Prof. Florian Dörfler
Complex Systems Control

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Mission

Recent years have witnessed a rapid development of a new science of complex networks, encompassing the study of dynamical phenomena and control over networks. Another emergent discipline are cyber-physical systems which integrate physical processes, computational resources, and communication and control capabilities. Technological examples of cyber-physical systems and complex networks include, among others, critical infrastructures such as energy systems and the power grid. A crucial question in the operation of complex, networked, and cyber-physical systems is whether all information is communicated to a central decision maker, or whether multiple decision makers share their local information. The latter strategy is often advantageous regarding robustness, resilience, and computational and communication complexity.

In our research on cyber-physical, complex, and networked systems, we focus on energy systems and electric power networks. Recent political and societal developments are leading to the deregulation of energy markets and the increasing adoption of renewables. In the face of the ever-increasing power demand, these developments are also leading to more stressed power networks operating near their stability margins, as documented by recent outages and the accompanying economic losses. In view of the growing complexity of future smart grids, the volatility of deregulated energy markets, and the integration challenges posed by renewable energy sources, a deeper understanding of the dynamical network phenomena as well as their control is increasingly important. The technological instrumentation of the grid and the recent theoretical advances in complex networks and cyber-physical systems provide excellent opportunities to handle the challenges of the future energy supply via coordinated control, monitoring, and optimization.

Curriculum Vitae

Prof. Florian Dörfler
Professor of Complex Systems Control

2014-present: Assistant Professor (Tenure Track),
Automatic Control Laboratory, ETH Zurich

2014: Visiting Professor at Caltech, Rigorous Systems Group

2013-2014: Assistant Professor at University of California,
Los Angeles, USA

2011-2014: Affiliated with Los Alamos National Laboratory,
Center for Nonlinear Studies, USA

2013: PhD in Mechanical Engineering at University of California,
Santa Barbara, USA

2009-2013: Graduate Studies at University of California,
Santa Barbara, USA

2008: Dipl. Ing. in Engineering Cybernetics at University of Stuttgart, D

2003-2008: Diploma Studies at University of Stuttgart, D,
and University of Toronto, CAN

Awards

2016: IEEE Circuits and Systems Guillemin-Cauer Best Paper Award
(awarded for best paper in IEEE Transactions on Circuits and Systems)

2015: UC Santa Barbara Mechanical Engineering Department Best PhD Award (in recognition of outstanding achievements during PhD studies)

2014: IFAC Automatica Best Paper Award
(awarded for best application paper 2012-2014)

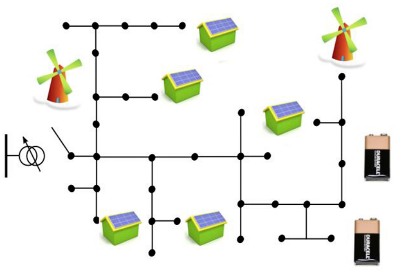
2013: Top Five Finalist for Best Student Paper Award at European Control Conference (as co-author and co-advisor)

Achievements and Future Research

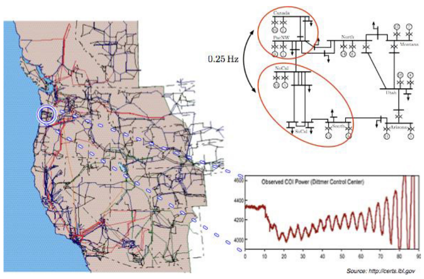
Plug-and-Play Control and Optimization in Microgrids
Motivated by the growing interest in smart grid architectures, we are interested in the problems of synchronization, voltage stabilization, load sharing, secondary regulation, and economic optimality in microgrids. Microgrids are low-voltage electrical distribution networks, heterogeneously composed of distributed generation, storage, load, and managed autonomously from the larger transmission network. Whereas traditional power system operation and control is hierarchical and centralized, microgrids are ad hoc networks without a centralized decision maker. These unique challenges call for scalable, robust, and plug'n'play control strategies with low communication complexity.

Slow Coherency and Wide-Area Control
Inter-area oscillations in bulk power systems are typically poorly controllable by means of local control. Recent research efforts have been aimed at developing wide-area control strategies that involve communication of remote signals. In conventional wide-area control, the control structure is fixed a priori. In contrast, our work employs the recently-introduced paradigm of sparsity-promoting optimal control to simultaneously identify the optimal control structure and optimize the closed-loop performance. Our approach is based on recent advances in compressed sensing, machine learning, and network-theoretic insights into slow coherency.

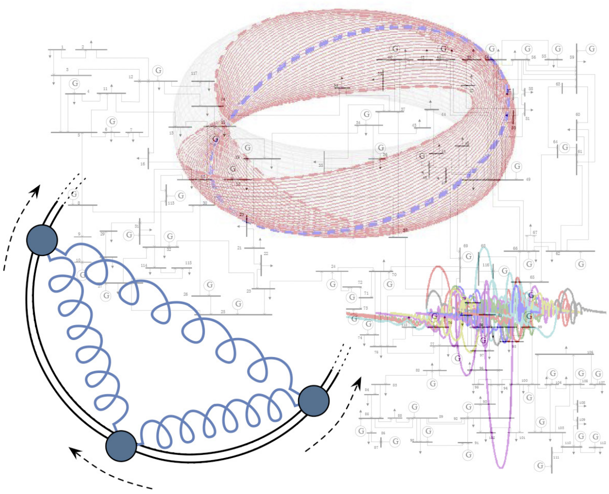
Exploring Complex Energy Networks
First principle modeling of interconnected energy networks reveals – aside from the complex network topology and rich dynamic behavior of the individual network components – a highly nonlinear network coupling among different components through the so-called power flow equations. The power flow equations are the basis for the modeling of interconnected power systems, and they are pervasive in all control, optimization, and monitoring problems. Despite their omnipresence, these complex network interactions are poorly understood. In earlier work, we revealed some partial insights by means of coupled oscillator analogies which resolved many control, dynamics, and optimization problems. However, these insights were only partial and limited to certain phenomena. In future work, we aim to fully understand the complex and nonlinear power flow coupling. Our ambitious objectives include providing precise conditions for feasibility of the power flow, convexity of related optimization problems, and stability and controllability of the complex and highly nonlinear and non-localized network dynamics.



An islanded microgrid with distributed renewable generation



Inter-area oscillations leading to the 1996 blackout in the Western US power system (Source: http://certs.lbl.gov/)



Rotor swing dynamics in a complex power network