7. A review of Some Terms and Solutions

Windup

- Improper updating of the integral term, transfer function or controller states during the saturation. Here y will not track w after saturation.

Anti-Windup

- Use the *conditioning technique* to update the integral term, transfer function or controller states in such a way that y will track w after system comes back from the saturation. Figures 7.1 to 7.4 show the anti-windup solution for different types of controllers.

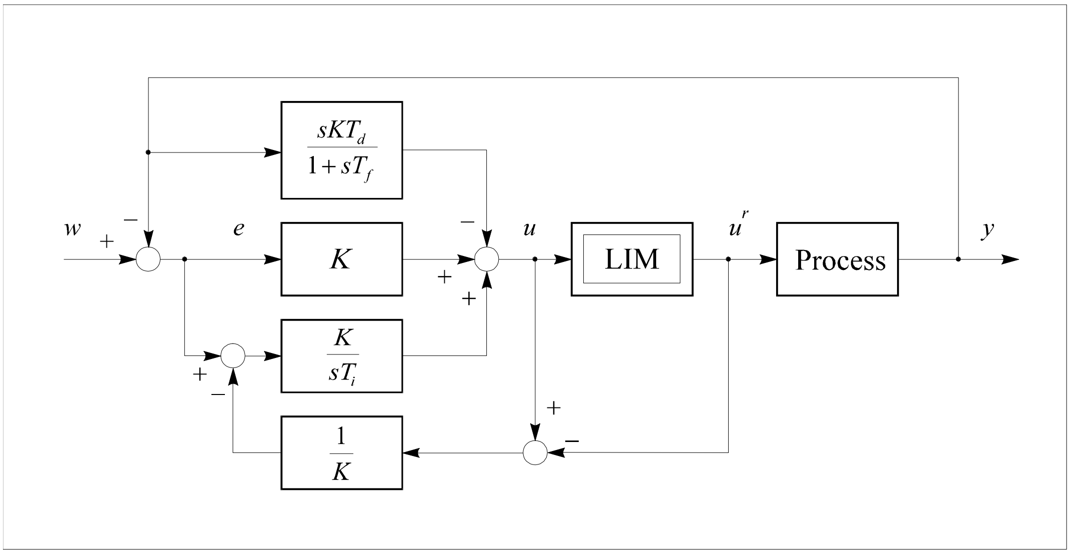

Fig. 7.1. Anti-windup solution for PID controller

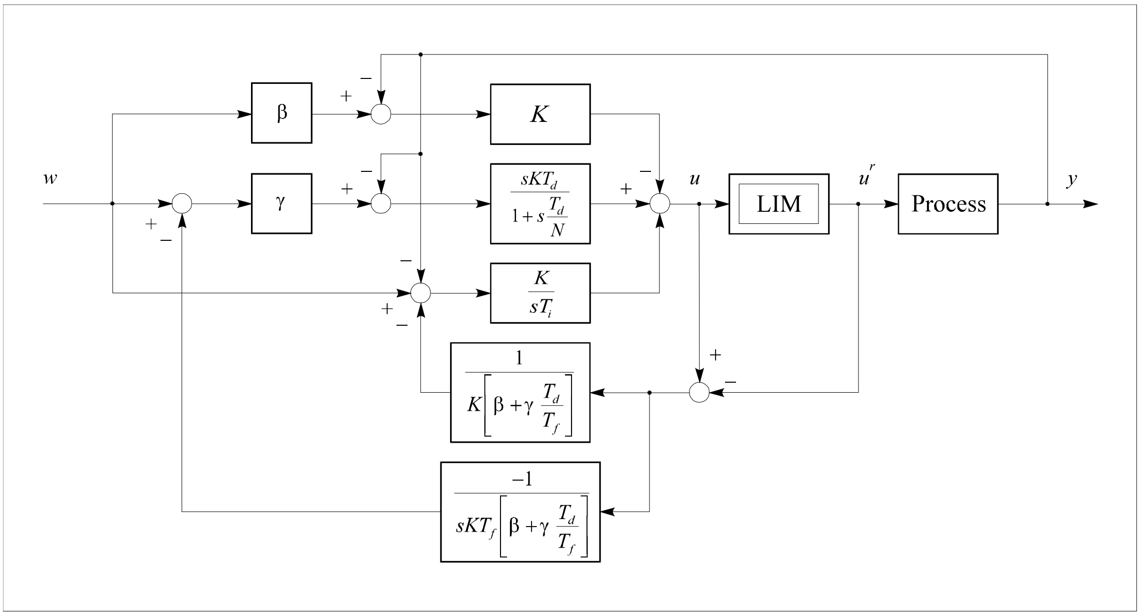

Fig. 7.2. Anti-windup solution for generalised PID controller

