Module-based Modeling and Control of Systems with Wind Power Plants

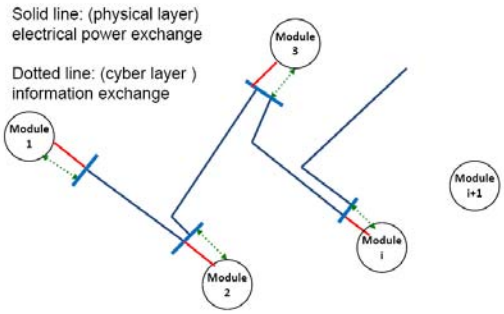
Le Xie (lx@andrew.cmu.edu) and Marija D. Ilić (milic@ece.cmu.edu)

Motivation

- To provide systematic means of analyzing the grid dynamics with high penetration of wind power.
- To design control and information protocols for guaranteed performance of power systems with high penetration of distributed energy sources.

Approach

- Structure-preserving model [4]: treat components as modules (both loads and generators) connected via transmission network.



- Specify module related state variables and network related state variables. The system is modeled in a set of ODEs rather than DAEs.

$$\dot{x}^i_{\text{mod}} = f(x^i_{\text{mod}}, x^i_{\text{net}}, u^i, p^i)$$

$$\dot{x}_{\text{net}} = 0x_{\text{net}} + Hx_{\text{mod}}$$

where $x_{net} = \begin{bmatrix} x^1_{net} & x^2_{net} & \dots \end{bmatrix}$;

$x_{\text{mod}} = \begin{bmatrix} x^1_{\text{mod}} & x^2_{\text{mod}} & \dots \end{bmatrix}$;

H = power flow Jacobian;

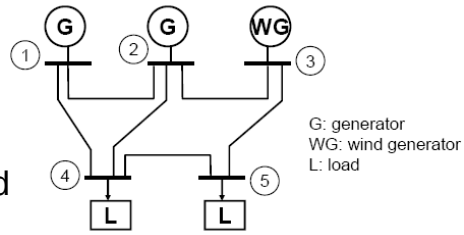
x^i_{mod} = module related state variabls;

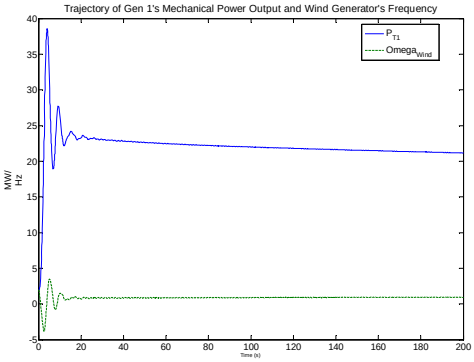
$x^i_{net} = \begin{bmatrix} P^i & Q^i \end{bmatrix}$ (injected power to the network at node i).

Theorem: the whole system is bounded-input-bounded-output (BIBO) if (i) all the modules are locally stabilizable and (ii) matrix H satisfy *Hicks* condition [1].

Example

- Linearized wind turbine model with random mechanical torque input [3];
- Linear dynamic load model [4].





- All the modules are locally stabilizable;
- Power flow Jacobian satisfy the Hicks condition.

This system is BIBS stable with wind power integration

Conclusions/ Future Work

- A module-based model of power systems with wind power integration is proposed.
- Analytically guaranteed stability performance could be specified from the proposed model.
- Examples show the potential of designing cyber-physical structure for guaranteed system performance with distributed energy penetration.
- Future work should include investigation of the dynamic aggregation of modules for pre-specified performance over a broad range of operating conditions.

Acknowledgement

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References

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