Persistence, multifractality, and complexity of the German weather-driven electricity spot prices

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The integration of volatile renewable power sources can prove a central challenge in the transition to a sustainable energy system. Electricity markets are central in coordinating electric power generation across Europe. These markets rely evermore on short-term trading to facilitate the balancing of power generation and demand and to enable systems integration of small producers. Electricity prices are themselves afflicted by volatility induced endogenously from evolving market structures and schemes, as well as exogenously by varying power generation from different renewable and non-renewable generation. Electricity prices in these spot markets show pronounced fluctuations, featuring extreme peaks as well as occasional negative prices. In this presentation, we highlight a few distinct statistical properties of electricity prices from the European Power Exchange market, in particular the hourly day-ahead, hourly intraday, and 15-min intraday market prices. We utilise various statistical physics methods to quantify the fluctuations, correlations, and extreme events and reveal different time scales in the dynamics of the market. The short-term fluctuations show remarkably different characteristics for time scales below and above 12 hours. Fluctuations are strongly correlated and persistent below 12 hours, which contributes to extreme price events and strong multifractal behaviour. On longer time scales, they get anticorrelated and price time series revert to their mean, witnessed by a stark decrease of the Hurst coefficient after 12 hours. The long-term behaviour is strongly influenced by the evolution of a large-scale weather pattern with a typical time scale of four days. We elucidate this dependence in detail using a classification into circulation weather types. The separation in time scales enables a superstatistical treatment, which confirms the characteristic time scale of four days, and motivates the use of q-Gaussian distributions as the best fit for the empiric distribution of electricity prices.

References

[1] C. Han, H. Hilger, E. Mix, Ph. C. Böttcher, M. Reyers, C. Beck, D. Witthaut, L. Rydin Gorjão, Complexity and Persistence of Price Time Series of the European Electricity Spot Market, PRX Energy 1, 013002 (2022).