Proposal #6: Generating Value from Detailed, Realistic Synthetic Electric Grids

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PSERC

PSERC IAB Meeting
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IAB Team Members

Thanks for your support and more are welcome to join the team!

- Harvey Scribner (SPP)
- Jim Price (CAISO)
- Bryan Palmintier (NREL)
- Di Shi (GEIRI),
- Evangelos Farantatos, Paul Myrda (EPRI),
- Cho Wang (AEP)
- Steven Judd (ISO-NE)
- Melvin Schoech (CenterPoint)
- Al Engelmann (ComEd)
- Yazhou Jiang and Anil Jampala (GE)
- Mahesh Morjaria (First Solar)
- Patrick Panciatici (RTE)
- Jianzhong Tong (PJM)
- Baj Agrawal (APS)
- Felica Ruiz (MISO)

Project Period and Requested Funding

- The project period is the standard two years, from July 1, 2020 to August 31, 2022
- Total requested funding is 220K, with the amount split equally between the years
  - 110K per year
- Total funding per researcher is 27.5K per person per year
- TAMU has internal funds that will be used on this project; this includes funding for equipment, data sets, travel and consulting services

Summary and Tasks

- The goal of the project is to work closely with the industrial team to generate value from large-scale, detailed and realistic synthetic electric grids
  - The project builds on recent ARPA-E work by the PIs to develop grids that can be used for research, education, commercial development and public engagement
- The four project tasks are
  1. Developing customized grids
  2. Developing specific grid scenarios
  3. Exploring decision making with uncertainty
  4. Expanding the scope of synthetic grids for coupling with other infrastructures

Motivation: A Common Industry Request

- We’re gathering all this data. Can you help us figure out what to do with it?
- However, often, after a lot of talks with lawyers to develop nondisclosure agreements (NDAs), at most a subset of the desired data and/or models is available
  - The data and models usually cannot be shared, and often is a lot of associated metadata is removed
  - There is a high cost to industry to provide this data
  - It isn’t just the amount of data (e.g., who has the most terabytes!) but rather the breadth of the data and whether the data is coupled to models

Changing the Question

- Assume you have all the information possible about the electric grid (data, models, coupled infrastructures) and can share it.
- And it can be provided with low access cost.
- **What would you do with it?**
    - This allows for large amounts of data fusion!
- The focus of this project is mostly on how to develop such information sets using synthetic grids, showing initial value, and sharing the results with others

Synthetic Electric Grids

- Synthetic electric grids are models of electric grids that were not created to represent any actual electric grid
- The below image shows the five bus synthetic grid I used as an undergraduate

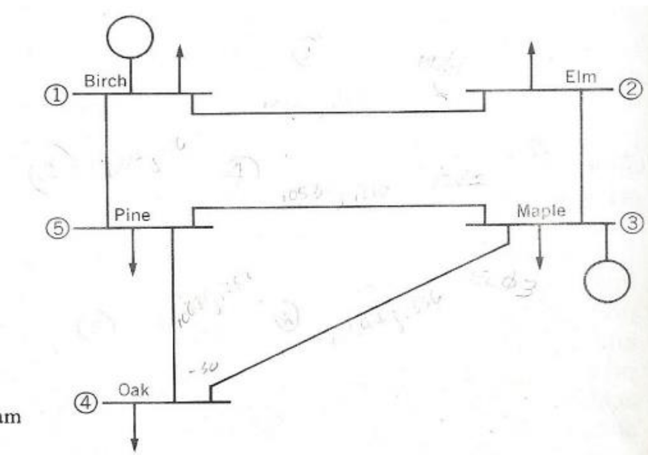
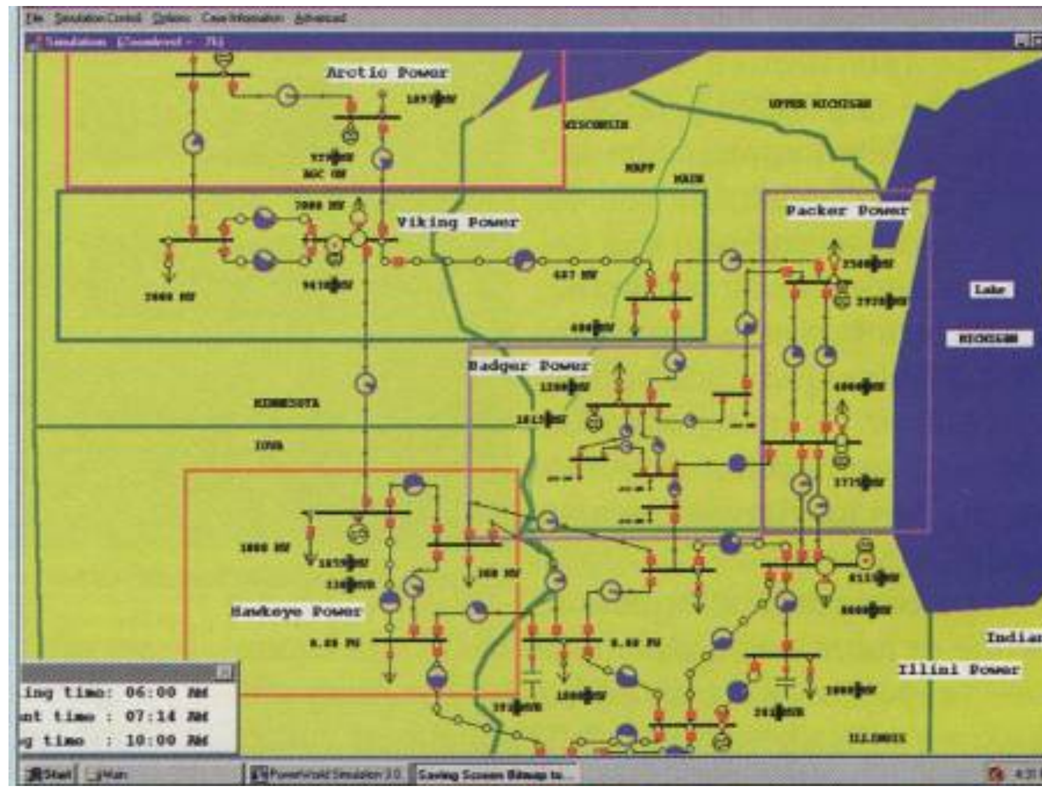


