Complex Networks Project Report

Modelling power grid network failures

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The aim of this document is to present the project completed as a part of the Complex Networks (CN) course. The project forming a part of the course incorporated the complex networks simulation framework described throughout the course. We used Python numpy’s library implementation of the complex networks concepts to develop and visualize the solution. Furthermore, we outline the solution developed throughout the course of the project. Finally, we provide some insights into results, and discuss possible future work that could be completed on the project.

## The Problem

Electrical grids consist of various elements such as power stations, transformation stations, substations, and transmission lines. These elements of the power grid can potentially be an object of a hostile attact, or can suffer from a critical failure due to various factors. These factors include atmospheric conditions, external power gird network influences, or systemic failures. Such failures can have significant consequences on the overall power grid of a country. An example of such failure would be the blackout around Orchard Road arean in Singapore on the 13th of December 2015. This failure had a negative impact on the economy of the area, forcing several shops to close early. Through development of a simulation of such failures, ande identifying the most critical aspects of the power grid network, we will be able to devise a contingency plan for such failures as well as attempt to focus on mitigating these.

## The Task

We aim to develop a simulation of response of a power grid network to failures or downgrades in the system. This will include devising a network of electrical supply grid elements. Such network will be developed with the use of numpy library. We will emulate transmission lines by assigning a capacity to each transmission line. This would allow us to see how impact of a node outage propagates to other elements of the network. And, subsequently, what impact it has on the overall system.

## The Solution

To implement the network, and solve the issue we will implement the following strategy.

We use the available power grid network of the US[[2]](#footnote-2). We assign a capacity to each edge of the network to represent its capacity to transport electricity. Similarly, we assign a capacity to each node (vertice) representing this node’s production or consumption of electricity. To analyze netowork’s response to failueres or unfavourable events, we then remove nodes from the network and/or decrease their capacities. Finally, we observe how it impacts the system. Particularly, we look at whether the network could be load balanced to ensure sufficient energy supply to each node after the failure event. The process described allows us to infer how the power grid network behaves under such unfavourable conditions. In Table 1, we show a summary of this process. In subsequent sections, we focus on presenting the details of the method of implementation of this solution, and what results we present.

Table 1: High level overview of the solution. Steps performed to complete the simulation.

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| 1. Set up a network based on the US power grid topology |
| 1. Populate the network with attributes for edges and vertices    * Capacities of vertices- energy production (positive) or consumption (negative)    * Capacities of edges - transmission lines' bandwidth |
| 1. Load balance the network to ensure all capacities of vertices are non-negative |
| 1. Remove a node or an edge (or decrease capacity) - introduce a failure |
| 1. Attempt load balancing again to see if the failure is critical |
| 1. Present results and statistics about the network |

## Method

We use the US power grid network topology compiled by Watts and Strogatz throughout the project. Although the topology is reasonably extensive, it contains 6594 edges and almost 4941 vertices, it does not include any numerical values signifying electricity being produced or consumed by each of these vertices. Similarly, it lacks bandwidth capacities for all edges contained in the topology. Consequently, before attempting to balance the network, or test if it is balancable, we had to populate the network accordingly. Only then, we could perform meaningful operations on the network, such as balancing or removing nodes and observing the response.

### Populating the network

We decided to populate the network

### Balancing the network

## Results

## Summary and conclusions

## Future work

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2. US power grid topology from D. J. Watts and S. H. Strogatz, Nature 393, 440-442 (1998) [↑](#footnote-ref-2)