Comparison of schemes for windup protection

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Automatic control is all around us, it can be applied on just about anything, and when it is tuned correctly, you will probably not even notice that it is there. The first things that might spring to mind might be the assembling of cars in a automobile factory, or trajectory and flight control of space shuttles, or various systems of a power plant. There are, however, automatic control much closer to home; in aeroplanes, or in your car, controlling the temperature of your fridge, or the fan speed in your computer.

The most common kind of controllers used are the *P*, *PI* and *PID* controllers, that stands for *proportional-integral-derivative* controller. The proportional part looks at the current error, the integral part looks at past error, and the derivative part tries to predict future error, these are then added together to give a combined control signal to give the right amount of control signal for the task at hand. The controllers are often tuned with an ideal case in mind, where there is no limitations to the control signal, but in the real world a motors acceleration or maximum torque is limited, the valve can not be more than fully open, or completely closed, and the fan can not get more than a limited amount of voltage. If the limit of the actuator is reached, a windup effect can occur, caused by the integrator in the controller. When the controller is unable to reach the setpoint, the integrator will add up the past error, and will grow larger and larger. This is called integral windup.

Consider a car that from standing still would want to drive at exactly 100 km/h. Even with the pedal to the metal, the car would not be able to reach 100 km/h instantly. When the car reaches the targeted velocity the integrator would still want to go a little faster for a while, so that the average speed becomes 100 km/h. The longer it took for the car to reach the targeted velocity the faster the integrator would want to go to compensate, but when it is satisfied, the deceleration down to 100 km/h is also limited, resulting in a higher average speed than what was intended. The cycle then repeats, since the integrator now instead wants to slow down to compensate. The velocity of the car oscillates around the targeted velocity a couple of times, a simple look on how this can unfold can be seen in figure 1 where the system output oscillates around the desired value.

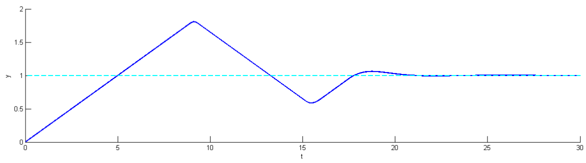

Figure 1: PI control of a single integrator with no windup protection and saturated actuator.

There are several different ways to counter this windup effect, and this master thesis have focused on comparing some of them for both PI and PID control. The thesis contains two traditional anti-windup methods and two variations of these methods. The methods are compared for processes taken from a test batch. For each process different cases were tested, such as step response, both load disturbance and a setpoint change after a time of saturation. For PID control disturbances in form of measurement noise, and a pulse, was also tested.

Simulations were done in *Simulink* in *Matlab*. By running simulations strengths and weaknesses could be found for the methods, as well as analysis on the behaviour of the methods. All the various anti-windup methods are a vast improvement, but no method is uniformly superior and the anti-windup method should be chosen for the problem at hand. It may be possible to further improve the traditional methods for windup protection, and a proposal for a mixture of two methods are suggested in the thesis work.