Figure 8.1 One-line diagram for Example 8.1.

Image Source: W.D. Stevenson, *Elements of Power Systems*, Fourth Edition, McGraw-Hill Book Company New York, 1982 (the first edition was in 1955)

Geographical Synthetic Electric Grids

- Synthetic electric grids can be created with or without reference to actual geography
- The image shows an early geographically-based synthetic electric grid
- This grid was designed to show concepts to regulators

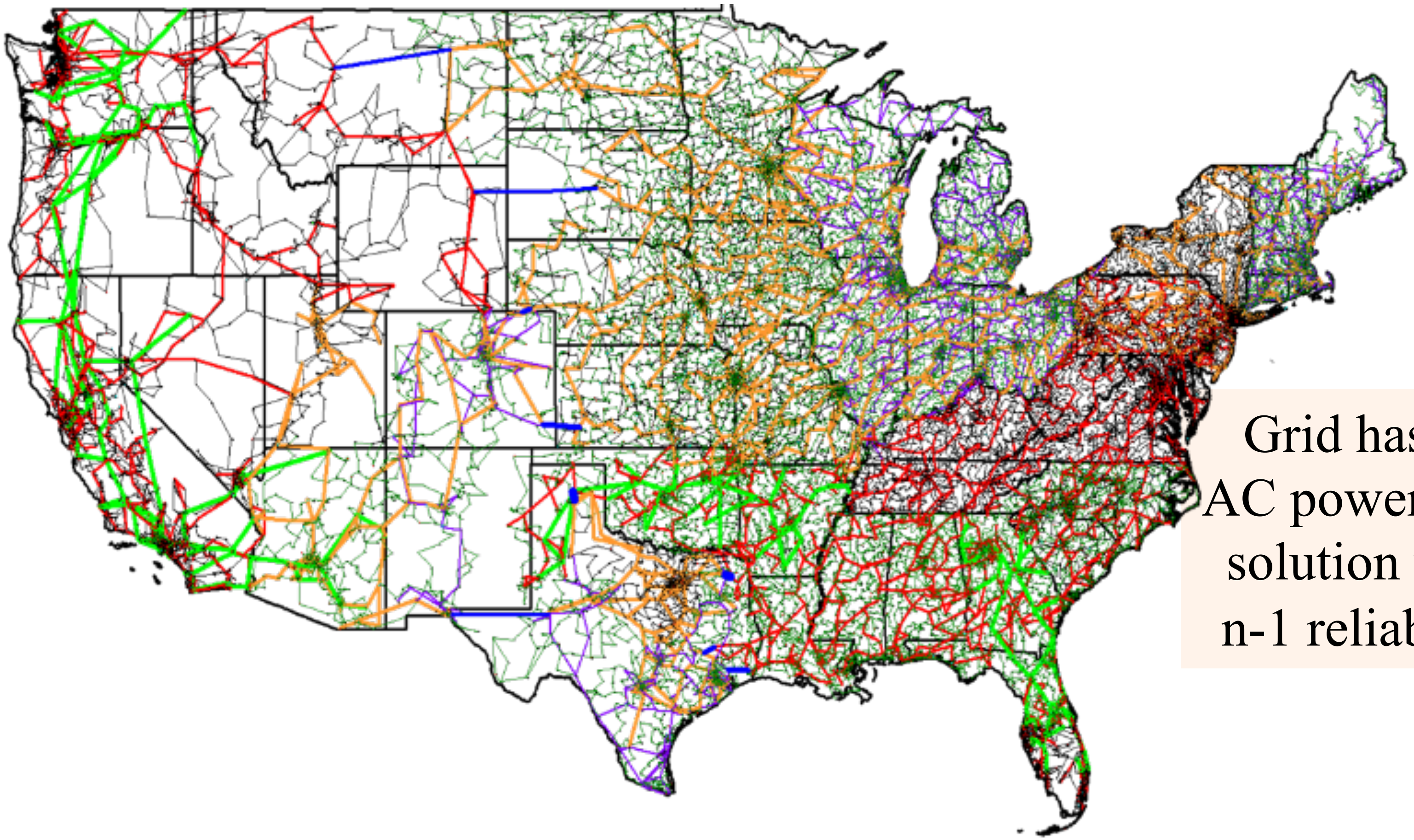


High-Quality Synthetic Electric Grids

- High-quality synthetic electric grids are designed to have a wide range of characteristics that are similar to those found in actual electric grids
  - “Realistic but not real” to quote Wisconsin teammates
  - Fictional, but hopefully good fiction
  - **Developed techniques can be applied to real grids**
- However, importantly these grids are not designed to try to duplicate any actual grid
- Over the last three years tremendous progress has been made through ARPA-E at both the transmission and distribution levels

Large-Scale Grids are Now Available

This is an 82,000 bus synthetic model that we publicly released in summer 2018. Both schools have expertise in creating such grids

