SOE 18: Focus Session: Modern Power Grid, Nonlinear Dynamics and Self-Organization (joint with DY)

The drastic change from our traditional energy system based on fossil fuels to one based dominantly on renewable sources provides an extraordinary challenge for the robust operation of future power grids. Complementing standard approaches of electric engineering with principles of self-organization and methods from nonlinear dynamics may help us to understand collective dynamical grid features, emerging due to increasing decentralization, line upgrades, and correlated fluctuations. The Focus Session provides a snapshot of current research in this emerging cross-disciplinary field and points to pressing problems to be addressed in the near future. (Organizers Dirk Witthaut and Marc Timme)

Time: Wednesday 15:00–17:30 Location: H44

Invited Talk SOE 18.1 Wed 15:00 H44
Energiewende 2.0 * the transformation of energy systems in uncertain times — •Jürgen-Fr. Hake and Wolfgang Fischer — FZ Jülich

The German Energiewende represents a very ambitious national political program. The specific targets range from GHG emissions reduction motivated by the mitigation of climate change to technology specific goals emphasizing renewable energy in contrast to nuclear energy. The scope of the Energiewende covers a period of time of about 40 years. Scenario-based analyses point out the feasibility of this politically enforced transformation. A closer look at these scenarios also shows their limitations with respect to the socio-economic foundation and the technological differentiation. Moreover, in many cases linear models are used to describe the system under investigation which might be regarded as another weak point. These deficiencies require an integrated assessment covering **in- depth description of the anticipated major socio-political trends, **the economic embedding of the energy sector, and **an detailed well-balanced technology portfolio. A major criterion for all national initiatives is the compatibility with the transformation of the EU system.

Invited Talk SOE 18.2 Wed 15:30 H44
Basin Stability and its Consequences for Power Grids — •Jürgen Kurths, Peter Menck, and Peng Ji — Potsdam Institute for Climate Impact Research, P.O. Box 601203, 14412 Potsdam,

The human brain, power grids, arrays of coupled lasers, and the Amazon rainforest contain the same seed of trouble: multistability. With undesired states looming in state space, it matters strongly how stable the desired state is against major perturbations. Surprisingly, this basic question has so far received little attention. Here we claim that the traditional linearization-based approach to stability is too local to answer it. As a complement, we suggest to quantify stability in terms of basin stability, a new measure related to the volume of the basin of attraction. Basin stability is non-local, non-linear, and easily applicable even to high-dimensional systems. Its consequences for evaluating stability of power grids and their will be discussed.

Invited Talk SOE 18.3 Wed 16:00 H44
Requirements and Concepts for Self-Organized Agent-Based Control in Smart Distribution Grids — •Astrid Niesse — OFFIS - Institute for Information Technology

Transforming the existing power generation to renewable, distributed generation implicates an increase in complexity for the control of the overall system. We propose a distributed control method to launch products of self-organized coalitions of small active units in a power grid at markets for trading active power as well as ancillary services. Our concept combines the integration of grid restrictions into proactive scheduling of active power with provision of ancillary services, and additionally provides reactive scheduling of active power, e.g. in the case of ancillary service activation.

In this talk, an overview on requirements for distributed control on smart distribution grid is given, along with results on how this ICT-based approach can be realized using software agents.

Invited Talk SOE 18.4 Wed 16:30 H44
A 100% renewable power system in Europe — •Martin Greiner[1], Sarah Becker[2], Rolando Rodriguez[1], Tue Jensen[1], Timo Zeyer[1], Anders Soendergaard[1], and Gorm Andresen[1] — [1]Aarhus University, Aarhus, Denmark — [2]FIAS, Frankfurt, Germany

Todays overall macro energy system based on fossil and nuclear resources will transform into a future system dominantly relying on fluctuating renewable resources. At the moment it is not really clear what will be the best transitional pathway between the current and the future energy system. In this respect it makes sense to think backwards, which means in a first step to get a good functional understanding of fully renewable energy systems and then in a second step bridge from there to todays energy system. Based on state-of-the-art high-resolution meteorological and electrical load data, simple spatio-temporal modelling, solid time-series analysis and the physics of complex networks, fundamental properties of a fully renewable pan-European power system are determined. Amongst such characteristics are the optimal mix of wind and solar power generation, the optimal combination of storage and balancing, the optimal extension of the transmission network, as well as the optimal ramp down of fossil and nuclear power generation during the transitional phase. These results indicate that the pathways into future energy systems will be driven by an optimal systemic combination of technologies, and that economy and markets have to follow technology.

SOE 18.5 Wed 17:00 H44
Synchronization and Voltage Stability in a Network of Synchronous Machines — •Katrin Schmietendorf and Rudolf Friedrich — Institute for Theoretical Physics, University of Münster, Germany

Since the progressive integration of renewable energy sources involves substantial changes in grid topology and feed-in characteristics, the questions of power system stability and design have to be reconsidered. Power system stability, or more precisely rotor angle stability, is related to synchronization phenomena as the classical synchronous machine representation can be shown to correspond to a modified version of the prominent Kuramoto model. The Kuramoto model describes the dynamics of a population of coupled oscillators displaying a phase transition from incoherence to partial synchronized states. In this talk we extend the classical Kuramoto-like model which assumes constant voltages by adding dynamical voltage equations. This yields a model which allows to treat both rotor angle and voltage stability and involves the feature of rotor angle and voltage stability interplay. We compare the behaviour of small networks of synchronous machines governed by the classical and the extended model during and after being subjected to different types of disturbances and discuss the implications for the simulation of complex power grids.

SOE 18.6 Wed 17:15 H44
How trading impacts distribution in complex power grids — •Sebastian Klipp[1], Dirk Witthaut[1], and Marc Timme[1,2] — [1]Network Dynamics, Max Planck Institute for Dynamics and Self-Organization, 37077 Göttingen — [2]Faculty of Physics, University of Göttingen

Instabilities in the collective dynamics of power grids may induce transmission line overloads or even large-scale power outages. One possible source of instability is the energy trading market that modifies locations, times, and volumes of electric power generation and demand. Here we investigate how economic factors can influence the distribution of energy-flow in a power-grid. We reveal that and how the interdependence of the economic and the physical network can induce dynamic instabilities and explain the mechanisms underlying them. These results offer a complementary perspective on the development of smart power grids and the integration of renewable energies.