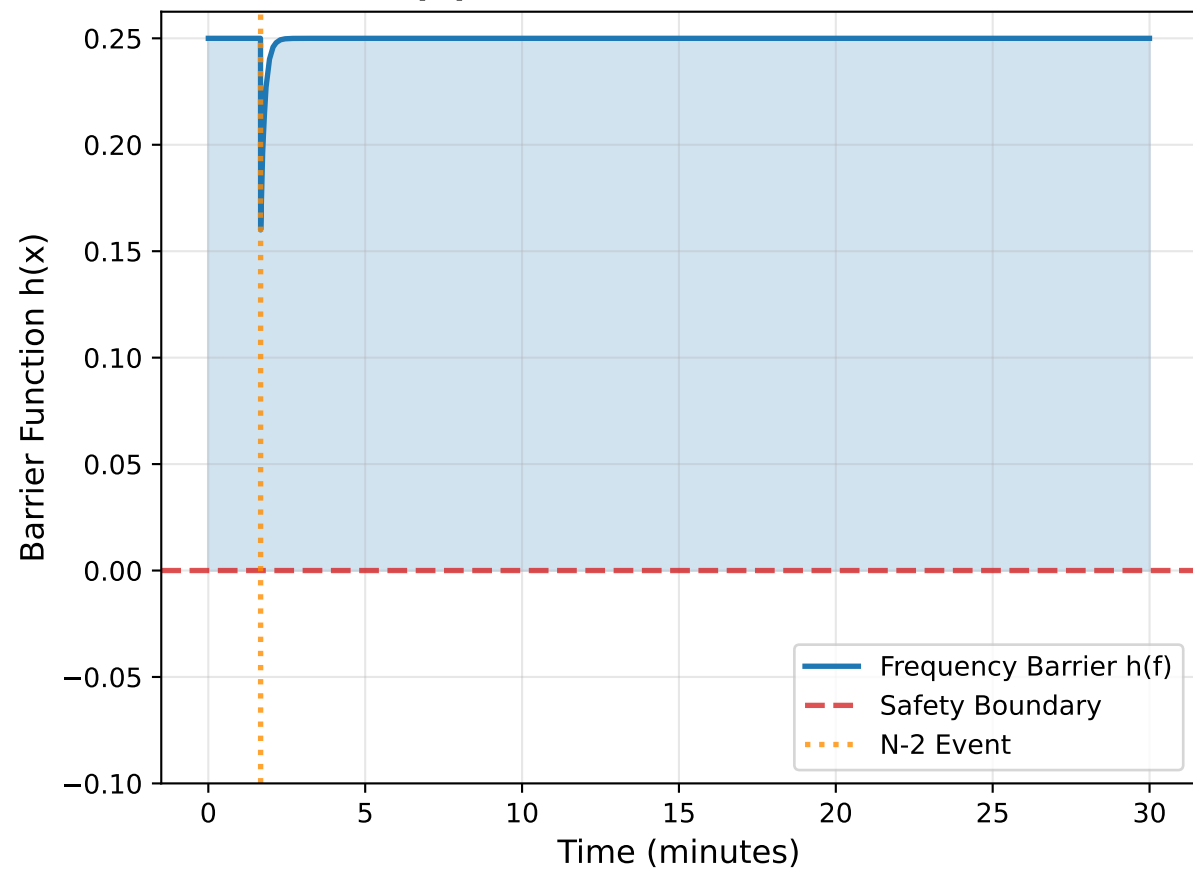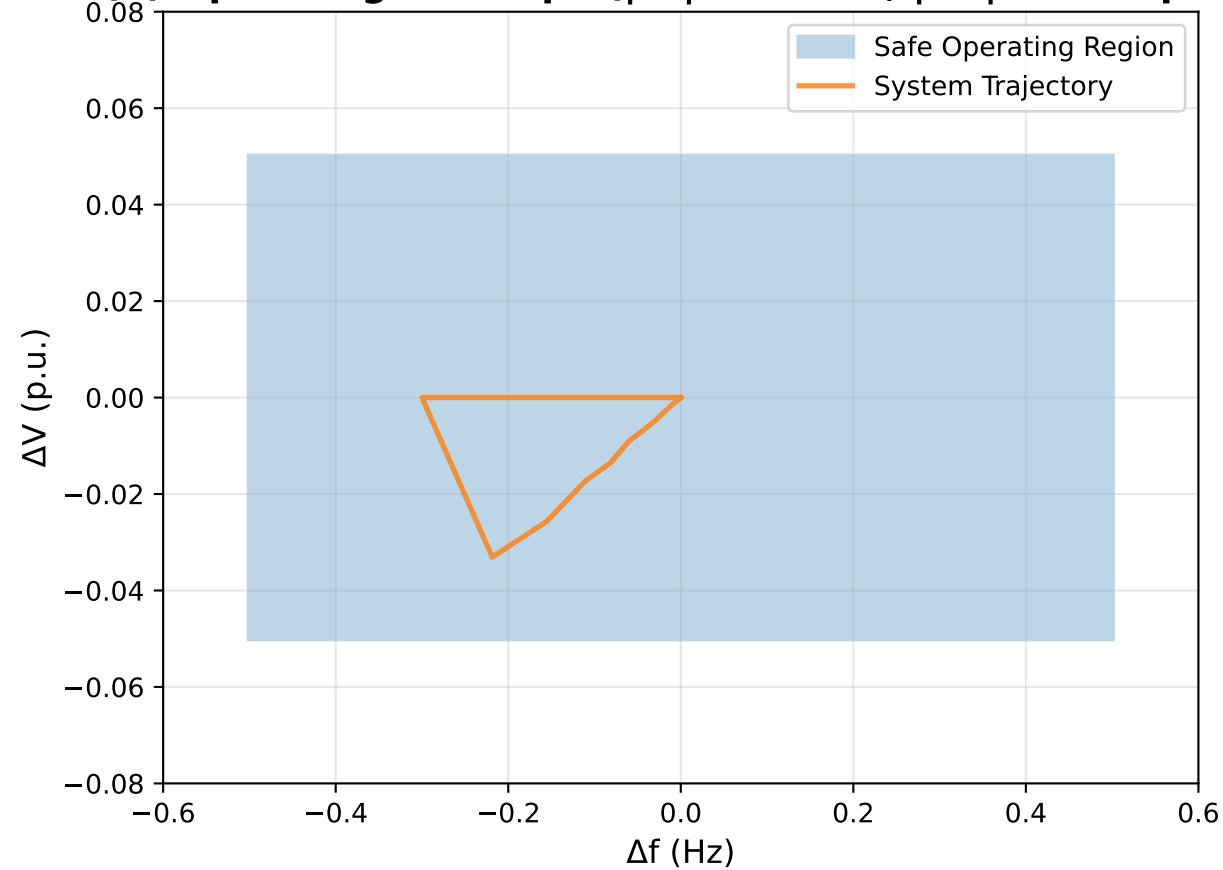# Control Barrier Function Safety Verification - Realistic Simulation

