DY 79: The Physics of Power-Grids – Fluctuations, Synchronization and Network Structures (joint session DY/SOE)

Time: Friday 10:00–12:15 Location: EB 107

DY 79.1 Fri 10:00 EB 107

Qualitative Stability and Synchronicity Analysis of Power Network Models in Port-Hamiltonian form — •Simona Olmi[1], Volker Mehrmann[2], Riccardo Morandini[2], and Eckehard Schöll[1] — [1]Institut fuer Theoretische Physik, Sekr. EW 7-1, TU Berlin, Hardenbergstr. 36, D-10623 Berlin — [2]Institut fuer Mathematik MA 4-5, TU Berlin, Str. des 17. Juni 136, D-10623 Berlin

In view of highly decentralized and diversified power generation concepts, in particular with renewable energies such as wind and solar power, the analysis and control of the stability and the synchronization of power networks is an important task that requires different levels of modeling detail for different tasks. A frequently used qualitative approach relies on simplified nonlinear network models like the Kuramoto model. Although based on basic physical principles, the usual formulation in form of a system of coupled ordinary differential equations is not always adequate. We present a new energy-based formulation of the Kuramoto model as port-Hamiltonian system of differential-algebraic equations. This leads to a very robust representation of the system with respect to disturbances, it encodes the underlying physics, such as the dissipation inequality or the deviation from synchronicity, directly in the structure of the equations, it explicitly displays all possible constraints and allows for robust We demonstrate the advantages of the modified modeling approach with analytic results and numerical experiments.

DY 79.2 Fri 10:15 EB 107

Influence of network topology in shaping the dynamics of power grid networks — •Halgurd Taher, Simona Olmi, and Eckehard Schöll — Institut fuer Theoretische Physik, Sekr. EW 7-1, TU Berlin, Hardenbergstr. 36, D-10623 Berlin

The increase of the inclusion of renewable energy sources into the power grid is rather a paradigm change for the entire European power grid, bringing new challenges for power grid operation. The reason behind this is the fact that the power output of renewable energy sources typically strongly fluctuates and, furthermore, the possible geographical locations for power plants based on renewable energies depend on geographical factors, thus including different forms of perturbations into the network. In this talk we investigate the role played by topology in shaping the dynamics of the German power grid and we present a new investigation method able to highlight the instabilities of the system. Based on the knowledge of the unstable nodes and directions suggested by the application of the Lyapunov vector, we are thus able to design a control method that enhances the synchronization and stabilizes the network, acting on small number of nodes/links. This minimal intervention suggests a procedure to control real grids that allows to save time, money and energy.

DY 79.3 Fri 10:30 EB 107

Influence of noise in shaping the dynamics of power grids — •Liudmila Tumash, Simona Olmi, and Eckehard Schöll — Institut für Theoretische Physik, TU Berlin, Hardenbergstr. 36, D-10623 Berlin

The aim of this work is to investigate complex dynamic networks which can model high-voltage power grids with renewable, fluctuating energy sources. For this purpose we use the Kuramoto model with inertia to model the network of power plants and consumers [1]. In particular, we analyze the synchronization transition of random Erdös-Renyi networks of N phase oscillators with inertia (rotators) whose natural frequencies are bimodally distributed. We also implement Gaussian white noise and investigate its role in shaping the dynamics.

[1] Filatrella, G., Nielsen, A. and Pedersen, N. Eur. Phys. J. B (2008) 61: 485.

DY 79.4 Fri 10:45 EB 107

Load Dependence of Power Outage Statistics — •Soumyajyoti Biswas[1] and Lucas Goehring[1,2] — [1]Max Planck Institute for Dynamics and Self-Organisation, Göttingen, Germany — [2]Nottingham Trent University, Nottingham, UK

The size distributions of power outages are shown to depend on the stress, or the proximity of the load of an electrical grid to complete breakdown. Using the data for the US and Canada between 2002-2017, we show that the outage statistics are dependent on the usage levels during different parts of the day. At higher load, not only are more failures likely, but the distribution of failure sizes shifts, to favor larger events. At a finer spatial scale, different regions within the US can be shown to respond differently in terms of the outage statistics to variations in the usage (load). The response, in turn, corresponds to the respective bias towards larger or smaller failures in those regions. We provide a simple model, using realistic grid topologies, which can nonetheless demonstrate such biases as a function of the applied load, as in the data. Given sufficient data, the method can be used to identify vulnerable regions in power grids prior to major blackouts.

