

Research Activities in Power Systems and Power Electronics (2013-2017)

Romeo Ortega

Laboratoire des Signaux et Systèmes

CNRS-CentraleSupélec

Gif-sur-Yvette, France

Champs-sur-Marne, France, 6/10/2017

Organization

- Some words on our *modus operandi*
- Power systems
 - ▶ Modeling
 - ▶ Transient stability
 - ▶ HVDC systems
- Microgrids
 - ▶ Modeling
 - ▶ Droop control
- Alternative energy generation
 - ▶ Wind: speed estimation and control
 - ▶ Photovoltaic arrays: irradiance estimation and control
- Power converters
 - ▶ Control
 - ▶ Constant power loads
- Current research

Modus Operandi

- Physically (not mathematically)-based approach to control

- ▶ Physical systems satisfy energy conservation:

$$\text{Stored energy} = \text{Supplied energy} + \text{Dissipation}$$

- ▶ Reasonable control objective:

$$\text{Desired stored energy} = \text{New supplied energy} + \text{Desired dissipation}$$

- ▶ This is the essence of **Passivity-Based Control** (PBC)

$$\text{PBC} = \text{Energy Shaping} + \text{Damping Assignment}$$

- **PID control** (being passive) fits naturally in the PBC framework.
- An essential component is **close collaboration** with experts of the fields
 - ▶ To identify the problems of interest
 - ▶ Maintaining mathematical rigor be consistent with practical scenario
 - ▶ Comparative experiments with existing techniques
 - ▶ Provide tuning rules for them

Power Systems

- Detailed modular modeling: [F. Shaik, D. Zonetti, R. Ortega, J. Scherpen and A. van der Schaft: A port-Hamiltonian approach to power network modeling and analysis, *European Journal of Control*, Vol. 19, 2013.]
- Transient stability
 - ▶ First globally stable scheme: [D. Casagrande, A. Astolfi, D. Langarica and R. Ortega: Solution to the multimachine transient stability problem, *IET Generation, Transmission & Distribution*, Vol. 8, No. 8, 2014.]
 - ▶ Decentralized control: [D. Langarica, R. Ortega and D. Casagrande: Transient stability of multimachine power systems: towards a a global decentralized solution, *European Journal of Control*, Vol. 26, 2015.]
- HVDC systems
 - ▶ Control: [D. Zonetti, R. Ortega and A. Benchaib: Modeling and control of HVDC transmission systems: From theory to practice and back, *Control Engg. Practice*, Vol. 45, 2015.]
 - ▶ Power sharing: [D. Zonetti, R. Ortega et J. Schiffer: A tool for stability and power sharing analysis of a generalized class of droop controllers for high-voltage direct-current transmission systems, *IEEE Transactions on Control of Network Systems*, (to appear).]

Microgrids

- **Modeling:** [J. Schiffer, D. Zonetti, R. Ortega, A. Stankovic, T. Sezi and J. Raisch: A survey on modeling of microgrids: From fundamental physics to phasors and voltage sources, *Automatica*, Vol. 74, pp. 135-150, 2016.]
- **Droop control**
 - ▶ Analysis: [J. Schiffer, R. Ortega, A. Astolfi, J. Raisch and T. Sezi: Conditions for asymptotic stability of droop-controlled inverter-based microgrids, *Automatica*, Vol. 50, No. 10, pp. 2457–2469, 2015. ([Best Paper 2013-2016](#)).]
 - ▶ Effect of delays: [J. Schiffer, E. Fridman, R. Ortega and J. Raisch: Stability of a class of delayed port-Hamiltonian systems with application to microgrids with distributed rotational and electronic generation, *Automatica*, Vol. 74, pp. 71-79, 2016.]
 - ▶ Effect of clock drifts: [J. Schiffer, R. Ortega and J. Raisch: Modelling, analysis and experimental validation of clock drift effects in low-inertia power systems, *IEEE Transactions on Industrial Electronics*, Vol. 64, No. 7, pp. 5942-5951, 2017.]

