Power Grid Visualization

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Power Grid Basics

- Transmission
  - Converting to high voltage allows less power loss during transmission (step-up).
    - $P = IV = V^2 / R$
    - $P_{loss} = RI^2 = R (P / V)^2 = RP^2 / V^2 \approx 7.2\%$ in U.S.
  - High resistance causes high heat in transmission line (potentially very bad).
  - Need to step-down voltage before it reaches homes.

Power Grid Basics

- Very large graph consisting of power generators and consumers (nodes) and transmission lines (edges).
- Electricity distributed as a 3-phase AC current (new voltage waveform generated 3 times per cycle).
  - Need to convert to a single-phase before reaching homes.

Power Grid Basics

- Electronic demand is very variable.
  - Often cheaper to import electricity from another unburdened power plant.
  - The demand is often correlated locally (a hot day in the South), so energy may come from far away.
    - Grids span across countries (such as our own grid, which comprises of the U.S. and a portion of Canada)
- Power typically consumed within a second of generation.

Power Grid Basics

- We pay to keep the 3-phase AC current from going too far out of phase.
  - If a generator becomes too burdened, it requests a nearby generator to help, which may request another generator's help…
- Cascading failures.
  - Normally controlled by delays built into the system and the availability of alternate paths.

Human Response

- Each power station has a human controller.
  - If they detect a possible cascading failure, they must shed load.
- Assisted by power flow modeling tools.
- If they are unable to predict future events, they must fall back on a contingency plan and alert neighboring controllers.

Northeast Blackout of 2003

- August 13th, 2003
  - 50 million people affected.
  - 6 billion dollars in losses.
- Main cause determined to be untrimmed trees in the Cleveland area.
  - When a line hits a tree, the line is short circuited.
  - Causes other lines to pick up the slack.
    - Which causes increased load (resistance) on line → increased heat on line → line to sag more → line to hit overgrown tree.