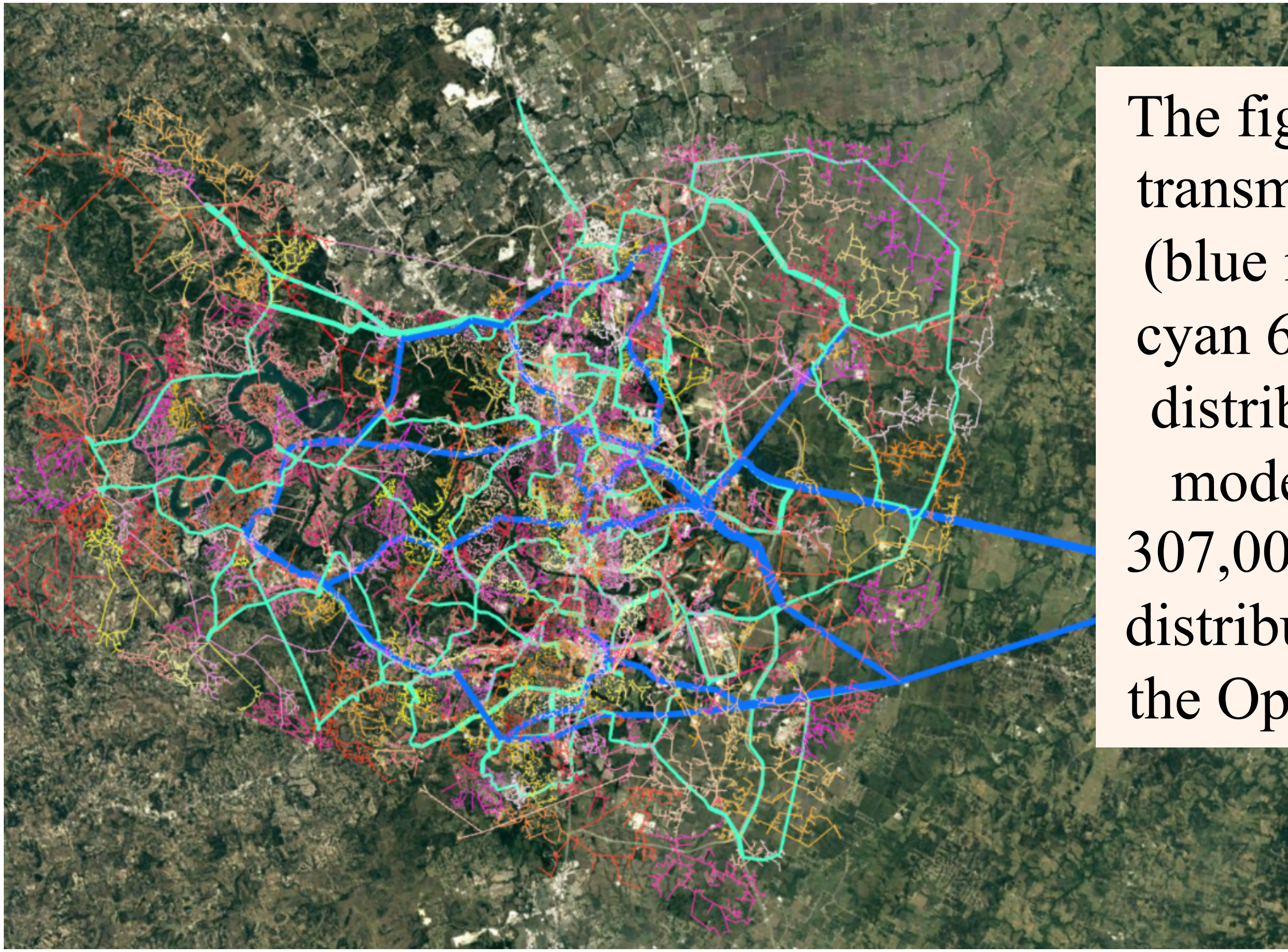


Grid has an AC power flow solution with n-1 reliability

Highly Detailed Combined T &D Grids

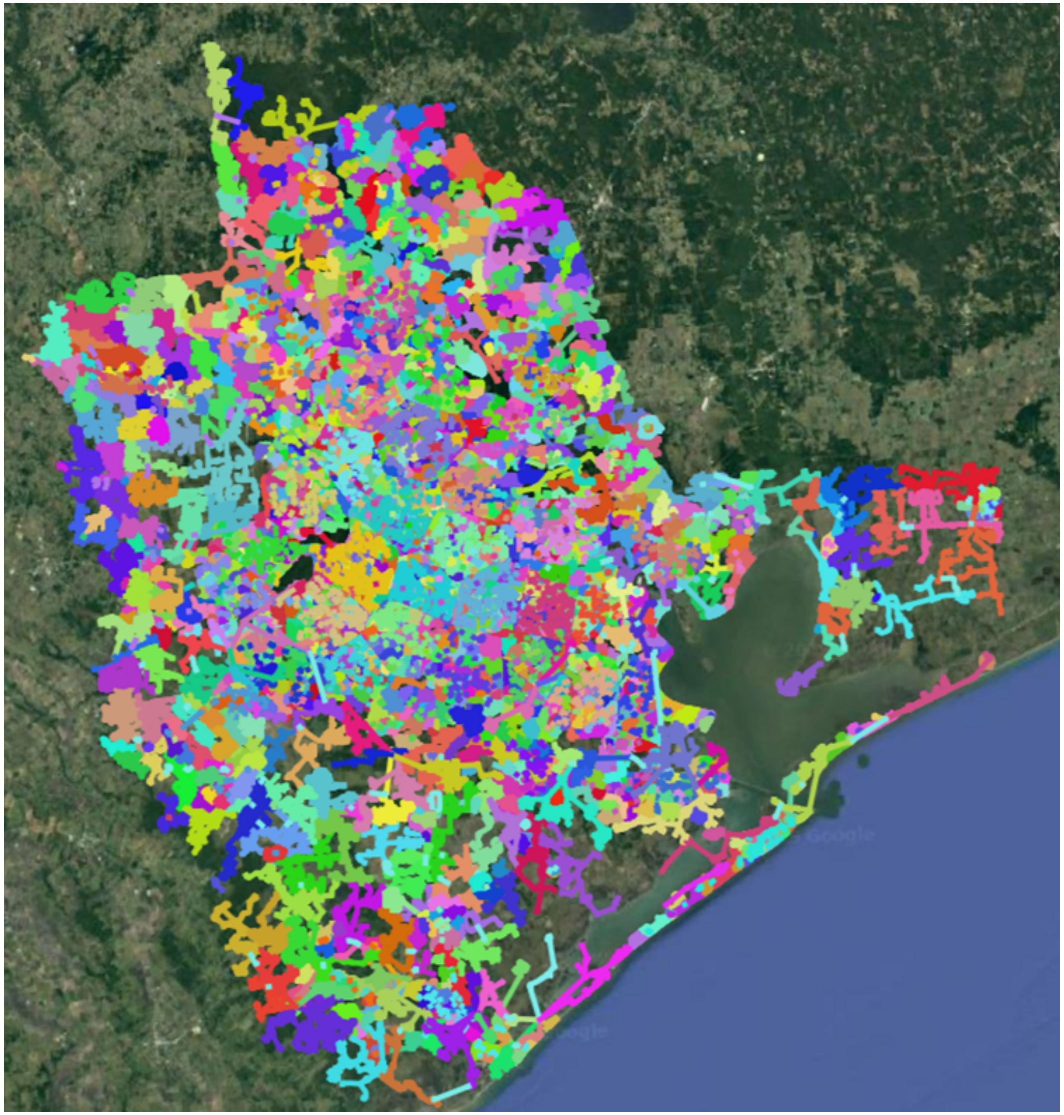
- Previous transmission grids were geographic to the zip code level
- On a current ARPA-E project we (with NREL) are developing “down to the meter” synthetic grids
- Actual parcel data is used to determine location of the electric meters. The parcels are connected by a distribution system, and the distribution system by a transmission grid
- Currently we have about 20% of the load in Texas done (Travis and Harris Counties)

Travis County, TX (Location of Austin)



