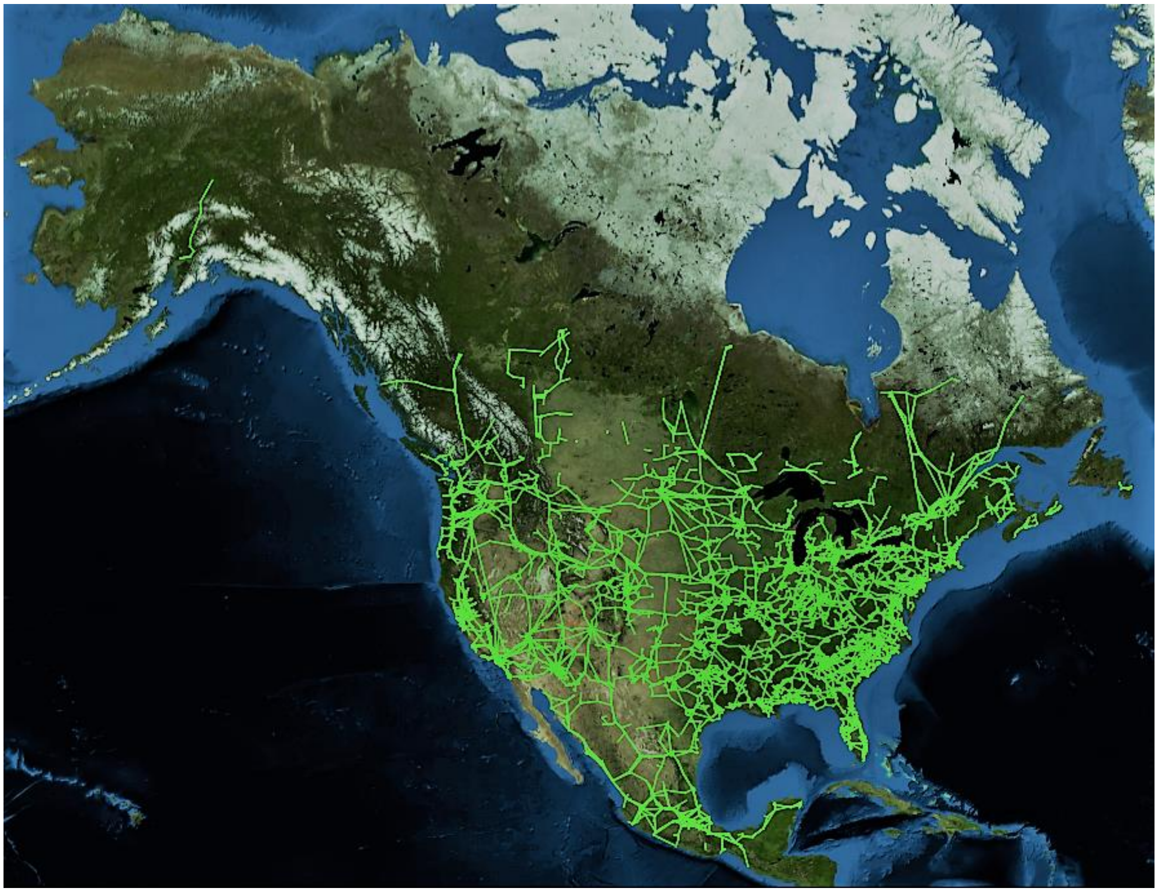

Power Grid Network analysis of North America

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Abstract

A power grid is an interconnected network consisting of generators and consumers of the power, transmitted between them along power lines (cables). Failures caused due to equipment malfunction or natural disasters in a part of the network have a cascading effect and can create islands followed by blackouts. In this project we would be using North American power grid dataset extracted by GridKit. This dataset consists of 16175 nodes, representing power stations and substations (transmission nodes and consumers), and 22460 edges representing the transmission lines. We would be analyzing the structural vulnerability of this dataset by modelling and quantifying the propagation of network failures. We would do this by removing various nodes of different centrality and calculating Connectivity metric of the resultant network.This would give an insight into the network which can be used to design reinforcement measures to help network's recovery from such adversaries.

Introduction

An electrical grid is an interconnected network for delivering electricity from producers to consumers. It consists of generating stations that produce electrical power, high voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers.

Failure of few important nodes can result in a large cascade.Thus, it is important to understand the vulnerable entities in the network to re-enforce backup strategies in the event of failure.

The project is based in python. We are using Networkx, Numpy, Matplotlib among other python libraries to analyze the network. These libraries are also helpful in reflecting the given dataset into realistic locations because of the presence of longitudinal and latitudinal availabilities of the power nodes listed in our dataset.

Method

Preprocessing:

The data set gathered contains nodes and edges. The nodes are categorized as generators, transmitters and distributors. The nodes are categorized as generators if in-degree of nodes is zero. Distributors on the other hand receive voltage from one major source and distribute to smaller lines. Thus the nodes which have only one high voltage in-degree link attached to it are categorized as distributors. The rest of the nodes are categorized as transmitters. This categorization is important to model the power flow from source till destination via all the nodes involved. It also helps us in better understanding the importance of each node, not only as to how others depend on it, but also how it depends on other neighboring nodes and beyond.