Test Conditions: Delay = 150 ms (jitter 10–150 ms), Packet Loss = 20% (Bernoulli i.i.d.), Violation dwell = 200 ms (min duration to count an event), h_freq = 0.25 - (Δf)², Δt = 0.100 s (10 Hz)
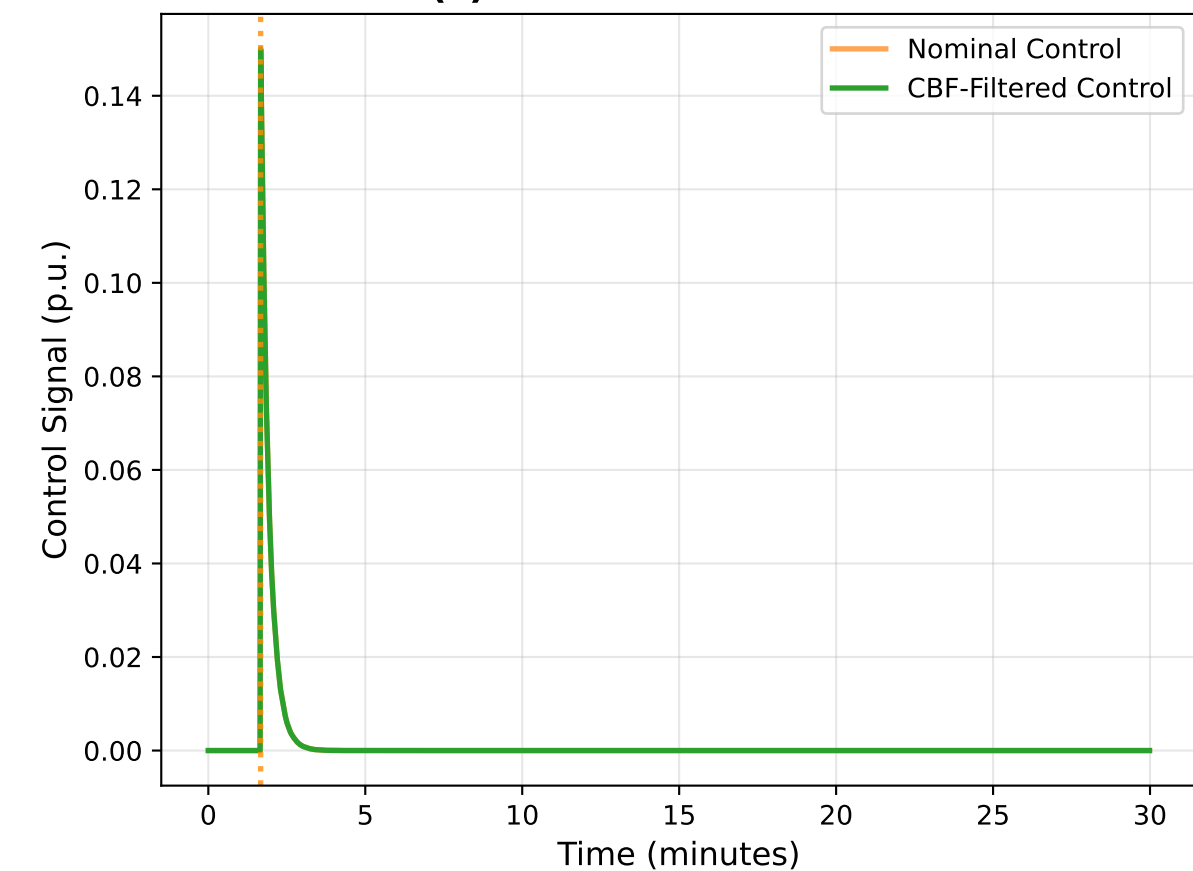

(a) Real Barrier Evolution

Legend:
- Frequency Barrier h(f)
- Safety Boundary
- N-2 Event

(b) Operating Envelope (|Δf| ≤ 0.5 Hz, |ΔV| ≤ 0.05 p.u.)

Legend:
- Safe Operating Region
- System Trajectory

(c) Control Modification

Legend:
- Nominal Control
- CBF-Filtered Control

(d) N-2 Contingency Response

Violation events: 0 (this run)
Events/hour: 0.0/h
Target: < 2 events/h ✓
Max deviation: 0.300 Hz

Legend:
- Frequency Deviation
- ±0.5 Hz Limits
- N-2 Event
- Peak Response