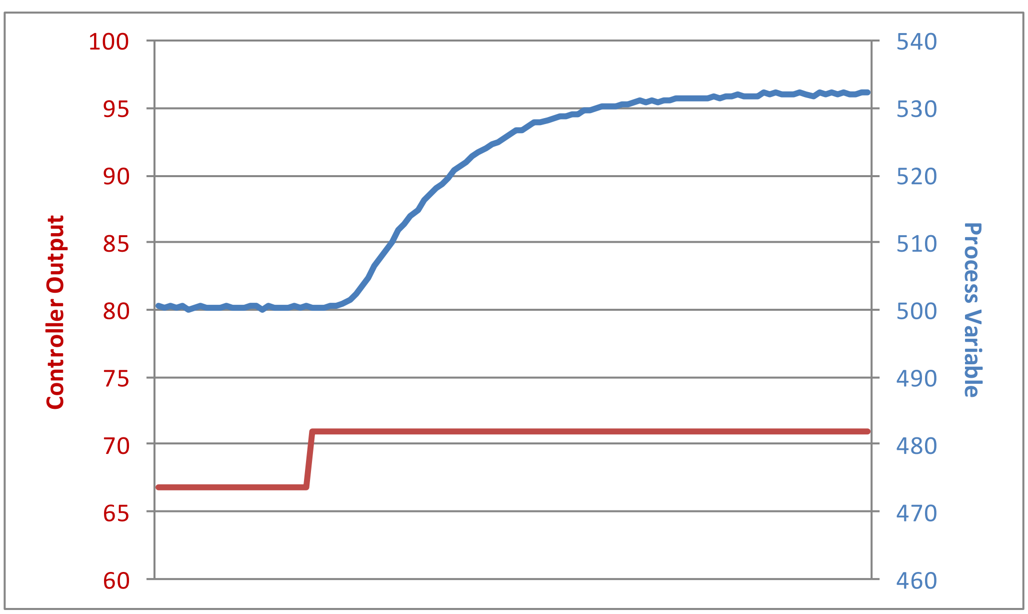

Figure 1 Step-response of a self-regulating process.

Integrating Processes

After a step change in controller output, an integrating process responds with a steady ramp instead of reaching a stable value. The process variable will only stabilize if the controller output is returned to its original position, as shown in Figure 2. A common example of an integrating process is liquid level in a tank. If we change the balance between flow in and flow out, the level will keep on ramping up or down.

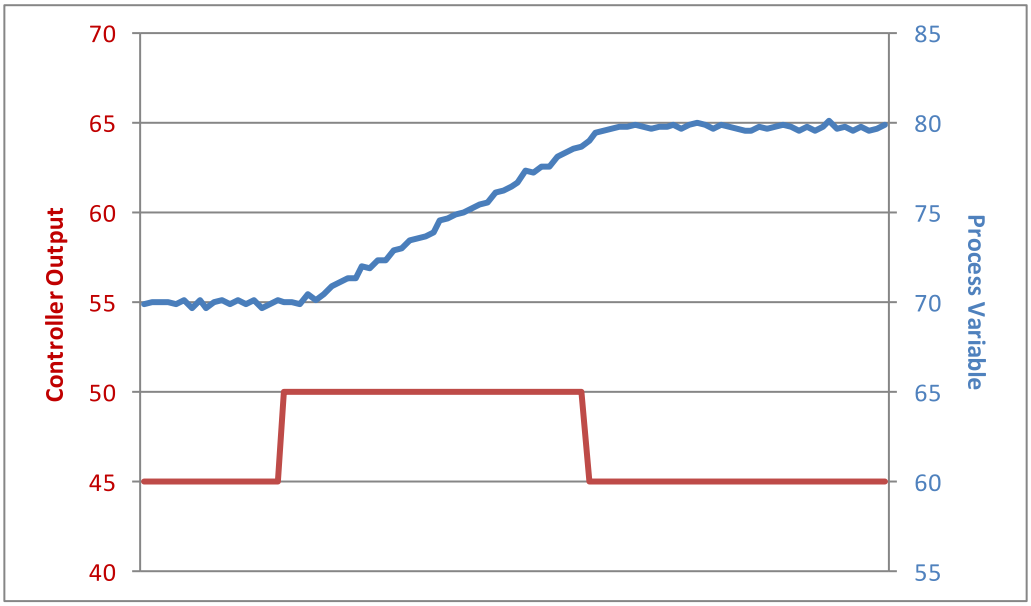

Figure 2 An integrating process stabilizes only after the controller output is returned to its original level.

