SOE 4: Physics of Power Grids (joint session DY/SOE)

Time: Monday 11:30–12:30 Location: ZEU 147

SOE 4.1 Mon 11:30 ZEU 147

Dynamic Vulnerability of Oscillatory Networks and Power Grids — •Xiaozhu Zhang[1], Cheng Ma[2], and Marc Timme[1] — [1]Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), Cluster of Excellence Physics of Life, Technical University of Dresden, 01062 Dresden, Germany — [2]School of Physics, Nankai University, Tianjin 300071, China

Driven by dynamic fluctuations, oscillatory networks such as AC power grids exhibit highly heterogeneous, nontrivial resonant patterns that jointly depend on the driving frequency, the interaction topology of the network and the nodes driven [1,2]. However, it remains an open problem to identify which nodes are most susceptible and may make entire systems vulnerable to dynamic driving signals. Here we propose a Dynamic Vulnerability Index (DVI) [3] for identifying those nodes that exhibit largest amplitude responses to dynamic driving signals with given power spectra, and thus are most vulnerable. The DVI is easy to compute and enables robust high-quality predictions. It shows potential for a wide range of applications across dynamically driven networks, e.g. for identifying the vulnerable nodes in AC power grids driven by power fluctuations from renewable energy sources and customers' behaviour.

[1] X. Zhang et al., Science Advances 5:eaav1027 (2019).
[2] S. Tamrakar et al., Scientific Reports 8:6459 (2018).
[3] X. Zhang et al., arXiv:1908.00957 (2019).

SOE 4.2 Mon 11:45 ZEU 147

Message Passing for State Estimation of Power Grids — •Tim Ritmeester and Hildegard Meyer-Ortmanns — Jacobs University, Bremen

The method of message passing is known from statistical physics and computer science. Here we use it to estimate the state of power grids in terms of the generator production and power flow, based on redundant error-prone measurements. We illustrate the method on the IEEE300-grid, and show that it outperforms standard least-squares approaches if the influence from distant nodes matters. We perform our analysis in this regime and show under what circumstances missing data can reliably be retrieved and how placement of modern measurement devices such as PMUs (Phasor Measurement Units) affects the accuracy of the estimate.

SOE 4.3 Mon 12:00 ZEU 147

Large-deviation properties of the basin stability of power grids — •Yannick Feld and Alexander K. Hartmann — Institute of Physics, University of Oldenburg, Germany

Due to climate change the usage of fossil power sources has to be reduced. This results in more and more fluctuating power sources, which makes maintaining a stable energy grid more challenging and the properties of extremely stable (or unstable) power grid typologies are of interest. We use a dynamic model of power grids, specifically the Kuramoto-like model [1].

An advanced, however, nonlinear way to characterize the stability of power grids against (possibly large) fluctuations is the *basin stability*. Thus, we study numerically [2] the probability distribution of the basin stability for two random graph ensembles, namely an *Erdős-Rényi* and a *small-world* ensemble. Using *large deviation techniques* [3], we were able to measure [4] the probability distribution ranging over eight decades in probability, which is considerably larger than possible using standard sampling. Additionally we investigated the correlations of the basin stability with other measurable quantities like *backup capacity* [3] and number of leafs (dead ends).

[1] G. Filatrella, A.H. Nielsen, and N.F. Pedersen, Eur. Phys. J. B **61** 485-491 (2008)
[2] A.K. Hartmann, *Big Practical Guide to Computer Simulations* (World Scientific, 2015).
[3] T. Dewenter and A.K. Hartmann, New J. Phys. **17**, 015005 (2015)
[4] Y. Feld and A.K. Hartmann, Chaos **29**, 113103 (2019).

SOE 4.4 Mon 12:15 ZEU 147

Enhancing power grid synchronization and stability through time delayed feedback control — Halgurd Taher[1], •Simona Olmi[1], and Eckehard Schöll[2] — [1]Inria Sophia Antipolis Mediterranee Research Centre, 2004 Route des Lucioles, 06902 Valbonne, France — [2]Institut fuer Theoretische Physik, Technische Universitaet Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

We study the synchronization and stability of power grids within the Kuramoto phase oscillator model with inertia with a bimodal natural frequency distribution representing the generators and the loads. We identify critical nodes through solitary frequency deviations and Lyapunov vectors corresponding to unstable Lyapunov exponents. To cure dangerous deviations from synchronization we propose time-delayed feedback control, which is an efficient control concept in nonlinear dynamic systems. Different control strategies are tested and compared with respect to the minimum number of controlled nodes required to achieve synchronization and Lyapunov stability. As a proof of principle, this fast-acting control method is demonstrated for different networks (the German and the Italian power transmission grid), operating points, configurations, and models.