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Problem Statement (v3)

Changes from v2: We pretty much had this cemented down already by last report.

The modern world is an interconnected grid of powered devices. Nearly every single one of these devices are built upon the guarantee of a reliable electricity generation, regulation, and distribution system. But this system cannot be guaranteed. The systems that give electricity – the power plants, the arrays of windmills and solar cells, the dams, none of these exist solely in the abstract. Their tangible nature gives them a physical presence, and that presence gives them vulnerability.

It is the purpose of this team to analyze, model, and simulate a power distribution network to help lower the degree of this vulnerability. This simulation shall encompass parameters of the distribution network both specific to power distribution and specific to the network's identity as a network.

Elements specific to electricity distribution include power and capacity of production facilities (plants), capacity of distributors (such as transformers and substations), and resistance and usage of power lines. Plants can only produce so much power, and while this can be stored in, for example, flywheels, their storage capacity is limited as generating facilities are intended as making a resource that is consumed within a very short amount of time. Lines connecting distributors to both each other and to parent generators have resistance, a parameter that is

proportional to load and converts wanted electricity into unwanted heat energy. This means that the more power put through a line, the more power lost, requiring more put through, which loses more, etc. – a relationship similar to Konstantin Tsiolkovsky's tyranny of the rocket equation (call it the Tyranny of the Resistance Equation). Finally, the distributors are designed for their normal load values, and while there is a safety margin in this design, exceed the load by a sufficient degree can induce failures – potentially explosively – in a distributor.

Elements specific to the network identity include topics such as vertex degree, edge weight, the various measures of a vertex's centrality and importance to the entire graph, cut vertices and bridge edges. While considered a bad idea, the idea of *single points of failure* exist in nearly every field, and electricity distribution networks are rarely special. In graph theory, these SPOFs are called cut vertices, and their failure can separate a graph into two subgraphs. Combine this with the electrical model of a directed (one-way) graph, and cut vertices that fail after the generational phase of the network will split a network into two: one with no consumers and one with no producers.

One can thus state that the best way to avoid this problem is to ensure a higher degree of connectivity in the graph. However, this does not solve all the problems. The above-mentioned resistance means that electricity will prefer to take the electrically shortest path. This shortness preference translates to certain nodes being used more than others, and centrality measures this. It gives mathematical values for each node's influence in paths taken amongst random pairs of other nodes, and the specialized averaging of these influences combines to a node's total importance in the network. While they may look like any other

node, attacks committed on the identified more important nodes will deal disproportionate impact on the grid as a whole.

The combination of these two element types greatly complicates protection of electricity distribution networks, which is why we are forced to create a program to simulate these networks so that we may discover more detail about the exact values and the relative importances. Cut vertices are more deadly than central nodes, sure, but is resistance of a line just as important as the capacities of the stations on both sides? Only simulations will tell.