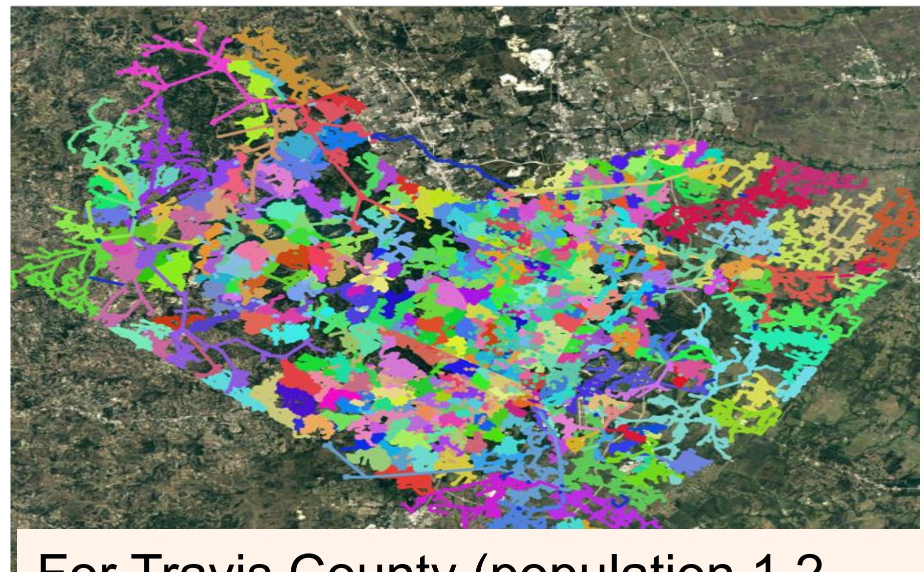
The figure shows the transmission system (blue is 230 kV and cyan 69 kV) and the distribution system modeled down to 307,000 meters. The distribution data is in the OpenDSS format.

Example Distribution Circuits



Coupled T&D Testing

- Full transmission and distribution system studies are being done using a co-simulation framework
  - A power flow package is used to solve the transmission system and OpenDSS is used to solve each of the distribution circuits
  - The simulations are coupled together using the national lab developed HELICS package; one year of simulations took about 3 hours



For Travis County (population 1.2 million) 307,236 meters are served by 488 distribution circuits

Different Levels of Modeling

- Just because we have detailed grids, doesn't mean we always simulate the coupled transmission and distribution models. Other options are
  - Transmission only
  - Distribution only
  - Full transmission with distribution topology; this can be quite useful for doing multi-infrastructure simulation in which we just need to know what parts of the distribution system are out-of-service or other data attributes (such as the location of electric vehicles)

The Need for Synthetic Grids

- Prior to 9/11/01, a lot of grid information was publically available
- Now access to data and models about the actual power grid in the US is quite restricted (e.g., critical energy/electricity infrastructure [CEII])
  - What is available is often partial, and can't be shared
- To do effective research, and to drive innovation, researchers need access to common, realistic grid models and data sets
  - Scientific principle of reproducibility of results

The Need for Synthetic Grids, cont.

- Synthetic grids and datasets are, of course, designed to augment, not replace actual grids
- But the synthetic grids offer some significant advantages, both to industry and researchers
  - Since there are no CEII or privacy concerns, full models and their associated datasets can be freely shared; this is particularly helpful for interdisciplinary research
  - Synthetic grids can allow future grid scenarios to be considered in-depth (i.e., high renewables or high impact, low frequency events) yet still be potentially public

The Need for Synthetic Grids, cont.

- Advantages, cont.
  - Synthetic grids can be customized to represent particular grid idiosyncrasies; utilities can provide this to researchers or potential vendors
    - We’ve deliberately designed ours using different voltage levels than those used in the actual grid (e.g., 500/230 versus 345/138 in Texas) to emphasis they are synthetic
  - The highly detailed (down to the meter grid) allow coupling with real infrastructures
    - We’re working with the Texas Transportation Institute to study electric grid/transportation couplings
  - Synthetic grids can be used for education, including vendor training and short courses

The Four Project Tasks and The Work Plan

1. Developing customized grids
2. Developing specific grid scenarios
3. Exploring decision making with uncertainty
4. Expanding the scope of synthetic grids for coupling with other infrastructures

Work Plan: (Q = quarter, KD=Davis, BL=Lesieutre, TO=Overbye, LR=Line Roald)

