P H Y S I K A L I S C H E S   K O L L O Q U I U M
E I N L A D U N G

CARL VON OSSIETZKY universität OLDENBURG
Institut für PHYSIK

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speaks

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about

Sustainable Stability of Electricity Grids: Smart Distribution of Power and Localization of Disturbances

The energy transition towards an increased supply of renewable energy raises concerns that our existing electricity grids, built to connect few centralized large power plants with consumers, may become more difficult to control and stabilized with a rising number of decentralized small scale generators. The fluctuations in the generated power by wind turbines and solar cells - both in time and geographically - demand to explore new strategies to store energy on all time scales and to distribute the power in the grid smartly. In order to guarantee their sustainable stability the electricity grids have to be extended in such a way that the generated power can be transmitted whenever and wherever power is consumed. At the same time, the spreading of disturbances throughout the grid has to be prevented to ensure the stability of the entire grid. We will begin with a review of existing electricity grids and the statistics of historical power outages. We will then present the results of recent simulations of the power flow in DC and AC model grids and the german transmission grid which show that the removal or addition of a transmission line has nonlocal consequences which decay with a power law of the distance to the disturbance [1,2]. Thereby, a local power outage can cause a large scale outage with a cascade of failures whose probability and distribution in the size of power outages is derived [3]. To get a better understanding of the nonlocal nature of such disturbances we discuss analytical and numerical results on the spreading of local phase perturbations in the grid in a model of nonlinear dynamic power balance equations [4]. Starting with an initially localized phase perturbation, we find it to spread in a periodic model grid diffusively throughout the grid. For general grid topologies the problem can be solved by mapping it on the tight binding model of bosons with inhomogeneous hopping amplitude. The disturbance remains either localized or becomes delocalized, depending on grid topology and distribution of consumers and generators. The physical mechanism of localization is the coherent scattering of waves in a random medium, the so called Anderson localization[5]. Localization results in an exponentially fast decay of phase fluctuations at all grid sites and is therefore improving the stability of the grid[4]. We conclude that localization of disturbances may be a key strategy to optimize future electricity grids.

[1] Darka Labavić, Raluca Suciu, Hildegard Meyer-Ortmanns, S. Kettemann, Eur. Phys. J. Special Topics 06/2014.

[2] D. Jung, S. Kettemann, unpublished (2015).

[3] S. Tamrakar, M. Rohden, D. Jung, S. Kettemann, unpublished (2015).

[4] S. Kettemann, subm. to Phys. Rev. Lett. (2015), arXiv:1504.05525.

[5] P. W. Anderson, Phys. Rev. 109, 1492 (1958).

All interested persons are cordially invited.
Gez. Prof. Dr. Carsten Agert, Dr. David Kleinhans