Study of heterogeneity effects in power grid networks on the community level

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Cascade failures in power grids occur when the failure of one component or subsystem causes a chain reaction of failures in other components or subsystems, ultimately leading to a widespread blackout or outage. Controlling cascade failures on power grids is important for many reasons like economic impact, national security, public safety and even rippled effects like troubling transportation systems. Monitoring the networks on node level has been suggested, either controlling all nodes of a network or a well defined subset [3]. It has also been shown that too strong heterogenity destroys synchronization in the powergrid system [1]. Heterogeneity ussually can be decreased in multiple ways, for example regulating the node attributes, edge attrbutes, modifying the network topology with edge adding or removing or even complete rewiring. We show new results for the distributions of edge admittances and weights of the European and Hungarian networks, as well as for the measured frequency heterogeneities [2]. Than we provide community detection algorithms and show the level of synchronization in them, by solving the set of swing equations. Detecting communities in networks aims to identify groups of nodes in the network that are more densely connected to each other than to the rest of the network. While several clustering methods exist, they split into hierarchical and non-hierarchical methods. Hierarchical methods build a hierarchy of communities by recursively dividing the network into smaller and smaller subgroups, while non-hierarchical methods directly assign nodes to communities. We chose the hierarchical Louvain method for its speed and scalability, this algorithm runs almost in linear time on sparse graphs [4], therefore it can be useful on generated test networks with increased size. It is based on modularity optimization.

Furthermore, we suggest that the most problematic nodes in terms of synchronization lie on the edges of their communities, and by simple bridge fortification between the communities in the network, we can increase stability. The resulating order parameters come close to the results of a more complicated bypass technique selection of nodes, fortifying the connection of "weak" nodes. It is worth mentioning that the network's modularity score increases by around 0.02 with the bypass technique. Finally, we compare the results with the same randomly selected number of nodes.

References

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