Technische Universiteit Eindhoven University of Technology

Distributed H_∞-based Control of Electrical Power Systems

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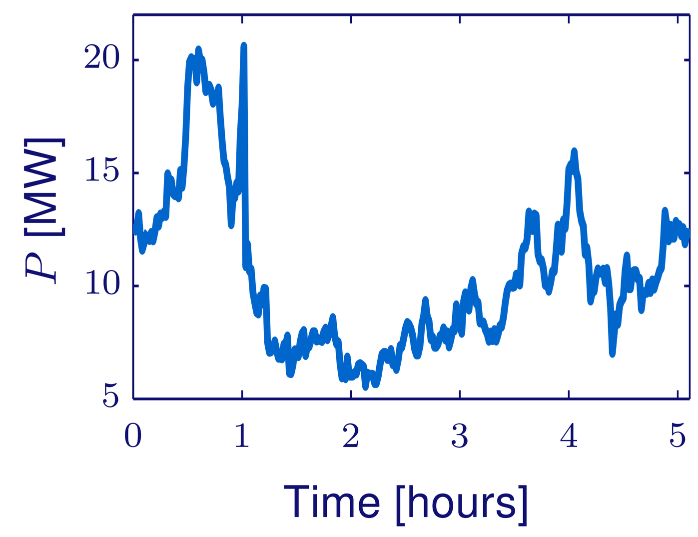
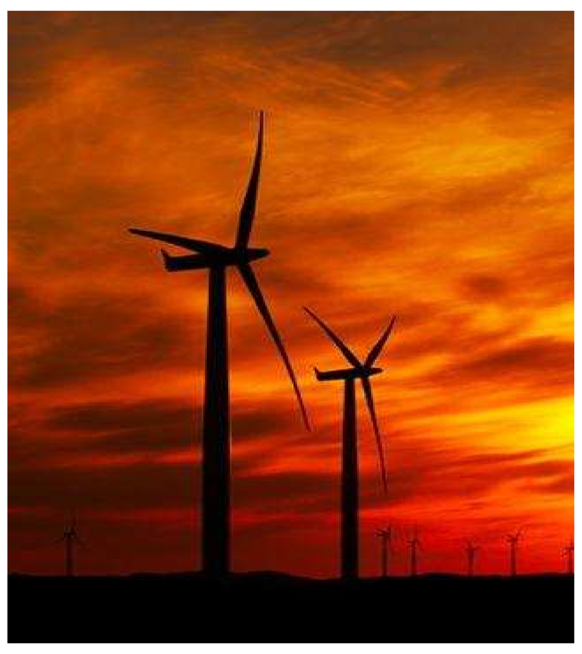


Fluctuations in wind turbine power output

Trends in electrical power networks

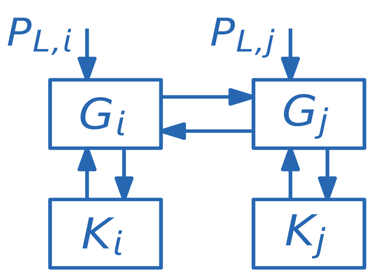
- *Market liberalization:*
  Competitive operation in which centralized control is no longer possible. Market induces imbalances.
- *Renewable energy resources:*
  Fluctuating and distributed power generation with multidirectional power flows.
- *Increase of complexity:*
  Hardly any stability and robustness guarantees with current AGC controllers.

Threatens grid stability whereas existing control schemes cannot cope with these trends!



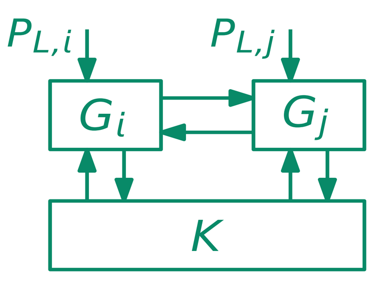
Control configurations

Control of systems that are physically connected over a network: a graph of interconnected systems.



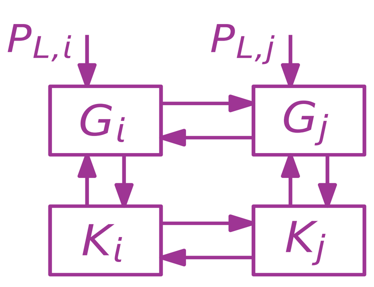
Decentralized control

- Feedback of local information only
- No communication between neighboring control areas.



Centralized control

- All information assumed available for control
- Infeasible because of geographical distances and prohibitive controller complexity



Distributed control

- Allows communication with neighboring controllers
- Novel techniques, topic of this paper.