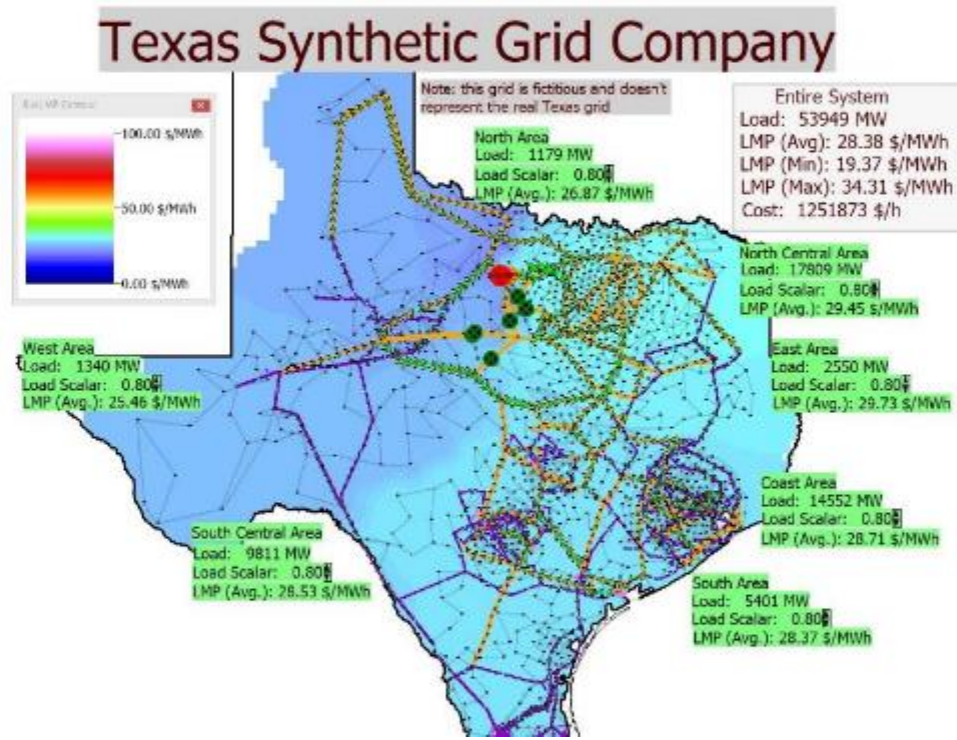
Task	**Researchers**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	***Q8***
1	BL, TO	x	x						
2	KD, LR		x	x	x	x			
3	KD, LR,TO				x	x	x	x	
4	KD, TO, BL	x	x	x	x	x	x	x	x

Task 1: Developing Customized Grids

- For this task we will work with our IAB members to build grids on footprints of interest with desired characteristics
  - We have lots of experience doing this!
  - Particular idiosyncrasies can be included in these grids
- These grids can then be used as desired by the IAB members
  - Fully public or not
  - Used by local universities for research and education
  - Provided to potential vendors
- Expected grids sizes up to ten thousands buses

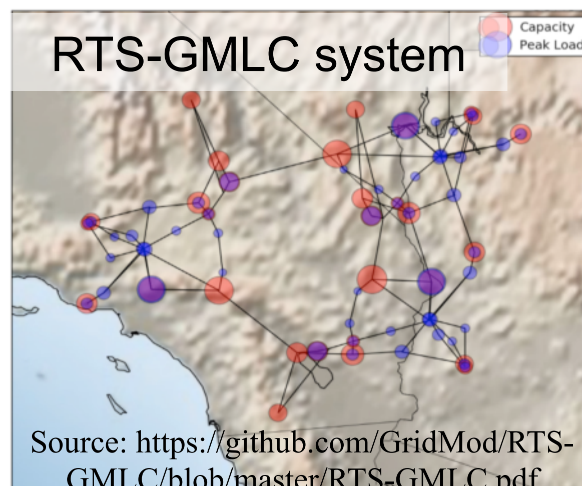
Synthetic Grid Applications: Innovative Electric Power Education

- Lab assignments involving a 2000 bus case have been integrated into Texas A&M's power classes
- Class includes large-system exercises for power flow, economic dispatch, contingency analysis, SCOPF, and transient stability



Task 2: Developing Specific Grid Scenarios

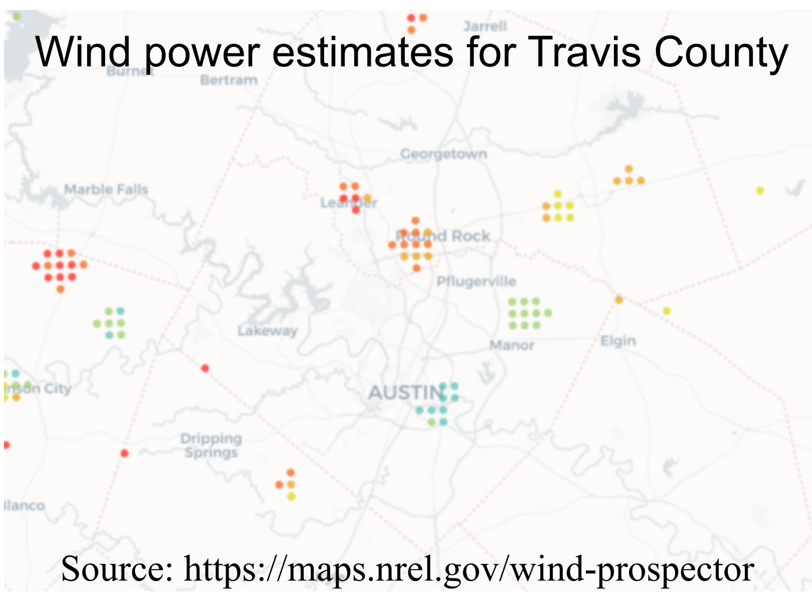
- For this task we will be developing specific scenarios
  - For example synthetic grids based on specific geographic footprints can be combined with data sets describing renewable energy resources
- Recent effort by NREL to update the RTS system with renewable energy generation
  - \+ Very useful!!!!! (**only** easily available data set)
  - \- Limited size
  - \- Grid arbitrarily located
  - \- Only one data set



