Derivative Backoff: A Process Value Saturation Problem for PID Controllers

Theorin, Alfred; Hägglund, Tore

2015

LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

Derivative Backoff:
A Process Value Saturation Problem for PID Controllers

Alfred Theorin (alfred.theorin@control.lth.se), Tore Hägglund

The PID controller is by far the most commonly used controller. To ensure good behavior under all circumstances, a PID implementation must consider many aspects. In particular, physical limits of signals must be considered. If physical limits for the control signal are not considered, there is integrator windup when the control signal saturates. An analogous issue has been discovered and named derivative backoff. If physical limits for the process value are not considered, there is derivative backoff when the process value saturates.

The derivative part of PID controllers predicts future process values by estimating the process value derivative. With a saturated process value there is no information about the process value derivative and thus the derivative part breaks down. At saturation, the derivative of the measured process value is 0 and, consequently, there is no derivative action. This makes sense as there is no information about future process values. However, the behavior when the process value saturates makes less sense, see Figure 1. Here, the process is controlled close to a physical limit (100) when a large load disturbance occurs. Just before the process value saturates, the process value derivative is positive, which means that the derivative action is negative. Shortly after the process value saturates, the derivative part is 0, that is, there is no derivative action. Together, this means that when the process value reaches its maximum, the negative derivative action backs off and thus the control signal increases. This is not a desirable behavior.

In Figure 1, the process $P = \frac{1}{(s+1)^4}$ and its corresponding MIGO design method parameters have been used. Note that MIGO produces a robust controller with optimal load disturbance handling. The example shows what derivative backoff looks like and demonstrates that it is an issue for industrially relevant processes with well tuned PID controllers.

To implement anti-backoff, that is, to avoid derivative backoff, the derivative action needs to be kept when the process value saturates. Different anti-backoff approaches have been evaluated and the proposed solution is to disable and immediately re-enable the derivative part bumplessly when the process value saturates. This requires that the process value limits are known, which is true for most control loops. The PID controller must also have integral action, since it is otherwise not possible to bumplessly disable the derivative part. This is also true for most PID controllers with derivative action. Further investigation is needed to find a good solution for controllers without integral action.

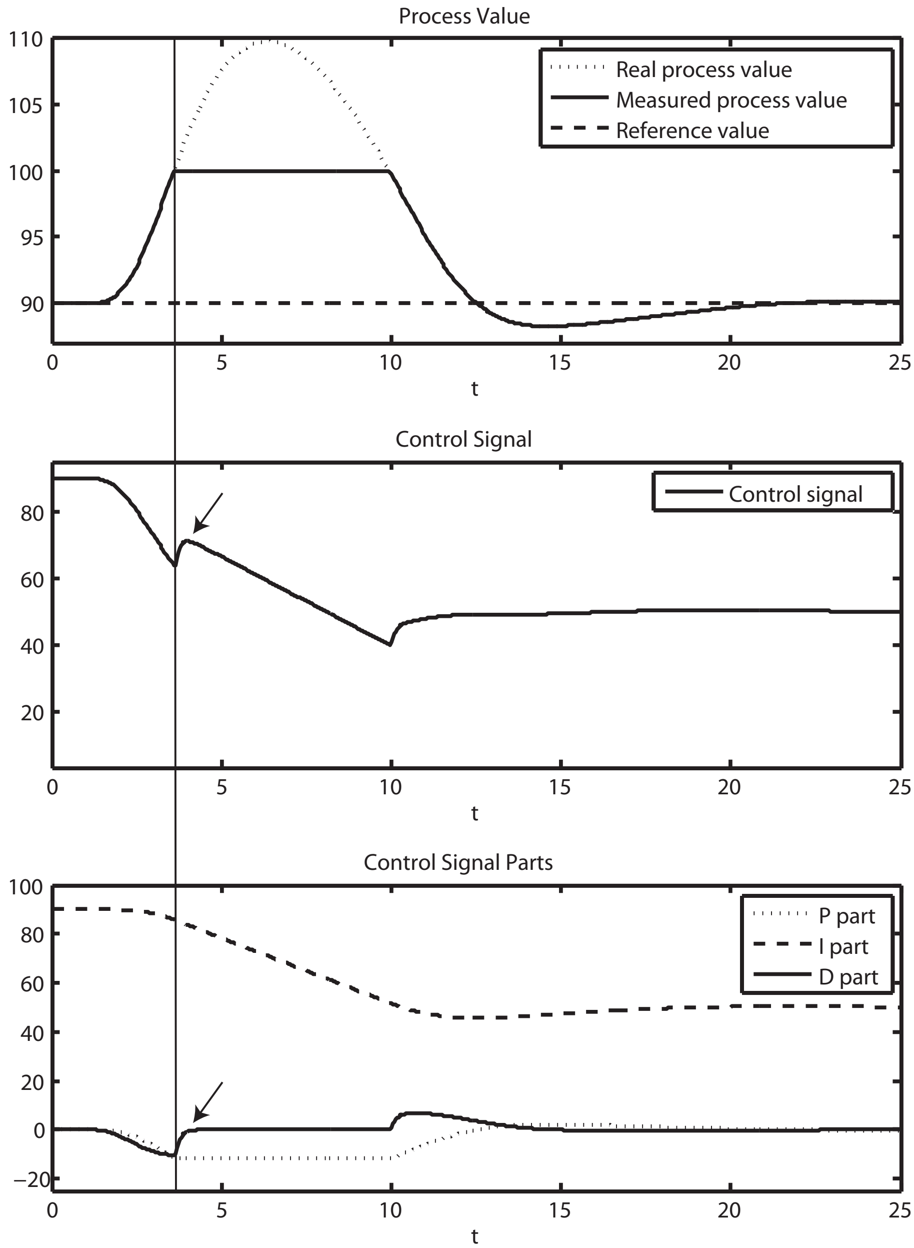

Figure 1: A large load disturbance occurs. When the process value saturates, the derivative part backs off and thus the control signal increases. The process value is thus pushed further away from the measurement range.