Differences in Tuning

Control loops for self-regulating processes are relatively easy to tune compared to integrating processes. Control loops for integrating processes can overshoot badly and can become oscillatory very quickly. Because of the fundamental difference in response to a step change in controller output, we have to treat self-regulating and integrating processes differently when tuning their controllers. This begins with applying different tuning rules. And while self-regulating processes require both proportional and integral control modes for good control performance, integrating processes rely heavily on the proportional control mode and much less on the integral control mode.

Throttle Pressure

Throttle pressure control loops can be a challenge to understand and tune because under certain conditions they act like self-regulating processes, while other times they act like integrating processes.

Throttle Pressure in Turbine-Following Mode

In turbine following mode, the throttle pressure controller manipulates the governor valves to control throttle pressure, and the unit load controller manipulates the firing rate to control MW produced.

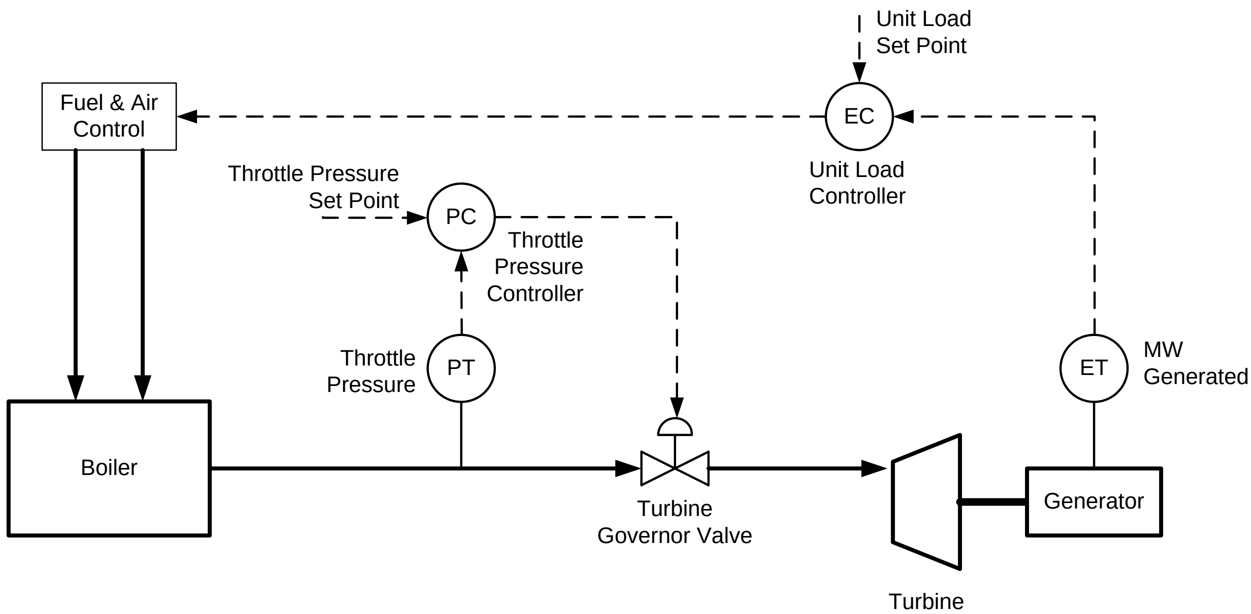

Figure 3 In turbine-following mode the throttle pressure is controlled by the governor valves and MW produced is controlled by the firing rate of the boiler.

We can place the throttle pressure controller in manual and step its output up by a few percent to determine the process type of throttle pressure (Figure 4). The governor valves respond to the step by opening a few percent and admitting more steam to the turbine. This increases the MW produced, and decreases the throttle pressure. The unit load controller responds to the increase in MW produced by decreasing the firing rate. This further decreases the steam pressure. The decrease in steam pressure results in less steam being admitted to the turbine through the governor valves (still at constant position). Because the MW production decreases, the unit load controller increases the firing rate until the MW produced and the firing rate are back at the levels from before the test. However, the throttle pressure will now be lower, but the more open governor valves admit the same amount of steam to the turbine as before the test.

This is a complex and interesting set of dynamics, but the final result of our step test is that the throttle pressure stabilizes at a lower value. So, in turbine-following mode, throttle pressure is a self-regulating process.