Source: https://github.com/GridMod/RTS-GMLC/blob/master/RTS-GMLC.pdf

Task 2: Developing Specific Grid Scenarios

- Synthetic grids with renewable resources
  - Synthetic grid for a give geographical footprint
  - Open resources with wind and solar data (available from NREL)
  - Publicly available aggregated data on total renewable energy production (available from system operators)



Wind power estimates for Travis County

Source: https://maps.nrel.gov/wind-prospector

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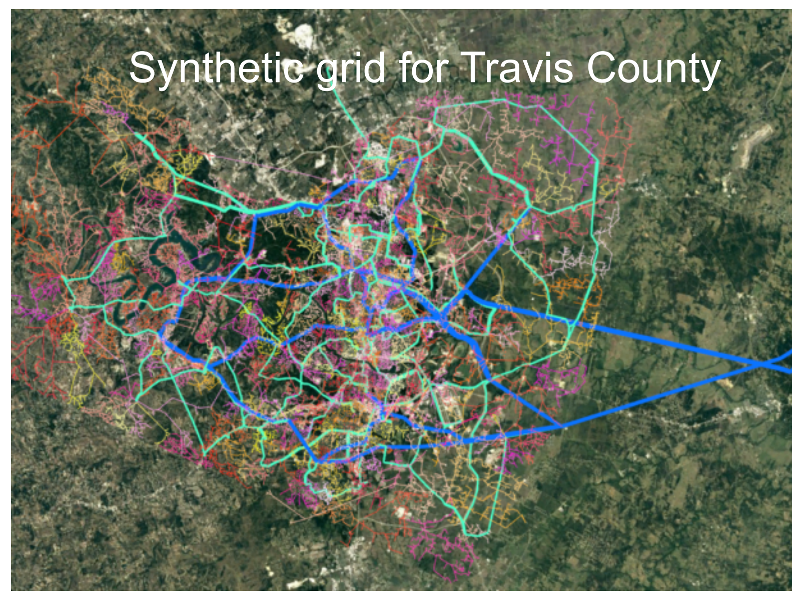
Synthetic grid for Travis County

Task 2: Developing Specific Grid Scenarios

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  - Other scenarios could explore the impact of
    - storage
    - HVDC
    - other grid technologies of interest to the IAB members

Giving Students (and Others) Experience In Grid Operations

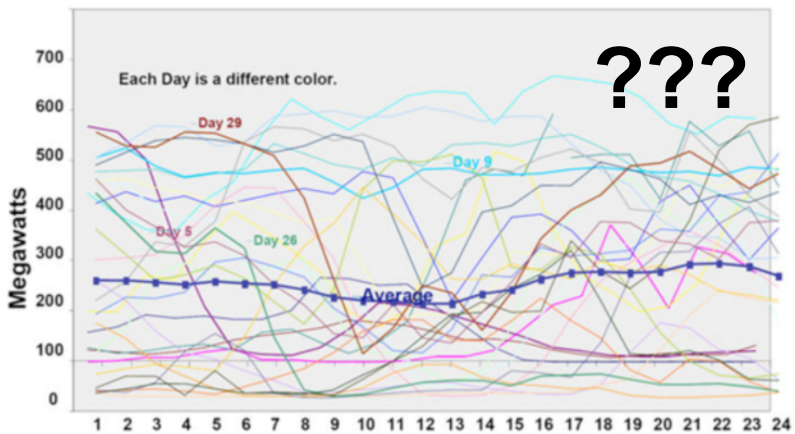
- Most electric power students have little or no experience in actually operating an electric grid (real or simulated)
- One of our goals is to provide such an experience both in an individually and as part of a team
  - This also generates data
- Developing this involves a combination of the electric grid, the scenario, and the associated simulation environment, and the path to give the users experience with the environment
- PSERC members, both university and industry, are invited to participate

The Simulation Environment at Texas A&M

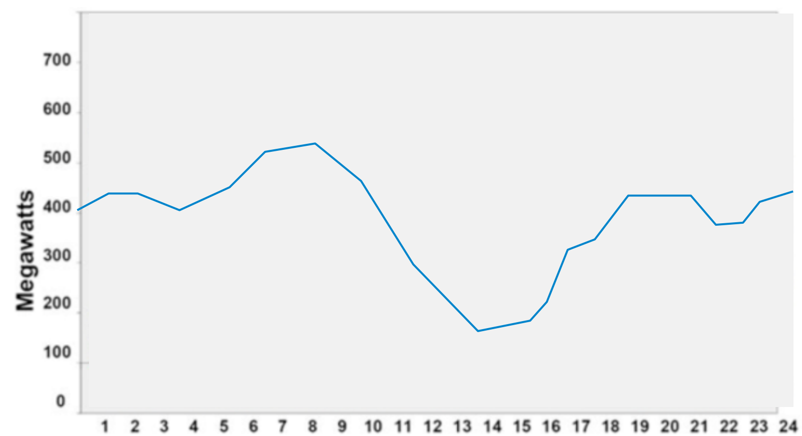
Task 3: Exploring Decision Making with Uncertainty