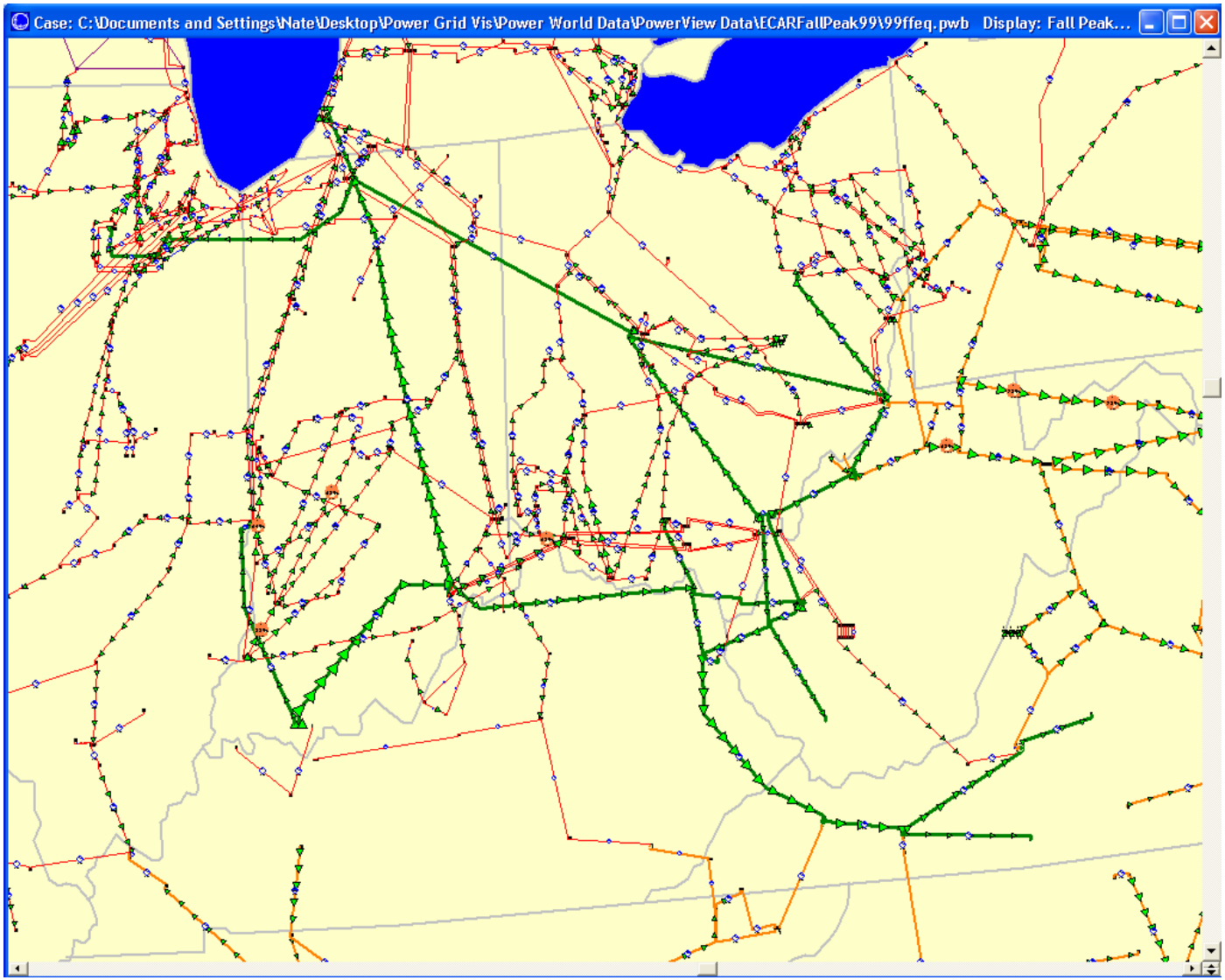
Visualizing Power Grids

- Large networks cannot be looked at all at once.
  - Need to generalize areas of the grid.
- Power stations also want to visualize the costs of generating electricity.
- The data is illegal to have.

