SOE 2: Energy Systems (joint SOE/DY/AKE)

Time: Monday 9:30–11:15 Location: GÖR 226

SOE 2.1 Mon 9:30 GÖR 226

Data-driven analysis of power grid fluctuations — •Benjamin Schäfer and Christian Beck — School of Mathematical Sciences, Queen Mary University of London, London E1 4NS, United Kingdom

The Paris conference 2015 set a path to limit climate change to "well below 2°C". To reach this goal greenhouse gas emissions have to be reduced and renewable generators, electrical mobility or smart grids are integrated into the existing power system.

The introduction of these new technologies raises several questions about control, stability and operation and therefore requires a solid understanding of existing and future systems and new conceptional approaches.

Here, we use data-driven approaches to work towards a quantitative understanding of the power grid with a particular focus on fluctuations, as they are for example introduced by the changing demand or volatile energy generation of renewable generators. We analyse time series from wind power plants, households and various power grids grids to understand differences in grid operation and design.

We highlight significant deviations from Gaussianity in several quantities and report on the progress of the Marie-Curie project DAMOSET, which focuses on building up an open data base of power grid frequency measurements.

SOE 2.2 Mon 9:45 GÖR 226

Linear response theory of power grids with correlated multi-node fluctuations — •mehrnaz anvari, anton plietzsch, and frank hellmann — Potsdam Institute for Climate Impact Research

Modern societies highly depend on electricity supply via power grids. Without electricity, people do not have access to food, transportation, medical treatment and so on. Moreover, in an extended outage the security of a community can be in danger. Therefore, stability of the power grid has highest priority. For that, the balance between the energy consumption and energy production should be provided. Recently the ongoing energy transition towards renewable generation fundamentally changes the conditions for the operation of the power system. The variable renewable energies, i.e. wind and solar are known as the sources of fluctuations, which can affect the stability of the power grid frequency. In previous works, linear response theory has been shown to be a powerful tool to study the impact of power fluctuations on frequency stability in complex power grid networks. However, so far this response theory has only be developed for single node fluctuations, while real power grids are subjected to fluctuations at multiple nodes. Employing the same theoretical technique, we therefore investigate the influence of the multi-node fluctuations in the power grid, when there exists spatial correlation between the fluctuating nodes.

SOE 2.3 Mon 10:00 GÖR 226

Modeling the dynamics of future power grids — •Raphael Kogler — Potsdam Institute for Climate Impact Research, Germany

An important aspect of tackling the problems posed by climate change is the transition from fossil-based and nuclear energy toward a greater share of renewable energy sources. For our power grids this means a gradual replacement of the conventional synchronous machines by converter-interfaced generation units.

While the dynamical behavior of synchronous machines is commonly modeled by the swing equation (the Kuramoto model with inertia), the dynamics of converter-interfaced units will be given by the specific control scheme applied to the converters. There are various proposals for such control schemes but no clear consensus as of yet.

However, as different as they appear, there are certain shared aspects when viewed in the context of complex amplitude oscillators. I discuss how the Stuart-Landau oscillator can serve as a paradigmatic model of such an oscillator and provide a basis for understanding the dynamics of future power grids.

SOE 2.4 Mon 10:15 GÖR 226

Facing heterogeneity - towards a unified description of power grid dynamics — •Frank Hellmann — Potsdam Institut für Klimafolgenforschung, Potsdam, Germany

Future power grids will feature a large variety of dynamical actors. In this talk I review a number of relevant dynamical nodes, their similarities and differences, and sketch how a unified perspective on these dynamical systems could look.

SOE 2.5 Mon 10:30 GÖR 226

An analysis of cost allocation methods for energy systems based on power flows — Fabian Hofmann[1], Markus Schlott[1], Matthias Hanauske[1], •Alexander Kies[1], Alexander Zerrahn[2], and Horst Stöcker[1] — [1]Frankfurt Institute for Advanced Studies, Frankfurt, Germany — [2]DIW Berlin, Berlin, Germany

The continuing expansion of renewable generation in Europe and the World has had profound impact on power system operation.

A first step on the way towards fair cost allocation schemes in electricity networks is the allocation of power flows. Power flow allocation refers to algorithms, which allocate the flow of electric power in electricity system components such as transmission lines to users of the system such as generators or consumers.

In this talk, different flow allocation methods are compared and evaluated using different criteria such as stability, computational effort and fairness.

SOE 2.6 Mon 10:45 GÖR 226

The role of transmission expansion in a cost-optimal highly-renewable European power system — •Fabian Hofmann — Frankfurt Insitute for Advanced Studies, Frankfurt, Germany

The transition towards a highly renewable European power system which is both cost-efficient and resilient requires detailed planning of infrastructure needs as well as a comprehensive trade-off between different technologies. Especially against the backdrop of high wind power potentials around the North Sea, the role of expanding the transmission system becomes increasingly important. The highly-refined open-source model PyPSA-EUR is used to showcase how different levels of transmission expansion impact the optimal setup of the European power system. It is shown that within the range of the first 25% total transmission expansion, the optimization opens up bottlenecks which suppress the exploitation of sites with good renewable resources. This leads to a strong decrease of curtailment, total system cost and peak line loading. By using flow tracing methods, it is further broke down how the transmission expansion changes the interplay of storage and generation technologies and enables to shift the optimal setup towards a more centralized and less storage based system.

SOE 2.7 Mon 11:00 GÖR 226

Explosive amortization times of photovoltaic systems? — •Raoul Schmidt, Malte Schröder, and Marc Timme — Chair for Network Dynamics, Institute for Theoretical Physics and Center for Advancing Electronics Dresden (cfaed), TU Dresden

To combat climate change, renewable energy systems such as photovoltaics (PV) are becoming increasingly important. The amortization time of a PV unit relates the energy (and CO_2) expended for production, transport and installation of a unit to its electric power generation (and thus potential savings in CO_2 emissions). Here, we consider the CO_2 budgeting dynamics of many PV units continuously added by new installations [von der Heydt, DPG Spring Meeting Berlin (2018)] and find that the resulting systemic amortization time necessarily is (much) larger than that of a single unit. We demonstrate analytically, that at constant installation rate, it already is twice the amortization time of a single unit, whereas at an exponentially increasing rate, it may be arbitrarily much larger, with resulting relevant time scales in between 10 and more than 30 years - beyond the life time of a PV unit. Intriguingly, evaluating installation data of the past two decades indicates an exponential installation rate that may cause such explosive increase of CO_2 budget amortization times on the global scale.