The distributed H_∞-control problem

Given graph of L interconnected LTI dynamical systems

$$G_i(s) \quad \text{col}(d_i, v_i, u_i) \mapsto \text{col}(z_i, w_i, y_i)$$

with *performance channel* (d_i, z_i), *interconnection channel* (v_i, w_i) and *control channel* (u_i, y_i), find L LTI controllers

$$K_i(s) \quad \text{col}(y_i, v_i^K) \mapsto \text{col}(u_i, w_i^K)$$

with same adjacency structure such that interconnected system is *well posed*, *internally stable* and *optimal* in the sense that

$$\|\mathcal{F}_\ell(G, K)\|_\infty = \sup_d \frac{\|z\|}{\|d\|} < \rho.$$

for some $\rho > 0$. Here, $d := \text{col}(d_1, \ldots, d_L)$, $z = \text{col}(z_1, \ldots, z_L)$ denote vectors of all disturbance and performance signals in the graph.

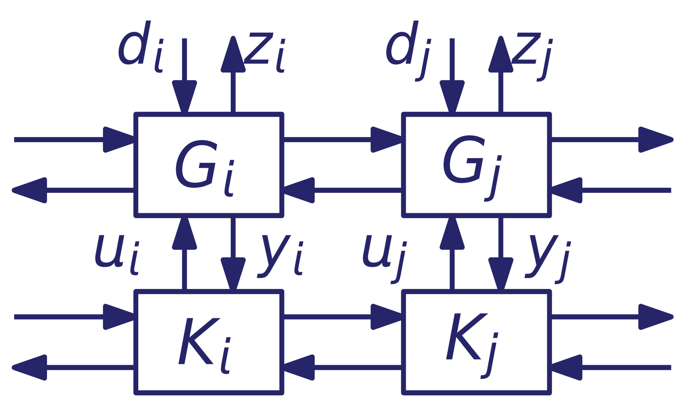
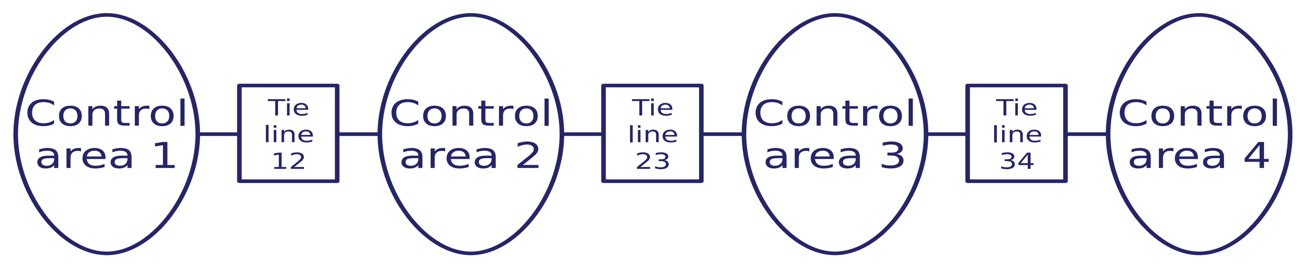


Figure 2: The distributed H_∞ control problem

Application and results



Simulation set-up with 4 interconnected control areas. Controlled variable $z_i = \text{col}(\omega_i, P_{\text{tie},ij})$ consists of frequency and tie-line power flows between areas. Robust implementation using LMI techniques of [1] to compute 4 interconnected controllers. Validation by stepwise load increase in area 2, simultaneous load decrease in area 3.