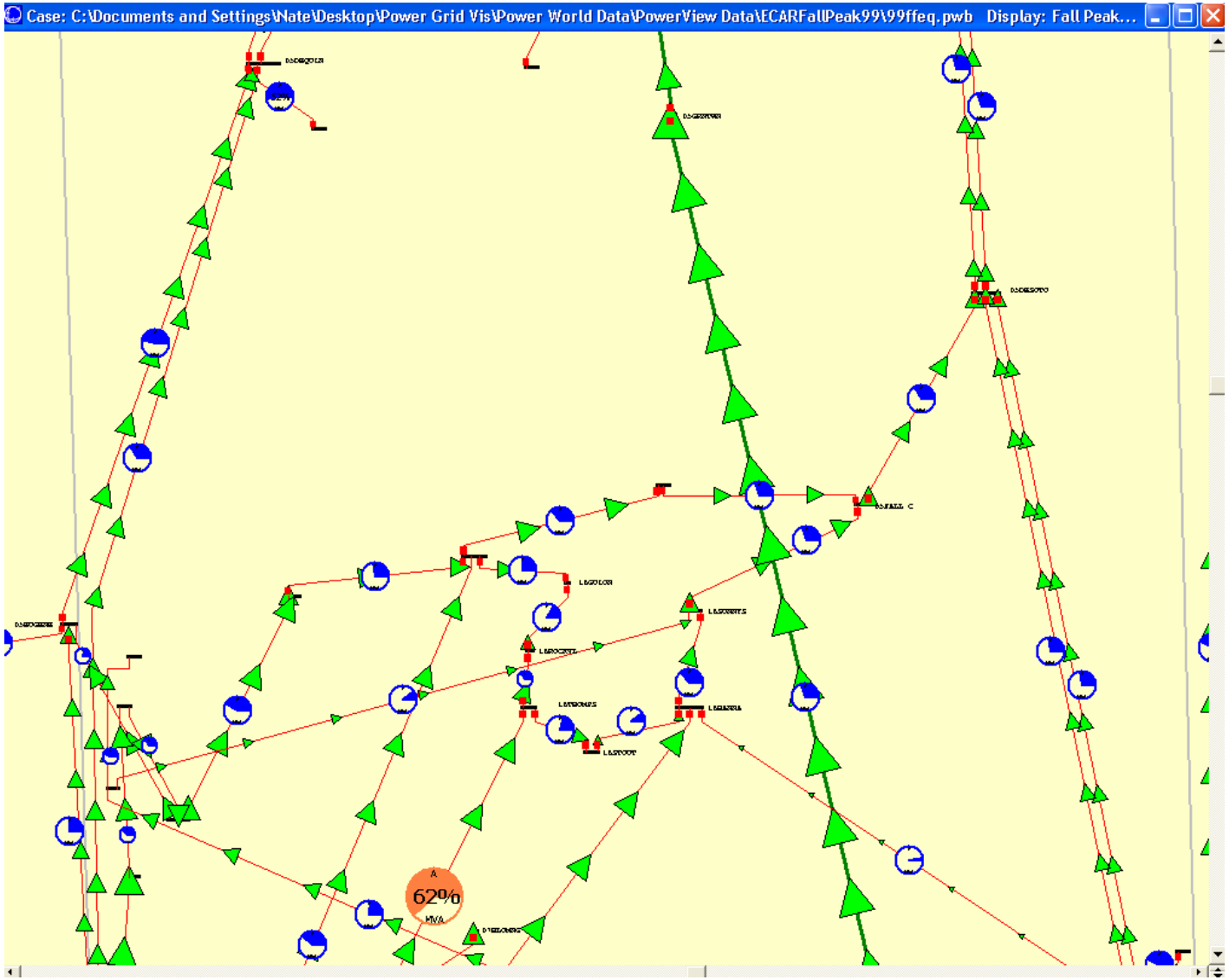
Previous Work

- Power World Corporation
  - Tom Overbye (also a professor ECE at UIUC)
  - Seems to be the standard.
  - Most (if not all) power grid visualization research stems from here.

Power World - Midwest



Power World - Central Indiana



Power World Critique

- Load information displayed using pie charts and moving arrows.
  - No use of color, speed of arrows, etc.
- Inability to change background color.
- Poor navigation.

- A lot of information is there, just have to right click an object.
- Models more than just transmission lines.

