Improving power-grid systems via topological changes or how can self-organized criticality help power-grids

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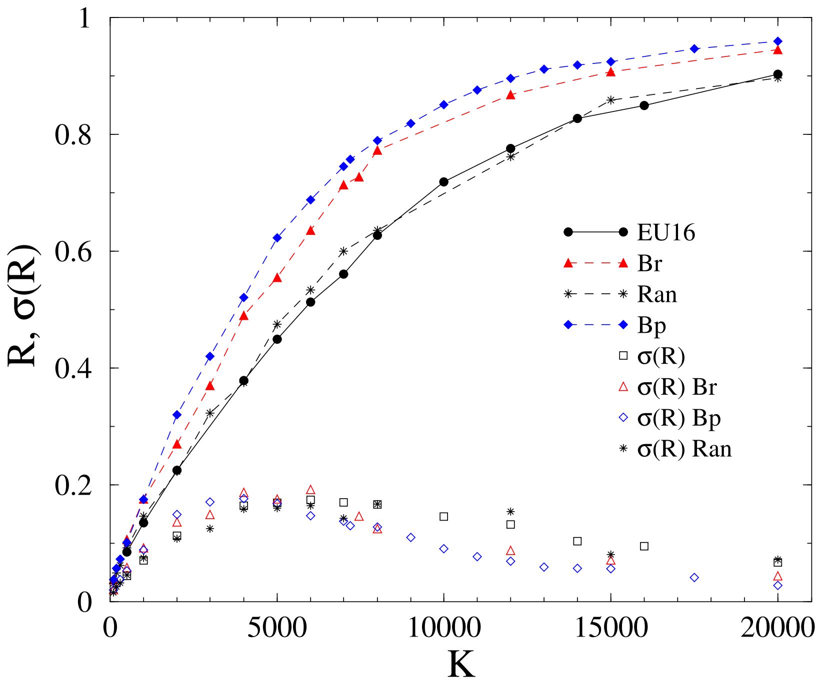
Summary

Failures in one part of a power grid can propagate throughout the system, potentially triggering cascading failures resulting in large-scale blackouts. Preventing these cascades is vital for maintaining economic stability, public safety, and essential services such as telecommunication. In this study, researchers examine the European power grid as a complex network to identify structural vulnerabilities and evaluate strategies for enhancing resilience. They simulate interventions such as adding new transmission lines at strategically selected locations and show that such modifications can reduce the risk of failures and improve coordination. These strategies are especially effective when the system operates near criticality — at the threshold between stability and instability — a regime associated with Self-Organized Criticality (SOC). In this regime, the system naturally evolves to a critical state where even small perturbations can have wide-ranging effects. The study also reveals the presence of Braess' Paradox, a counterintuitive phenomenon where adding a new link to a network can, under certain conditions, degrade overall performance due to adverse changes in flow distribution. Importantly, the impact of a new transmission line is not solely determined by its physical location but also by how it alters power flows across the network. To develop more resilient infrastructure, it is essential to model power grids with realistic heterogeneity in both connection types and interaction strengths.



Comparison of numerical solutions of R and its variance $\sigma(R)$ at the end of the thermalization in the steady state, for the original (EU16), randomly extended (Ran), bridged (Br) and bypassed (Bp) EU16 networks at $\alpha = 0.4$

Reference

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