A new anti-windup design paradigm for control systems

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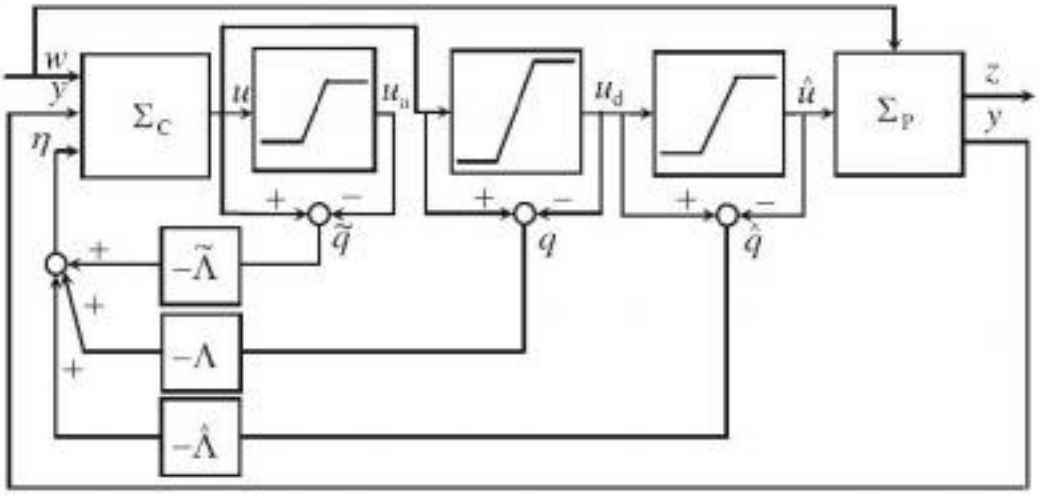
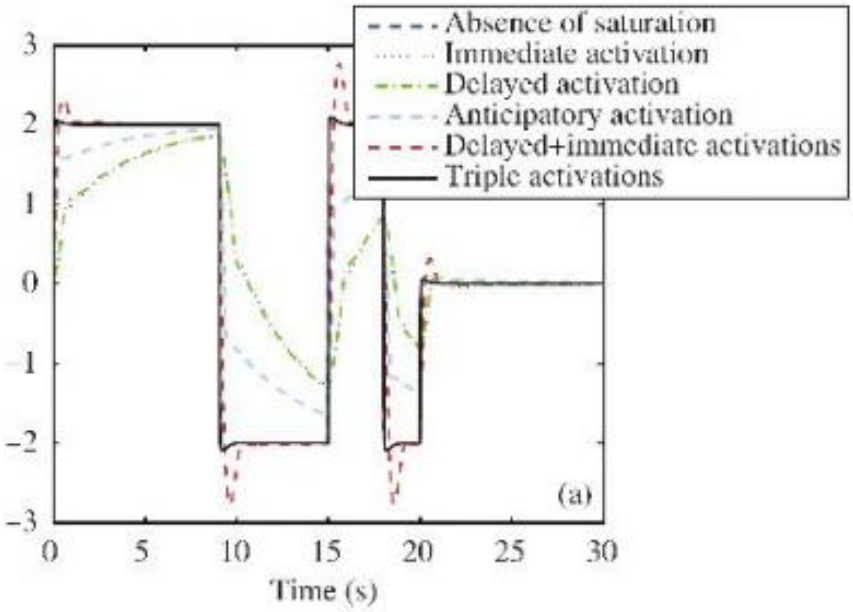


Actuator saturation is ubiquitous in engineering systems. Anti-windup approach to dealing with actuator saturation has been receiving considerable attention from both the industry and the academic community during the past decades. Professor Zongli Lin and his student Xiongjun Wu developed a new anti-windup design paradigm that is capable of achieving significantly improved performances of the resulting closed-loop system. Their work, entitled "Design of multiple anti-windup loops for multiple activations," was published in SCIENCE CHINA Information Sciences, 55(9), 2012.

The traditional anti-windup scheme involves a single anti-windup loop designed for activation immediately at the occurrence of actuator saturation, regardless of the facts that the system might just experience occasional slight saturation rather than operate consistently under severe actuator saturation. Realizing that, by allowing the nominal controller to act unassisted in the event of slight or moderate saturation, the robustness property of the nominal closed-loop system will have the inherent ability to overcome the adverse effects of such slight or moderate saturation, Sajjadi-Kia and Jabbari recently initiated a line of work that exploits the benefit of delayed activation of anti-windup mechanism. In particular, they have shown that significant improvement on the closed-loop transient performance can be achieved if the anti-windup loop is designed for delayed activation instead of immediate activation, and that further improvement can be achieved if two anti-windup loops are designed simultaneously, one for immediate activation and the other for delayed activation.



Subsequently, Professor Lin and his student Xiongjun Wu examined the idea of activating the anti-windup mechanism in anticipation of actuator saturation and showed that the anti-windup compensators, both static and dynamic ones, designed for anticipatory activation, will lead to significantly better closed-loop transient performance than with the designs for delayed activation. In their current SCIENCE CHINA Information Sciences paper, they report their development of a new anti-windup design paradigm, referred to as the triple loop anti-windup design that includes three anti-windup loops, simultaneously designed for immediate, delayed and anticipatory activations (see Figure 1 below).

This new design paradigm results in a closed-loop system that outperforms closed-loops systems resulting from other design methods mentioned above. Shown in Figure 2 below is a comparison of the tracking ability of the closed-loop system under the triple loop anti-windup design with those of the closed-loop systems under an anti-windup loop designed for immediate activation, delayed activation or anticipatory activation, and under two anti-windup loops, simultaneously designed for delayed and immediate activations. Also shown in the figure for reference is the response of the nominal closed-loop in the absence of actuator saturation. It is clear from this comparison that the closed-loop system with the triple loop anti-windup design demonstrates significantly stronger ability to recover the nominal closed-loop performance in the absence of actuator saturation.

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