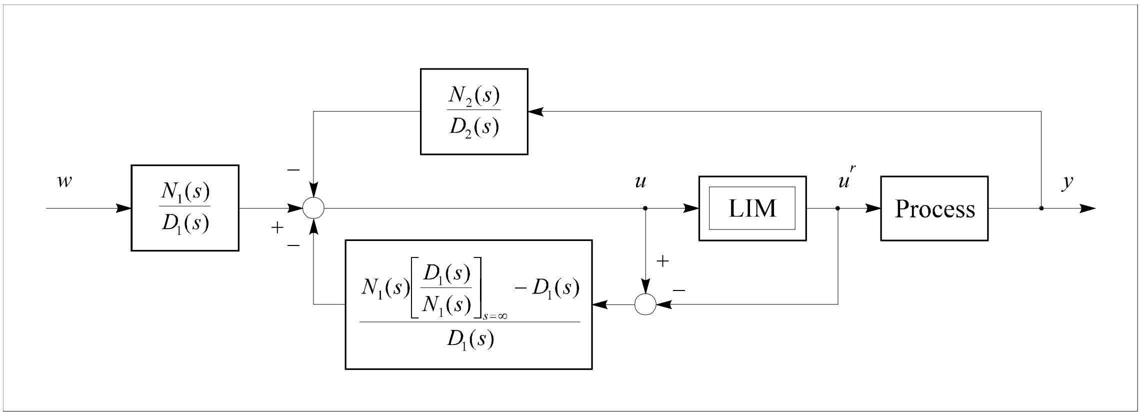

Fig. 7.3. Anti-windup solution for controller with rational transfer function

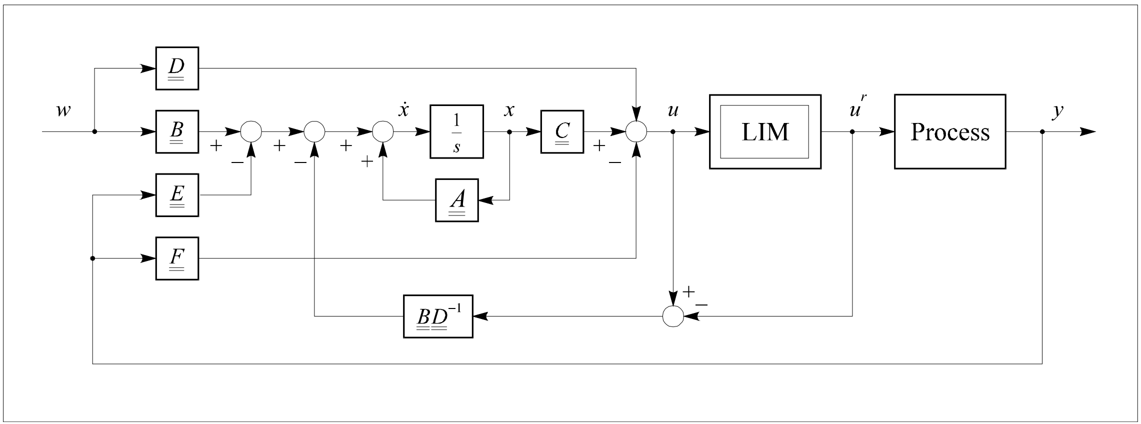

Fig. 7.4. Anti-windup solution for state-space controller

Bump Transfer

- Uncontrolled updating of the integral term, transfer function or controller states during manual mode. A big bump (jump) in u^r will appear at the time of switching.

Bumpless Transfer

- Use *incremental algorithm* to assure no bump at the time of switching.
- *Drawbacks*: It produces inferior tracking performance (y will not track w after switching).

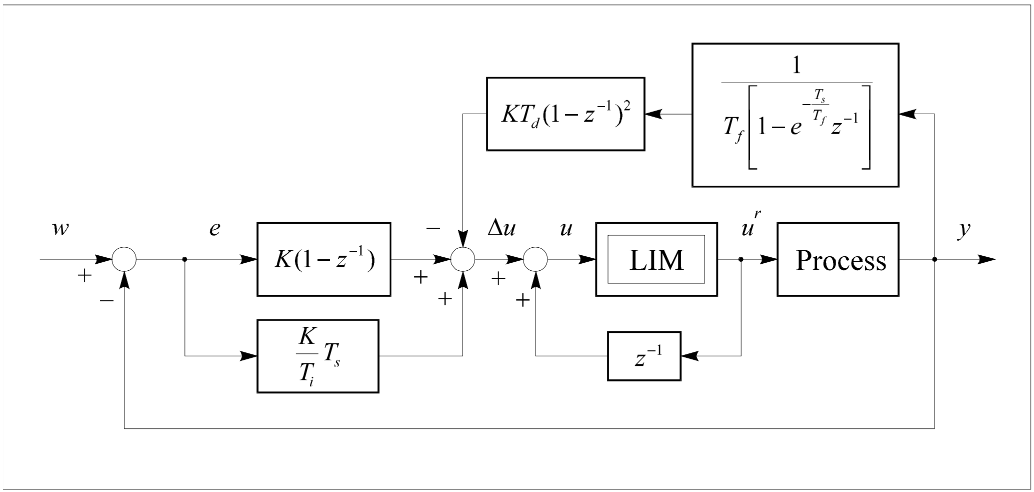

Fig. 7.5. Bumpless transfer - incremental algorithm.

