Nonlinear control perspectives in Tokamak plasmas: applications to FTU and JET

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Advantages of nonlinear control solutions

- May overcome intrinsic limitations of linear control (e.g., overshoots, disturbance rejection, etc).
- Can handle soft and hard constraints more efficiently.
- Can directly address nonlinearities in a plant (saturations, quantization, general nonlinearities).
- Allows bumpless switching between different controllers.
- Often small extensions and modifications of substantially linear control schemes lead to large stability and performance improvement.
Handling input nonlinearities

- Anti-windup: address plant input distortion during transients

- Dynamic allocation: address steady-state input specs
Anti-windup application: FTU

- Small signal nonlinearity in current control of F coils
- Circulating current in thyristor bridges causes nonlinear response and destabilizes the closed-loop
- Anti-windup solution recovers closed-loop stability
Dynamic allocation application: JET

- Coil current saturation may cause experiment loss
Dynamic allocation application: JET

- Trade in some shape performance to move coils out of sat
Dynamic allocation application: JET

Similar tools allow to achieve elongation control at FTU
**FTU: NL extremum seeking application**

**Framework:**
Additional RadioFrequency heating injected in the plasma by way of Lower Hybrid (LH) antennas: plasma reflects some power

**Goal:**
Optimize coupling between the Lower Hybrid antenna and the plasma, during the LH pulse
Nonlinear extremum seeking for RH heating

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Additional promising NL techniques

- Reset control systems: overcome limitations of linear sols

- Quantized actuation via (quasi) time-optimal control
Noise suppression via nonlinear filtering

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Nonlinear filtering: zoom
Summary

• Nonlinear control solutions have been illustrated on examples
  • with input nonlinearities causing transient problems
  • with input nonlinearities causing steady-state problems
  • in the extremum seeking context maximizing RFH efficiency

• More generally several tools are available and can be used to improve upon what is achieved by linear tools

• Typically, interaction between control theorists and applied control people uncovers directions where nonlinear control can help