The complexity of power-grid frequency dynamics – An application in superstatistics

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Power grids constitute one of the most complex human-made systems of our time. The delivery of electrical power, centralised or decentralised, depends almost exclusively on power grid networks. The dynamics of electricity in conventional power grids follow strict physical laws. Yet, the inherent variability of supply and demand, augmented with the volatile nature of power generation, leads to inherently ever-changing statistics of power-grid-specific variables. In this presentation, we focus on power-grid frequency, the key signature of power-grid stability, and show that this exhibits known signatures of complex systems, specifically, heavy-tailed distributions. We show that we can recover the statistics of power-grid frequency increments via superstatistics. Moreover, we show that we can disentangle different 'strengths' of superstatistics – given by differing q-indices – across a synchronous power grid, yet with the current data, it is still difficult to detail exactly the type of hyper-distributions governing the statistics of the increments. We will lastly allude to the connection between multifractality and superstatistics in power-grid systems.

References

[1] L. Rydin Gorjão, B. Schäfer, D. Witthaut, C. Beck, Spatio-temporal complexity of power-grid frequency fluctuations, New J. Phys., 23, 073016 (2021).
[2] B. Schäfer, C. Beck, K. Aihara, D. Witthaut, M. Timme, Non-Gaussian power grid frequency fluctuations characterized by Lévy-stable laws and superstatistics, Nat. Energy, 3(2), 119-126 (2018).
[3] L. Rydin Gorjão, D. Witthaut, C. Beck, S. Kettemann, work-in-progress (2023).