Complex Network Analysis of the Indian Power Grid

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Indian power grid is vulnerable to catastrophic failures as evidenced by two major countrywide blackouts in July 2012 and numerous other smaller ones. The traditional methods for analysing the power grid have failed to identify said vulnerabilities. This calls for newer approaches to predict and prevent future cascading failures of the grid.

Network Theory has found widespread application in fields as diverse as gene-expression, traffic congestion, epidemic dynamics, social network dynamics and memetics, to name just a few. It has also been applied to power grids to identify their vulnerabilities. Network metrics like betweenness centrality and their many electrically extended siblings have successfully predicted the vulnerabilities of different nodes, especially to targeted attacks. But most of these studies have concentrated on the western world [4, 5]. In particular, there have been no more than three studies done on the Indian power grid [1, 2, 3], only one of which analysed the entire country [1]. The countrywide study focussed on the mechanism and prevention of July 2012 failures. A network theoretic study into the vulnerabilities of individual lines and stations using the latest complex network techniques and available data set has never been carried out. Our study fills this gap.

For this study we represented the entire Indian power grid as of 2015 (including approved/not yet exisiting utilities) as a weighted graph, considering not just the topology but also the line voltage and node-type in our analysis. We found that the topological metrics for the Indian and the US power grid showed similarities indicating that electric power grids have approximately similar topologies. We employed the popular local load redistribution model for cascading failures and ran it for three different attack strategies - random, betweenness, and degree based.Edges and nodes were assigned probabilities based on the attack strategy under consideration and removed like wise. We found the Indian power grid to be robust to random failures but particularly vulnerable to betweenness based attacks. Our study also indicated optimum line capacities for minimizing the probability of cascade failures.

Focussing on individual nodes and edges, our study indicated the most vulnerable lines and stations based on the size of the black-out caused upon their removal. We were able to observe grid wide cascades for even a single node/line removal implying the high topological vulnerability of the Indian Power Grid to targeted attacks.

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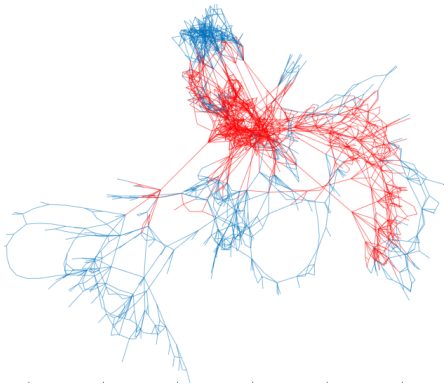

Figure 1: Cascade failure simulation on the Indian Power Grid

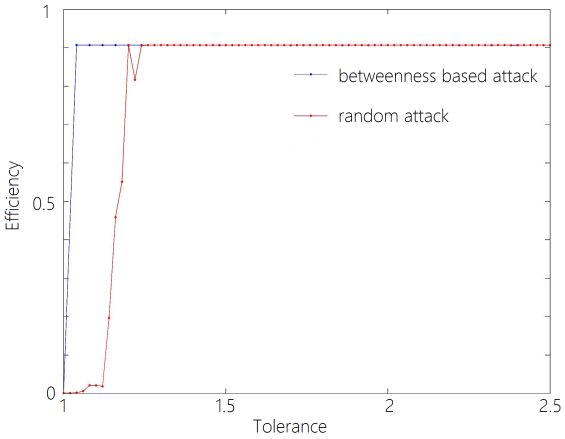

Figure 2: Network efficiency as the tolerance(capacity) is increased

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