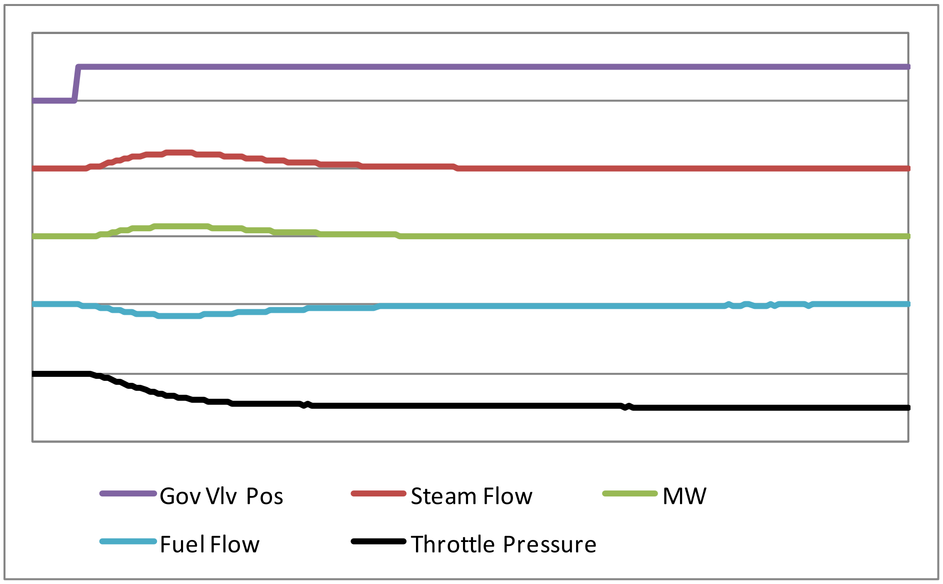

Figure 4 In turbine-following mode, throttle pressure decreases like a self-regulating process after a step change in governor valve position.

Throttle Pressure in Boiler-Following Mode

In boiler-following mode the load controller manipulates the governor valves to control megawatts produced. The throttle pressure controller manipulates the boiler firing rate to control throttle pressure.

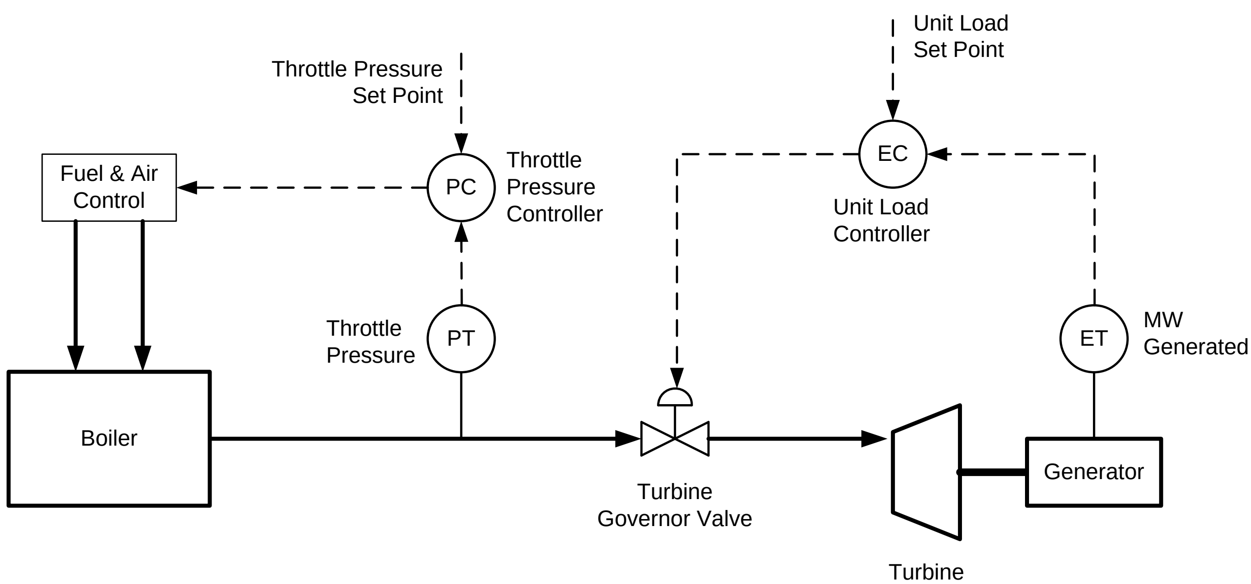

Figure 5 Boiler-following mode the throttle pressure is controlled by the firing rate of the boiler and MW production is controlled by the governor valves.