Conditioned Transfer

- Use the *conditioning technique* to achieve good tracking performance after switching. The solution is equivalent to ones presented in Figures 7.1 to 7.4 with exception that the limiter have to be replaced by the switch.

Anti-Windup and Conditioned Transfer

- Use the *conditioning technique* to achieve both, *anti-windup* and *conditioned transfer* in the system with limitations and non-linearities. The solution is shown in Fig. 7.6, where LIM_C represents controller limitations, LIM' represents estimated process limitations, NL' is an estimated process non-linearity and u^m stands for manual signal or other kind of signal (e.g. an output of the another controller). Note that LIM' can also be placed on the right side of the switch or switch can be placed in front of the NL'^{-1}.
  The solution for other controllers is the same except that PID controller have to be replaced by another controller type.

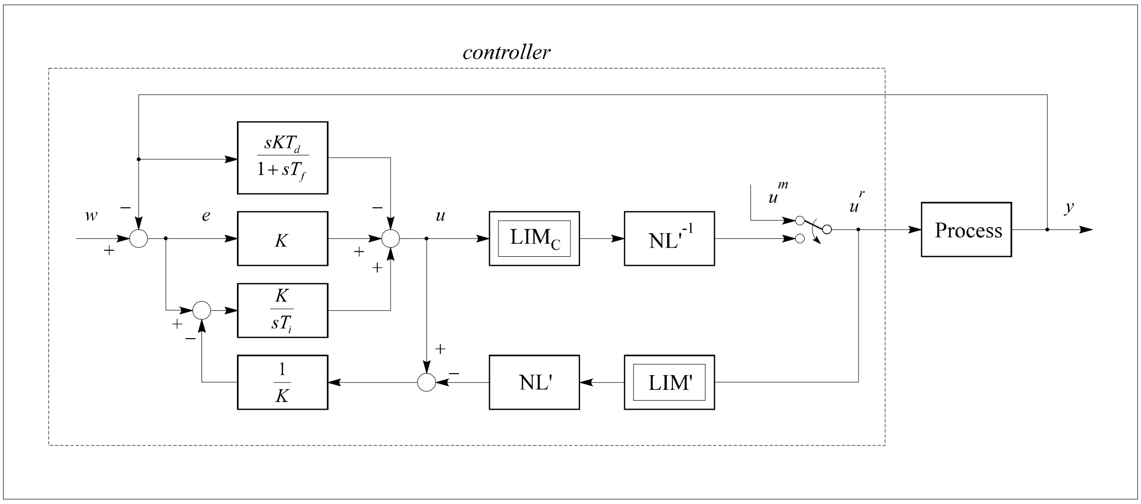

Fig. 7.6. Anti-windup and conditioned transfer - conditioning technique.

8. Conclusions

We have given a simple and comprehensive view of anti-windup, bumpless and conditioned transfer techniques. Using the so-called realisable reference, we have shown that the conditioning technique is the most suitable anti-windup method for the usual applications.

Two types of transfers between manual and automatic mode or between different controllers are described. Although bumpless transfer is a well known concept, it is not the best choice since the tracking performance is degraded. The new notion of the conditioned transfer is thus introduced for the first time. This technique assures good tracking performance after switching from manual to automatic mode or when switching between different controllers. In this work we also proposed the method of variable K_a for very restricted processes and solution of anti-windup for non-square matrix D state-space controllers.

During our research in the field of anti-windup and conditioned transfer we also noticed that the settling time of the limited system, when conditioning technique is not used, highly depends on the integral time constant (T_i) of the PID controller. The bigger is T_i, the longer is the settling time.

We have also made some additional steps toward anti-windup solution for matrix D rank deficient controller where we are on the way to find practical method of tuning the anti-windup compensator.

Another control problems which often appear in real systems are disturbances and noise. During our research we found that incremental algorithm appears to be very sensitive to noise.

Our further work will be therefore concentrated on mentioned open questions and on implementing the proposed anti-windup algorithms into discrete-time controllers and studying possible problems which can appear in such design.

One, also important further field of our research, will be anti-windup solutions for controllers with variable structure.

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