

Primary and Secondary Control for High Penetration Renewables

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Primary & Secondary Controls Today

Existing practice – Large synchronous generators (almost) alone as controllers regulating frequency & maintaining electromechanical stability of grid.

To date, renewable resources largely excused from these control responsibilities; trials on-going with responsive load participation in regulation.

Participants in voltage control more diverse (exciters, SVCs, switched capacitors), but role of renewables still evolving.

Evolving Visions: Control Philosophy(ies) for Renewables/Responsive Load

Challenge of power variability widely recognized.

NERC flagging reduced system inertia, decreased electromechanical stability with high penetrations of power-electronic coupled renewables.

FERC beginning to incentivize control potential of responsive load to complement renewables.

Need control philosophy and design tools to accommodate very different nature of control capabilities from renewables & loads & storage.

Key Issues:

- i) Need control design suited to diversity of renewables – “actuators” with widely differing technical capabilities (unlike largely uniform character of synchronous machines in the past)
- ii) Must improve quantification of individual controller’s contributions to system regulation, electromechanical stability needs (e.g., only specifying droop & ramp rate grossly inadequate)

Control Design Tools:

- i) For regulation & electromechanical stability, “actuation” is control of power output. In linear regime, need full state space and/or frequency-domain dynamic controller description (contrast - droop specifies only dc gain, no dynamics!!!)
- ii) The critical nonlinearities in control action are state dependent saturation limits (contrast - ramp rate is just one of these possible state dependent limits). New technologies have other technical limits - e.g., battery energy.

(with apologies to Zangwill & Garcia, we borrow the title of their classic text...)

“Pathways to Solutions”

i) General: Tremendous advances in computational power available to controllers; expansion in number & bandwidth of measurements that can inform control action.

ii) Specific: regulation with saturation limits well suited to tools of Linear Quadratic (LQ) Optimal Control design and more recent LMI techniques. Indeed, LQ design for AGC was examined, but abandoned as impractical, 70’s & early 80’s.

Today, confluence renewables’ need to contribute to grid control & stability, advanced computation & sensing imply...

Opportunity for Designs Based on LQ Optimal Control and Convex Optimization to be Enablers for High Penetrations of Renewables

PSerc first steps, under “Control and Protection Paradigms of the Future”
[1] C. L. DeMarco and C. A. Baone, “Smart grid control design methods for distributed energy storage in frequency regulation markets,” in Proceedings of the 18th International Federation of Automatic Control World Congress, Milan, Italy, Sept. 2011.

[2] C. A. Baone and C. L. DeMarco, “From each according to its ability: Distributed grid regulation with bandwidth and saturation limits in wind generation and battery storage,” to appear, IEEE Transactions on Control Systems Technology (accepted for publication September 2011).

[3] C.A. Baone, C. L. DeMarco; “Saturation-bandwidth tradeoffs in grid frequency regulation for wind generation with energy storage,” Proc. of the Innovative Smart Grid Technologies Conference (ISGT), Anaheim, CA, Jan. 2011.