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# A new index for topological vulnerability in power transmission networks

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**Abstract:** Large interconnected systems that provide critical infrastructures, such as power transmission networks, can be affected by occasional or random failures. The vulnerability of such structures can be analyzed taking into account the electrical properties of the network, its topology, and the environment where it is located. This work aim to introduce indexes that allows to classify how vulnerable a network is in regard to the topology of the transmission networks. As so, taking an energy transmission network, it can be represented by a complex network and its topology can be studied by means of centrality measures. This work identifies centrality measures that can be used for identify power network vulnerability, such as the centrality of the generator tree, the intermediation of the current flow, the dimension of the disconnected components. These measures reflect the reality of the functioning of these networks, as they consider their connections and the distribution of energy in the network. Based on these measures, we propose a new index to assess vulnerability, composing the characteristics of measures previously studied in the literature. This new index comprises measures of centrality that can be used for the vulnerability analyse of transmission networks.

**Keywords:** Vulnerability index, complex network, effective resistance, power grid.

## 1. Introduction

Power grid vulnerability analysis from topology perspective holds a bright prospect of providing system operators a fast with easy to interpret information on critical operating point in a disturbed network [1]. Transmission networks can be represented by a complex networks due to the high amount of connections between their components. These components can be represented by generators and substations (consumers) and their connections are made by transmission lines.

A simulation of cascading faults in the network can be performed by removing the edges of the network. These edges are selected from indexes that measure their importance in the network. Each index selects and removes a border for a different purpose, and the efficiency of the network can be reduced for all applied indices. The idea for the new index proposed in this work is to use centrality measures that can be used in the context of energy transmission networks.

## 2. Results and Discussion

Betweenness centrality [3] measures the importance of a vertex/edge due to its participation in the shortest paths between vertices. For energy networks, information does not use the shortest path, but all of them. Therefore, we use a variation of this intermediation measure, the betweenness current flow [4].

Another way to identify important edges is through the spanning tree centrality measure [5] and number of disconnected components. We created a new index composing these three measures in a single index using a geometric mean between them. The Fig. 1 shows the result of this new measure in comparison with the metrics, in this example the metrics were simulated in the ieee118 network [6]. Efficiency[7] was used to measure the drop in network performance when the edges were removed. Effective resistance [8] was used to calculate efficiency.

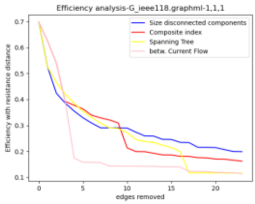


**Fig. 1.** This figure represents the simulation of attacks on the ieee118 network and the drop in efficiency by the three measures of centrality and the index composed of them.

## 3. Concluding Remarks

A new vulnerability index is presented, based on measures of centrality that can be applied in situations where flow analysis through several paths is important. In this way, it is possible to identify other edges, which even with a secondary importance influence the efficiency of the network in the face of events that can interrupt the distribution of energy, such as severe weather events.

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