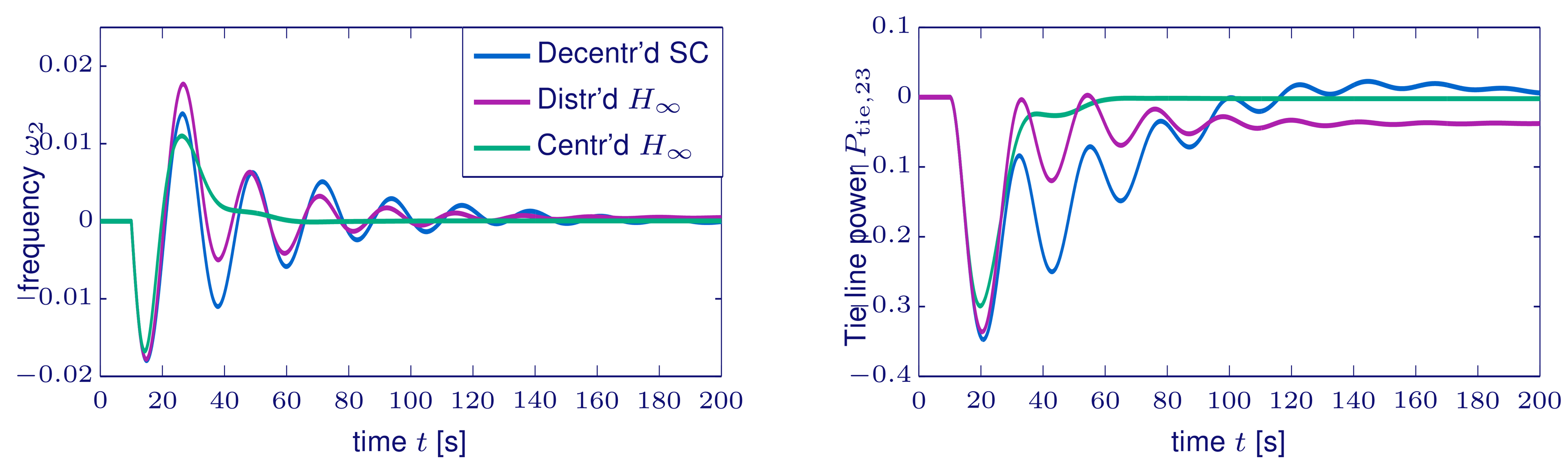


Figure 4: Closed loop responses of frequency ω_2 and tie line power $P_{\text{tie}23}$ in control area 2

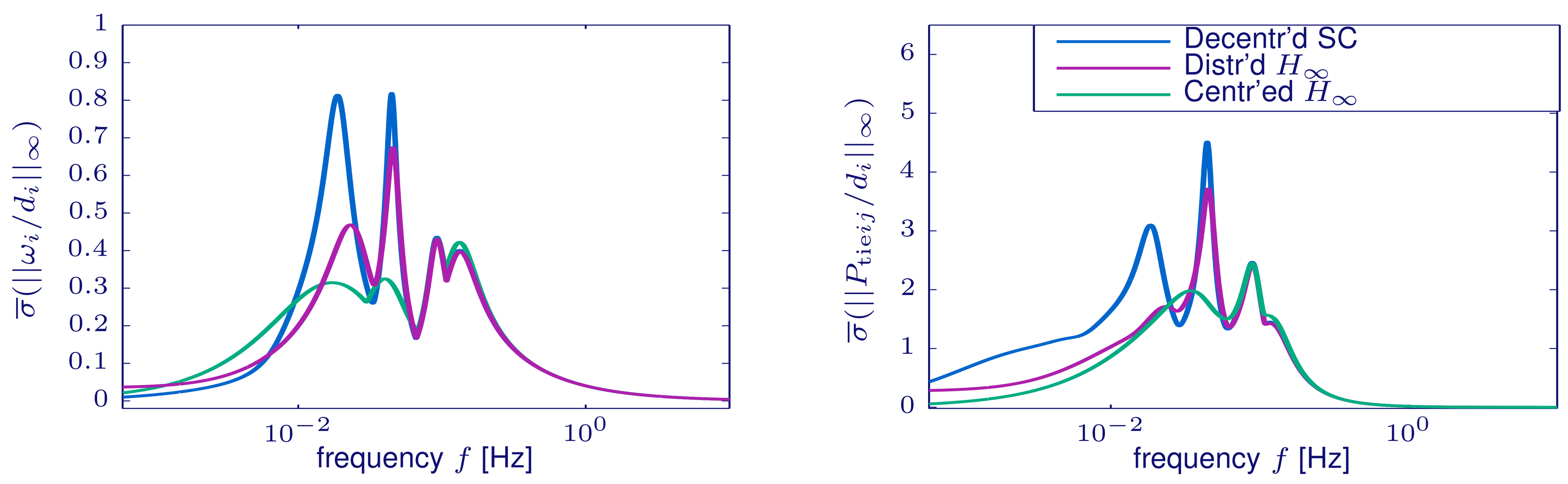


Figure 5: Closed loop spectra of frequency ω_2 and tie line power $P_{\text{tie}23}$ in control area 2

References

[1] C. Lambort, R. S. Chandra and R. D'Andrea, Distributed control design for systems interconnected over an arbitrary graph, IEEE Transactions on Automatic Control, vol. 49, no. 9, pages 1502–1519, 2004