- Decisions taken with uncertain information might often seem like **bad decisions** in hindsight

Optimal dispatch given uncertain renewable generation ≠ Optimal dispatch given actual renewable generation



Source: Wind energy from CAISO (2007)



Task 3: Develop Scenarios to Explore Decision Making with Uncertainty

Goals

- Create *scenarios* for exploring decision making under uncertainty
  - These can be simple or quite complex
  - Could consider quite stressed system conditions
- *Develop a platform* for testing and comparing approaches to make operational decisions
- Encourage discussion and sharing of best practices *across regions*

Task 4: Coupling Synthetic Grids With Other Infrastructures

- In this task we plan on exploring coupling our synthetic grids with other infrastructures
- This leverages the actual, parcel-level geographic coordinates in the highly detailed electric grids
  - Real and synthetic metadata can be used, such as the number of people at a location, the presence of electric vehicles, or the amount of distributed solar
- Our first focus will be on transportation, leveraging a partnership we have developed with the Texas Transportation Institute (TTI)

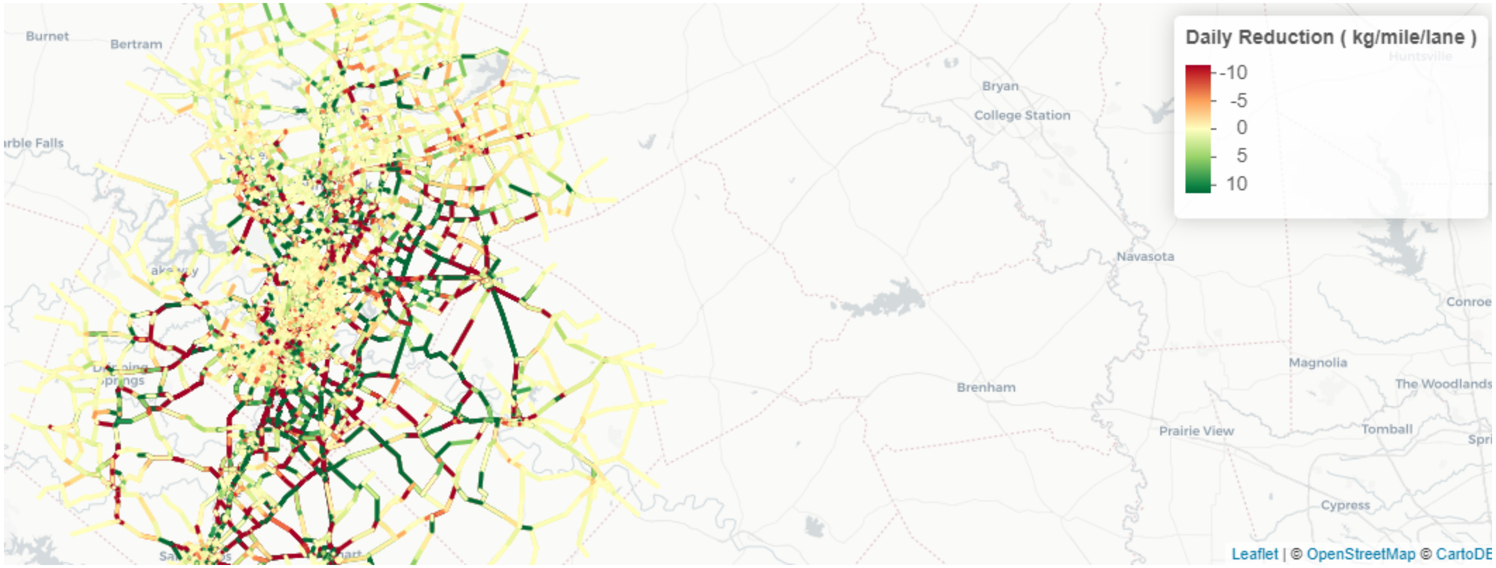
Traffic Simulation Software Coupled with Electric Grid Models

- The simulation used by TTI is called Transportation and Emissions Modeling Platform for Optimization (TEMPO)
  - The website is https://tempo-dashboard.io/
- TEMPO has a variety of modeling tools, including simulation using a dynamic traffic assignment model and a series of environmental models
  - If uses a pre-defined traffic network and minimizes travel time
  - It is run on a six second interval and can do an entire day

Traffic Simulation Software Coupled with Electric Grid Models

- The associated electric grid will be simulated with either power flow or dynamics resolution
  - An example scenario could be the impact of a large blackout on the two infrastructures
  - Traffic postdoc, Xiaodan Xu, has a Georgia Tech PhD

Image shows an emissions reduction scenario using TEMPO



Summary

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- The four project tasks are
  1. Developing customized grids
  2. Developing specific grid scenarios
  3. Exploring decision making with uncertainty
  4. Coupling the synthetic grids with other infrastructures
- We're very excited to be doing this project and to have such a strong PSERC IAB team!

Thank You!

Questions?