Algorithm:

This propagation of failures is done as follows:

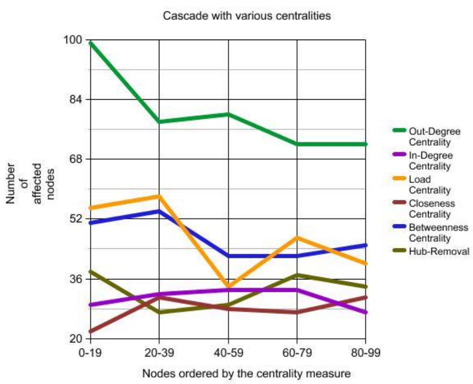
1) Selecting few high centrality node of chosen centrality
2) Calculate initial loads for all nodes
3) *Outer Loop*
   - Initially, removing nodes selected in step 1

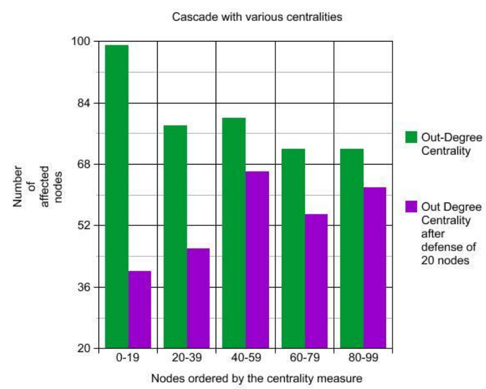
     Inner Loop:

     Getting cascaded nodes, i.e the nodes which are blacked-out (not powered by generator anymore), because of the step 3 and removing them from network. Going to step 5 once graph has every node powered a generator
   - Re-calculating loads for each node and removing the nodes which are overloaded.(Re-calculated load>Initial load).
   - This cascade ends when no node in the graph is overloaded.

Results

- Various centralities like Degree Centrality, Load Centrality, Out-Degree Centrality, In-degree centrality, Closeness-centrality are considered for analyzing the cascade if a failure occurs.





- 100 nodes with high centrality of each one of the centralities above mentioned are removed from the network, as shown, and the cascade is shown as gephi files stored in gephi-visualization folder.

  It is observed that out-degree centrality measure is the most optimal measure to understand the cascade taking place in a power grid network.

  The nodes and vertices files in the code folder are reformed after every centrality's cascade. These files are used to visualize nodes and vertices on a North America map using the 'basemap' library and longitude and latitude data of the nodes. The resultant cascade looks like as follows:

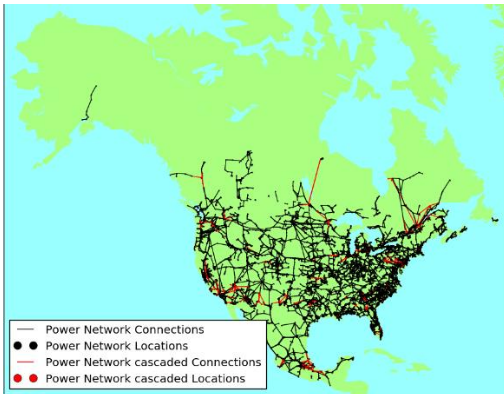


Figure 1

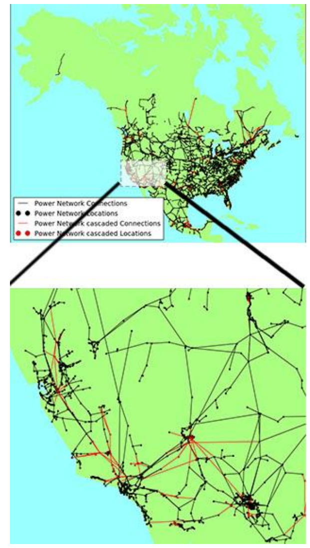


Figure 2

- In prone areas which are frequently affected, such power grid failures are more common. Such areas should have defense nodes to reduce such calamities. The before(Figure 3) and after (Figure 4) result of such defense is shown as an example in Florida.

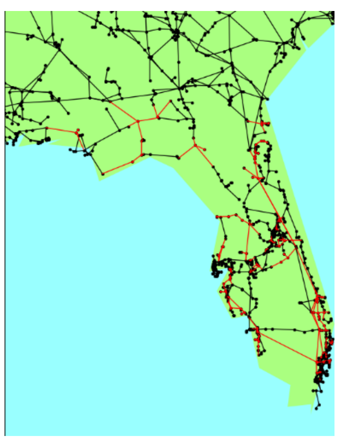


Figure 3

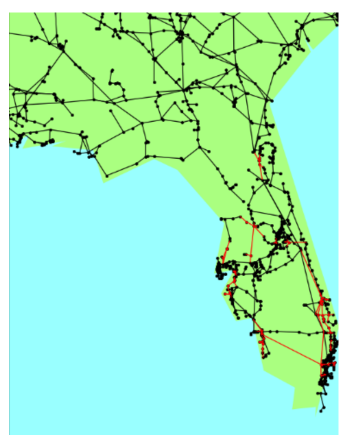


Figure 4

References

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