Imagine we could place the throttle pressure controller in manual but leave the load controller to control megawatts (most front-end controls do not allow this – for good reason). As before, we want to step the pressure controller's output up by a few percent to see what process type the throttle pressure is. If we increase the pressure controller's output, the fuel flow increases and more steam is produced in the boiler (Figure 6). This increases the steam pressure which increases the steam flow through the turbine and consequently increases the MW generated, but because our load controller is still in auto, it throttles down the governor valves to keep the generator load constant. So the additional steam has nowhere to go.

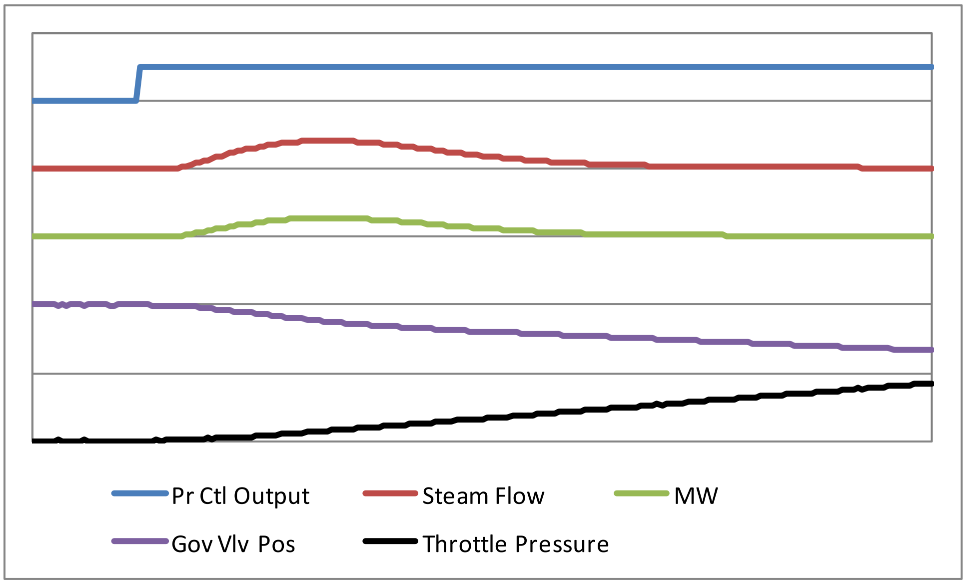

Figure 6 In boiler-following mode, the load controller throttles down the governor valves to control MW after a change in throttle pressure controller output, causing the throttle pressure to increase like an integrating process.

This situation is similar to a tank with more liquid flowing in than out – the tank level increases. In the case of the boiler and turbine, the steam pressure increases. As long as we have a mismatch between steam produced in the boiler and steam consumed by the turbine, the steam pressure keeps on increasing. This is the way an integrating process behaves. So in boiler-following mode, throttle pressure is an integrating process, with all the control challenges associated with an integrating process.

Tuning Implications

Because throttle pressure is an integrating process in boiler-following mode, but a self-regulating process in turbine-following mode, the two modes require different tuning settings – often implemented in two different controllers.

In boiler-following mode, the throttle pressure control loop has a tendency to oscillate, similar to the problem experienced with level control loops. This is bad for unit stability, because it causes the fuel flow to oscillate, which causes almost all other critical control loops to oscillate too.

Integral control mode is the primary source of oscillations in integrating processes. Therefore a tuner should take care not to use too much integral mode when tuning the throttle pressure controller in boiler-following mode. The tuning problem is compounded by the relatively slow dynamics of the boiler. This can cause tuners to use an excessively high controller gain and further destabilize the control loop. If boiler-following mode is being used, it may be beneficial to "help" the throttle pressure controller with a feedforward from unit load demand.

Conclusion

Although most pressure control loops contain self-regulating processes, throttle pressure is an exception being an integrating process when the unit runs in boiler-following mode. This requires special tuning considerations to ensure throttle pressure and fuel flow remain stable. Incorrect tuning of the throttle pressure controller can cause oscillations in all critical control loops around the boiler.

About the Author

Jacques Smuts is the founder and principal consultant of OptiControls Inc. (Houston, Texas). He provides control loop optimization services and training to industrial companies worldwide and has more than 20 years of experience in process control, including seven years in power plants.

Jacques has developed controller tuning and loop performance monitoring software that ranks among the top three applications in their class. He has trained hundreds of engineers and technicians in the field of process control, and has optimized thousands of control loops.

Jacques is an authority on control loop performance monitoring and optimization and has dedicated his career to improving the performance of industrial controls though his services, training, literature, and software. He regularly posts articles on process control at http://blog.opticontrols.com.

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