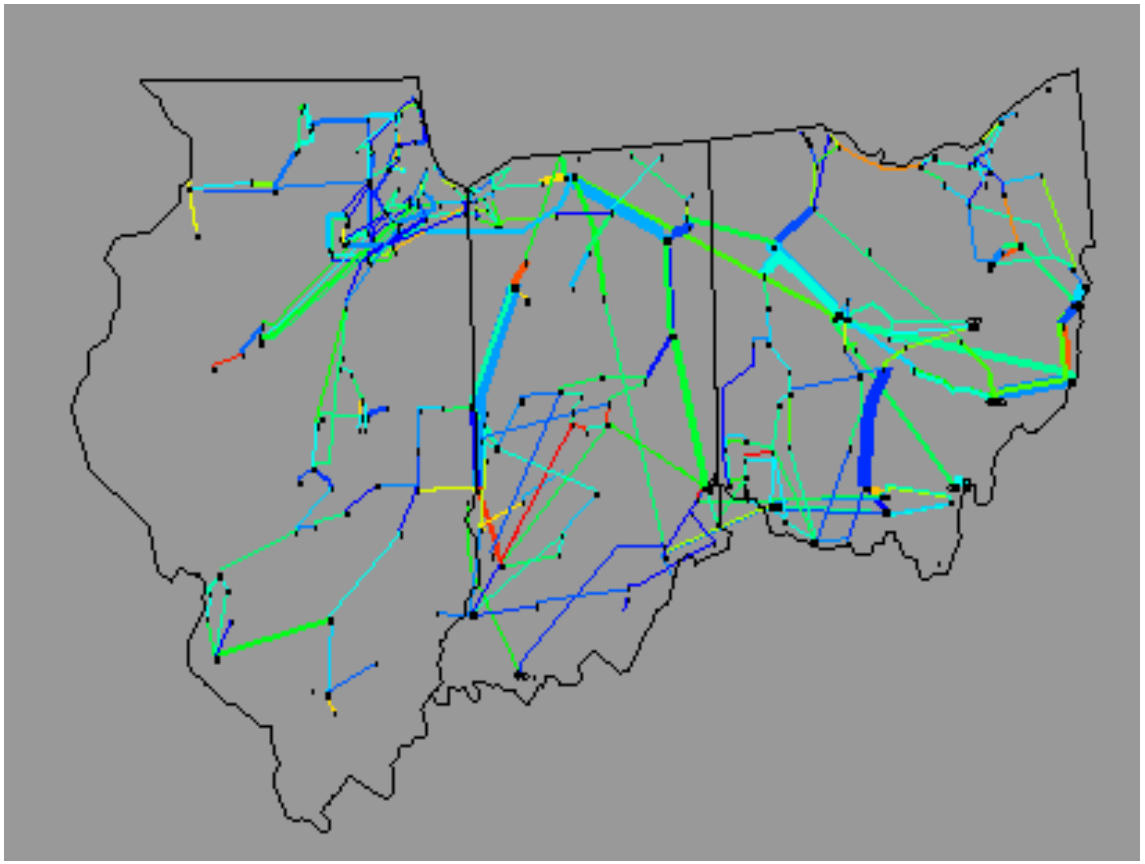
Obtaining Data

- As mentioned, having the data is illegal.
  - Can be used to gain a competitive advantage.
- Provided with large Power World datasets.
  - Power data is separate from graphical data.
    - Power data: Extracted an excel sheet using the Power World program.
    - Graphical data: In binary, had to reverse engineer.
      - This includes the outlines for states and bodies of water.

Improvements on Power World

- Better interface for controlling zoom and pan.
- Ability to change background color.
- Transmission line information displayed using:
  - Line Color
  - Line Thickness
  - Animated dashed line
  - A Chart
  - Arrow Size
  - Arrow Color
  - Arrow Speed
  - Arrow Transparency
  - Arrow Density
  - All customizable.

Demo



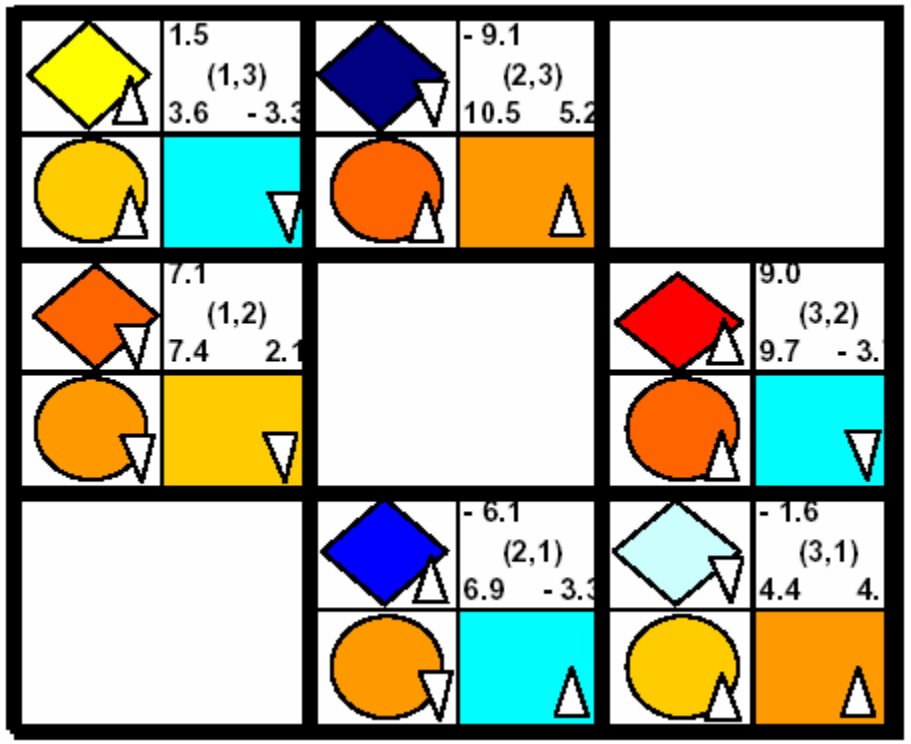
Ideas for More Improvement

- Need input from a power grid expert.
  - Is visualizing certain variables needed?
  - Can other values be derived from the data we have?
  - At what point should values be capped?
  - Is it important to maintain geographic information?

Ideas for More Improvement

- Textures
- 3D
- Virtual Reality
- Lose the U.S. map →

(courtesy Nick Wildman, former Purdue undergrad)



- Pop-up alerts.
- Any suggestions?