15 min. break

DY 79.5 Fri 11:15 EB 107

Asymptotic Dynamical States in Networks of Kuramoto Oscillators with Inertia — •Anton Plietzsch — Potsdam-Institut für Klimafolgenforschung — Humboldt-Universität zu Berlin

The frequency dynamics of power grids can be modeled by networks of oscillators. I will show analytic and numerical results on the possible asymptotic states in the Kuramoto model with inertia. These states include states that can be understood as synchronized, partially synchronized, and distinct novel states that have no analytic explanation so far. I will show some analytic criteria for the stability and existence of solitary states of single desynchronized oscillators as well as partially synchronized clusters with distinct frequency on networks.

DY 79.6 Fri 11:30 EB 107

Modelling and Suppressing power output fluctuations of photovoltaic power plants — •Mehrnaz Anvari[1], Benjamin Werther[2], Gerald Lohmann[3], Matthias Waechter[3], Joachim Peinke[3], and Hans-Peter Beck[2] — [1]MPIPKS, Dresden, Germany — [2]TU Clausthal, Germany — [3]Institute of Physics and ForWind, Oldenburg, Germany

The use of solar photovoltaic (PV) power has recently increased in electric distribution grids. By the end of 2014, for example, PV power had already reached a total installed capacity of over 178 GW worldwide, which is expected to increase to between 396 and 540 GW by 2019. However, the stochastic properties of solar energy, such as intermittency can negatively affect power quality and cause grid instabilities, especially in microgrids. In this study, we use high resolution (i.e. 1 Hz) measured irradiance data in Hawaii (as an exemplary data) to study the stochastic behaviour of short-term PV fluctuations, and classify its states as cloudy, sunny and flickering. Our main aim is the construction of a simple dynamical equation (jump-diffusion stochastic equation) that governs the stochastic process of PV-fluctuations, so that the statistics of the modelled time series are identical to those of the measured ones. Using the obtained dynamical equation, we generate new synthetic data sets with varying jump rates. Finally, we implement a straightforward filtering method, i.e. a combination of an inverter and a battery storage system to show the applicability of our proposed stochastic method.

DY 79.7 Fri 11:45 EB 107

Power Grid Stability: Bounding the First Exit from the Basin — •Paul Schultz[1,2], Frank Hellmann[1], Kevin N. Webster[1], and Jürgen Kurths[1,2,3,4] — [1]Potsdam Institute for Climate Impact Research (PIK), Member of the Leibniz Association, P.O. Box 60 12 03, D-14412 Potsdam, Germany — [2]Department of Physics, Humboldt University of Berlin, Newtonstr. 15, 12489 Berlin, Germany — [3]Institute for Complex Systems and Mathematical Biology, University of Aberdeen, Aberdeen AB24 3UE, United Kingdom — [4]Department of Control Theory, Nizhny Novgorod State University, Gagarin Avenue 23, 606950 Nizhny Novgorod, Russia

We study the stability of deterministic systems given sequences of large, jump-like perturbations. Our main result is the derivation of a lower bound for the probability of the system to remain in the basin, given that perturbations are rare enough. To quantify rare enough, we define the notion of the independence time of such a system. This is the time after which a perturbed state has probably returned close to the attractor, meaning that subsequent perturbations can be considered separately. The effect of jump-like perturbations that occur at least the independence time apart is thus well described by a fixed probability to exit the basin at each jump, allowing us to obtain the bound. To determine the independence time, we introduce the novel concept of finite-time basin stability, which cor- responds to the probability that a perturbed trajectory returns to an attractor within a given time. The independence time can then be determined as the time scale at which the finite-time basin stability reaches its asymptotic value.

DY 79.8 Fri 12:00 EB 107

Bridging from Kuramoto-like Networks to Real Power Grids: Lossy Grids, Voltage Regulation and Implementing Inverter Units — Katrin Schmietendorf[1], Joachim Peinke[1], and •Oliver Kamps[2] — [1]ForWind and Institute of Physics, Carl von Ossietzky Universität Oldenburg, Oldenburg, Germany — [2]Center for Nonlinear Science, Westfälische Wilhelms-Universität Münster, Münster, Germany

Kuramoto-like models of electric power grids give insights into power system dynamics on the short-term scale in terms of self-organized synchronization. From the applicational viewpoint, the most current issues in power system analysis concern grid decentralization and increasing feed-in fluctuations induced by renewables. In order to address these topics, certain complements to the basic Kuramoto approach have to be taken into account. We investigate three supplements, which are particularly relevant for the integration of renewable energy plants on the distribution grid level: (i) transferlosses due to non-zero line conductance on the low and medium voltage levels, (ii) local voltage regulation by means of a proportional controller, and (iii) different approaches on implementing inverter units into the Kuramoto-like framework. In this talk we present the implications of these model extensions on different aspects of system stability and power quality.