Alternative Energy Generation: Wind

- Wind speed estimation
 - ▶ Estimator: [R. Ortega, F. Mancilla and F. Jaramillo: A globally convergent wind speed estimator for windmill systems, *Int. J. on Adaptive Control and Signal Processing*, Vol. 27, No. 5, pp 413-425, 2013.]
 - ▶ Experimental comparison: [M. Soltani, T. Knudsen, M. Sventrup, R. Wisniewski, P. Brath, R. Ortega and K. Johnson: Estimation of rotor effective wind speed: A comparison, *IEEE Trans Control Systems Technology*, Vol. 21, No. 4, pp.1155–1162, 2013.)
- Control
 - ▶ Small windmill: [R. Cisneros, F. Mancilla–David and R. Ortega: Passivity–based control of a grid–connected small–scale windmill with limited control authority, *IEEE J. Emerging and Selected Topics in Power Electronics*, Vol. 1, No. 4, Dec. 2013, pp. 247–259.]
 - ▶ Maximum power extraction: [R. Cisneros, R. Gao, R. Ortega and I. Husain: PI passivity-based control for maximum power extraction of a wind energy system with guaranteed stability properties, *International Journal of Emerging Electric Power Systems*, Vol. 17, No. 5, pp. 567-573, 2016.]

Alternative Energy Generation: Photovoltaic Cells

- **Parameter estimation:** [M. Carrasco, F. Mancilla–David and R. Ortega: An estimator of solar irradiance in photovoltaic arrays with guaranteed stability properties, *IEEE Transactions On Industrial Electronics*, Vol. 61, No. 7, pp. 3359–3356, 2014.]
- **Maximum power extraction:** [A. Pyrkin, F. Mancilla, R. Ortega, A. Bobtsov and S. Aranovskiy: Identification of photovoltaic arrays' maximum power extraction point via dynamic regressor extension and mixing. *Int. J. on Adaptive Control and Signal Processing*, (to appear).]

Power Converters

- Control

- ▶ Observers: [A. Jaafar, A. Allawieh, R. Ortega and E. Godoy: PI stabilization of power converters with partial state measurements, *IEEE Trans Control Systems Technology*, Vol. 21, No. 2, pp. 560–568, 2013.]
- ▶ Multilevel: [R. Cisneros, M. Pirro, G. Bergna, R. Ortega, G. Ippoliti and M. Molinas: Global tracking passivity–based PI control of bilinear systems and its application to the boost and modular multilevel converters, *Control Engg. Practice*, Vol. 43, pp. 109–119, 2015.]

- Constant power loads

- ▶ Equilibria (DC): [N. Barabanov, R. Ortega, R. Griño and B. Polyak: On existence and stability of equilibria of linear time–invariant systems with constant power loads, *IEEE Trans. on Circuits and Systems*, Vol. 63, No. 1, pp. 114–121, 2016.]
- ▶ Equilibria (AC): [J. Machado, R. Griño, R. Ortega, N. Barabanov and B. Polyak: On existence of equilibria of multi-port linear AC networks with constant-power loads, *IEEE Trans. on Circuits and Systems*, (to appear).]
- ▶ Control: [W. He, R. Ortega, J. E. Machado and S. Li: An adaptive PBC of a buck-boost converter with a CPL, *Asian Journal of Control*, (to appear).]

Current Research

- ▶ Active adaptive damping for grid connected converters: estimation of the Thevenin equivalent. [TU Berlin and Leeds U]
- ▶ An equivalent to represent inertial and primary frequency control effects of an external system: estimation of equivalent inertia and active power balance. [U of Colorado, Leeds U]
- ▶ Stability of equilibria of networks (AC and DC) with constant power loads. [Imperial College, Russian Academy of Science, Norwegian U of Science and Techn.]
- ▶ Multilevel converters for HVDC systems. [Norwegian U of Science and Techn.]
- ▶ Parameter estimation of Lithium Ion batteries.[Institute IMDEA Energy]
- ▶ Control of wind system with solid state transformers. [North Carolina St. U, FREEDM NSF Center]